Biomass Energy Data Book

U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy

OAK RIDGE National Laboratory

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can be found on the Web at:
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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
LFG	Landfill Gas
MJ	Megajoule
MMBtu	One Million British thermal units
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
RPS	Renewable Portfolio Standard
SEO	State Energy Office
SRIC	Short Rotation Intensive Culture
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 third 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 third 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 four 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

Biomass Overview

Biomass is defined as any organic matter that is available on a renewable or recurring basis. It includes all plants and plant derived materials, including agricultural crops and trees, wood and wood residues, grasses, aquatic plants, animal manure, municipal residues, and other residue materials. Plants (on land or in water) use the light energy from the sun to convert water and carbon dioxide to carbohydrates, fats, and proteins along with small amounts of minerals. The carbohydrate component includes cellulose and hemi-cellulose fibers which gives strength to plant structures and lignin which binds the fibers together. Some plants store starches and fats (oils) in seeds or roots and simple sugars can be found in plant tissues.

In 2009, biomass production contributed 3.9 quadrillion Btu of energy to the 73.1 quadrillion Btu of energy produced in the United States or about 5.3% 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 3.9 quadrillion Btu of energy of the 94.7 quadrillion Btu of energy consumed in the United States in 2009 or about 4.1%. 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 trippled since 2005 and now accounts for about 40% of all biomass consumed. While most biofuels feedstocks are currently starches, oils and fats derrived from the agricultural sector, whole plants and plant residues will soon be an important feedstock for cellulosic biofuels. Algae is being developed as a source of both oil and cellulosic feedstocks. The industrial sector (primarily the wood products industry) used about 2.0 quadrillion Btu in 2009. 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 0.9 quadrillion Btu. This is less than the total amount of biofuels produced because some liquid biofuels are used by other sources.

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.

To stimulate progress in this direction, the Department of Energy's (DOE) Biomass Program began awarding cost-sharing contracts in 2007 to companies for the development of integrated biorefineries using cellulosic biomass. As of December 2010, there were 6 commercial biorefineries, 12 pilot biorefineries, 9 demonstration biorefineries and 2 research and development biorefineries. The names, locations and details of these biorefineries are available on an interactive map produced by DOE's Biomass Program.

With the passage of the 2008 Farm Bill in May of 2008, USDA extended or instituted several programs that provide incentives for the development of advanced biofuels using cellulosic biomass.

In 2009 biomass accounted for just over half of the renewable energy production in the United States.

Section: INTRODUCTION
Energy Production by Source, 1973-2009
(Quadrillion Btu)

	Fossil Fuels						Renewable Energy[a]						
Year	Coal	Natural Gas (Dry)	Crude Oil[b]	Natural Gas Plant Liquids	Total	Nuclear Electric Power	Hydro-electric Power[c]	Biomass[d]	Geo-thermal	Solar	Wind	Total	Total
1973	13.992	22.187	19.493	2.569	58.241	0.910	2.861	1.529	0.043	NA	NA	4.433	63.585
1974	14.074	21.210	18.575	2.471	56.331	1.272	3.177	1.540	0.053	NA	NA	4.769	62.372
1975	14.989	19.640	17.729	2.374	54.733	1.900	3.155	1.499	0.070	NA	NA	4.723	61.357
1976	15.654	19.480	17.262	2.327	54.723	2.111	2.976	1.713	0.078	NA	NA	4.768	61.602
1977	15.755	19.565	17.454	2.327	55.101	2.702	2.333	1.838	0.077	NA	NA	4.249	62.052
1978	14.910	19.485	18.434	2.245	55.074	3.024	2.937	2.038	0.064	NA	NA	5.039	63.137
1979	17.540	20.076	18.104	2.286	58.006	2.776	2.931	2.152	0.084	NA	NA	5.166	65.948
1980	18.598	19.908	18.249	2.254	59.008	2.739	2.900	2.476	0.110	NA	NA	5.485	67.232
1981	18.377	19.699	18.146	2.307	58.529	3.008	2.758	2.596	0.123	NA	NA	5.477	67.014
1982	18.639	18.319	18.309	2.191	57.458	3.131	3.266	2.664	0.105	NA	NA	6.034	66.623
1983	17.247	16.593	18.392	2.184	54.416	3.203	3.527	2.904	0.129	NA	0.000	6.561	64.180
1984	19.719	18.008	18.848	2.274	58.849	3.553	3.386	2.971	0.165	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	0.198	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	0.219	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	0.229	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	0.217	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	0.317	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	0.336	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	0.346	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	0.349	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	0.364	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	0.338	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	0.294	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	0.316	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	0.325	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	0.328	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	0.331	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	0.317	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	0.311	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	0.328	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	0.331	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	0.341	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	0.343	0.066	0.178	6.431	69.647
2006	23.790	18.993	10.801	2.356	55.940	8.214	2.869	3.324	0.343	0.072	0.264	6.872	71.025
2007	23.501	19.817	10.802	2.400	56.520	8.415	2.463	3.584	0.353	0.080	0.319	6.800	71.735
2008	23.850	20.834	10.509	2.419	57.613	8.427	2.511	3.867	0.360	0.097	0.546	7.381	73.421
2009	21.578	21.500	11.348	2.572	56.999	8.349	2.682	3.921	0.373	0.109	0.697	7.782	73.130

Source:
Energy Information Administration, *Monthly Energy Review,* August 2010. Table 1.2,
www.eia.doe.gov/emeu/mer/overview.html

Note: NA = Not available.

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

Energy Consumption by Source, 1973-2009
(Quadrillion Btu)

	Fossil Fuels					Renewable Energy[a]						
Year	Coal	Natural Gas[b]	Petro-leum[c,d]	Total[e]	Nuclear Electric Power	Hydro-electric Power[f]	Biomass[d,g]	Geo-thermal	Solar	Wind	Total	Total[d,h]
1973	12.971	22.512	34.840	70.316	0.910	2.861	1.529	0.043	NA	NA	4.433	75.708
1974	12.663	21.732	33.455	67.906	1.272	3.177	1.540	0.053	NA	NA	4.769	73.991
1975	12.663	19.948	32.731	65.355	1.900	3.155	1.499	0.070	NA	NA	4.723	71.999
1976	13.584	20.345	35.175	69.104	2.111	2.976	1.713	0.078	NA	NA	4.768	76.012
1977	13.922	19.931	37.122	70.989	2.702	2.333	1.838	0.077	NA	NA	4.249	78.000
1978	13.766	20.000	37.965	71.856	3.024	2.937	2.038	0.064	NA	NA	5.039	79.986
1979	15.040	20.666	37.123	72.892	2.776	2.931	2.152	0.084	NA	NA	5.166	80.903
1980	15.423	20.235	34.202	69.826	2.739	2.900	2.476	0.110	NA	NA	5.485	78.122
1981	15.908	19.747	31.931	67.570	3.008	2.758	2.596	0.123	NA	NA	5.477	76.168
1982	15.322	18.356	30.232	63.888	3.131	3.266	2.664	0.105	NA	NA	6.034	73.153
1983	15.894	17.221	30.054	63.154	3.203	3.527	2.904	0.129	NA	0.000	6.561	73.038
1984	17.071	18.394	31.051	66.504	3.553	3.386	2.971	0.165	0.000	0.000	6.522	76.714
1985	17.478	17.703	30.922	66.091	4.076	2.970	3.016	0.198	0.000	0.000	6.185	76.491
1986	17.260	16.591	32.196	66.031	4.380	3.071	2.932	0.219	0.000	0.000	6.223	76.756
1987	18.008	17.640	32.865	68.522	4.754	2.635	2.875	0.229	0.000	0.000	5.739	79.173
1988	18.846	18.448	34.222	71.556	5.587	2.334	3.016	0.217	0.000	0.000	5.568	82.819
1989	19.070	19.602	34.211	72.913	5.602	2.837	3.160	0.317	0.055	0.022	6.391	84.944
1990	19.173	19.603	33.553	72.333	6.104	3.046	2.735	0.336	0.060	0.029	6.206	84.652
1991	18.992	20.033	32.845	71.880	6.422	3.016	2.782	0.346	0.063	0.031	6.238	84.607
1992	19.122	20.714	33.527	73.397	6.479	2.617	2.933	0.349	0.064	0.030	5.993	85.956
1993	19.835	21.229	33.744	74.836	6.410	2.892	2.910	0.364	0.066	0.031	6.262	87.603
1994	19.909	21.728	34.562	76.258	6.694	2.683	3.030	0.338	0.069	0.036	6.155	89.260
1995	20.089	20.089	34.436	77.257	7.075	3.205	3.101	0.294	0.070	0.033	6.703	91.169
1996	21.002	21.002	35.673	79.782	7.087	3.590	3.157	0.316	0.071	0.033	7.166	94.172
1997	21.445	21.445	36.159	80.874	6.597	3.640	3.105	0.325	0.070	0.034	7.175	94.761
1998	21.656	21.656	36.816	81.369	7.068	3.297	2.928	0.328	0.070	0.031	6.654	95.178
1999	21.623	21.623	37.837	82.427	7.610	3.268	2.963	0.331	0.069	0.046	6.677	96.812
2000	22.580	22.580	38.263	84.732	7.862	2.811	3.008	0.317	0.066	0.057	6.260	98.970
2001	21.914	21.914	38.185	82.902	8.029	2.242	2.622	0.311	0.065	0.070	5.311	96.316
2002	21.904	21.904	38.225	83.749	8.145	2.689	2.701	0.328	0.064	0.105	5.888	97.853
2003	22.321	22.321	38.808	84.010	7.959	2.825	2.807	0.331	0.064	0.115	6.141	98.131
2004	22.466	22.466	40.292	85.805	8.222	2.690	3.010	0.341	0.064	0.142	6.247	100.313
2005	22.797	22.797	40.391	85.793	8.161	2.703	3.117	0.343	0.066	0.178	6.406	100.445
2006	22.447	22.447	39.955	84.687	8.215	2.869	3.277	0.343	0.072	0.264	6.824	99.790
2007	22.749	22.749	39.769	86.246	8.455	2.446	3.503	0.349	0.081	0.341	6.719	101.527
2008	22.385	23.791	37.279	83.496	8.427	2.511	3.852	0.360	0.097	0.546	7.366	99.402
2009	19.761	23.338	35.416	78.492	8.349	2.682	3.905	0.373	0.109	0.697	7.766	94.724

Source:
Energy Information Administration, *Monthly Energy Review,* August 2010. 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.

Except for corn and soybeans, all biomass resources being used in 2009 for energy are some type of residue or waste. Corn grain is used for ethanol and soybeans are used for biodiesel fuel.

Renewable Energy Consumption by Source, 1973-2009

(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	43	NA	NA	4,433
1974	3,177	1,538	2	NA	1,540	53	NA	NA	4,769
1975	3,155	1,497	2	NA	1,499	70	NA	NA	4,723
1976	2,976	1,711	2	NA	1,713	78	NA	NA	4,768
1977	2,333	1,837	2	NA	1,838	77	NA	NA	4,249
1978	2,937	2,036	1	NA	2,038	64	NA	NA	5,039
1979	2,931	2,150	2	NA	2,152	84	NA	NA	5,166
1980	2,900	2,474	2	NA	2,476	110	NA	NA	5,485
1981	2,758	2,496	88	13	2,596	123	NA	NA	5,477
1982	3,266	2,510	119	35	2,664	105	NA	NA	6,034
1983	3,527	2,684	157	63	2,904	129	NA	0	6,561
1984	3,386	2,686	208	77	2,971	165	0	0	6,522
1985	2,970	2,687	236	93	3,016	198	0	0	6,185
1986	3,071	2,562	263	107	2,932	219	0	0	6,223
1987	2,635	2,463	289	123	2,875	229	0	0	5,739
1988	2,334	2,577	315	124	3,016	217	0	0	5,568
1989	2,837	2,680	354	126	3,160	317	55	22	6,391
1990	3,046	2,216	408	111	2,735	336	60	29	6,206
1991	3,016	2,214	440	129	2,782	346	63	31	6,238
1992	2,617	2,313	473	146	2,933	349	64	30	5,993
1993	2,892	2,260	479	171	2,910	364	66	31	6,262
1994	2,683	2,324	515	190	3,030	338	69	36	6,155
1995	3,205	2,370	531	200	3,101	294	70	33	6,703
1996	3,590	2,437	577	143	3,157	316	71	33	7,166
1997	3,640	2,371	551	184	3,105	325	70	34	7,175
1998	3,297	2,184	542	201	2,928	328	70	31	6,654
1999	3,268	2,214	540	209	2,963	331	69	46	6,677
2000	2,811	2,262	511	236	3,008	317	66	57	6,260
2001	2,242	2,006	364	253	2,622	311	65	70	5,311
2002	2,689	1,995	402	303	2,701	328	64	105	5,888
2003	2,825	2,002	401	404	2,807	331	64	115	6,141
2004	2,690	2,121	389	500	3,010	341	64	142	6,247
2005	2,703	2,136	403	577	3,117	343	66	178	6,406
2006	2,869	2,109	397	771	3,277	343	72	264	6,824
2007	2,446	2,098	413	991	3,503	349	81	341	6,719
2008	2,511	2,044	436	1,372	3,852	360	97	546	7,366
2009	2,682	1,891	447	1,567	3,905	373	109	697	7,766

Source:
Energy Information Administration, *Monthly Energy Review,* August 2010, 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 95% of the renewable transportation fuels consumed in the United States in 2009 while biodiesel accounted for about 5%. In the industrial sector, biomass accounted for nearly all of the renewable energy consumed.

Section: INTRODUCTION
Renewable Energy Consumption for Industrial and Transportation Sectors, 1973-2009
(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	1,649	NA	1,682	19	NA	19
1983	33	1,690	155	0	28	1,874	NA	1,907	34	NA	34
1984	33	1,679	204	1	34	1,917	NA	1,950	42	NA	42
1985	33	1,645	230	1	41	1,917	NA	1,950	51	NA	51
1986	33	1,610	256	1	47	1,914	NA	1,947	59	NA	59
1987	33	1,576	282	1	54	1,912	NA	1,945	67	NA	67
1988	33	1,625	308	1	54	1,988	NA	2,020	68	NA	68
1989	28	1,584	200	1	55	1,840	2	1,870	69	NA	69
1990	31	1,442	192	1	48	1,683	2	1,716	62	NA	62
1991	30	1,410	185	1	56	1,651	2	1,683	72	NA	72
1992	31	1,461	179	1	63	1,704	2	1,737	81	NA	81
1993	30	1,484	181	1	74	1,740	2	1,772	96	NA	96
1994	62	1,580	199	1	82	1,862	3	1,927	107	NA	107
1995	55	1,652	195	2	86	1,934	3	1,992	113	NA	113
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	328	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	603
2008	17	1,344	144	12	532	2,031	5	2,053	786	40	827
2009	18	1,217	160	13	617	2,007	4	2,029	894	40	934

Source:
Energy Information Administration, *Monthly Energy Review*, August 2010, 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 2009, biomass accounted for about 76% of the renewable energy used in the residential sector and about 86% of the renewable energy used in the commercial sector.

Section: INTRODUCTION

Renewable Energy Consumption for Residential and Commercial Sectors, 1973-2009

(Trillion Btu)

	Residential Sector				Commercial Sector[a]						
	Biomass					Biomass					
Year	Wood[b]	Geo-thermal[c]	Solar[d]	Total	Hydro-electric	Wood[b]	Waste	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	53	978	1	76	22	1	99	3	102
1990	580	6	56	641	1	66	28	1	94	3	98
1991	610	6	58	674	1	68	26	0	95	3	100
1992	640	6	60	706	1	72	32	0	105	3	109
1993	550	7	62	618	1	76	33	0	109	3	114
1994	520	6	64	590	1	72	35	0	106	4	112
1995	520	7	65	591	1	72	40	0	113	5	118
1996	540	7	65	612	1	76	53	0	129	5	135
1997	430	8	65	503	1	73	58	0	131	6	138
1998	380	8	65	452	1	64	54	0	118	7	127
1999	390	9	64	462	1	67	54	0	121	7	129
2000	420	9	61	490	1	71	47	0	119	8	128
2001	370	9	60	439	1	67	25	0	92	8	101
2002	380	10	59	449	0	69	26	0	95	9	104
2003	400	13	58	471	1	71	29	1	101	11	113
2004	410	14	59	483	1	70	34	1	105	12	118
2005	430	16	61	507	1	70	34	1	105	14	119
2006	390	18	67	475	1	65	36	1	102	14	117
2007	430	22	75	527	1	69	31	2	102	14	118
2008	450	26	88	565	1	73	34	2	109	15	125
2009	430	33	101	563	1	72	34	2	108	17	125

Source:

Energy Information Administration, *Monthly Energy Review*, August 2010, 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.

Total industrial biomass energy consumption was approximately 2,031 trillion Btu in 2008. The bulk of industrial biomass energy consumption is derived from forestlands. More than one-half of this total is black liquor – a pulping mill by-product containing unutilized wood fiber and chemicals. Black liquor is combusted in recovery boilers to recover valuable chemicals and to produce heat and power. Wood and wood wastes generated in primary wood processing mills account for another third of total industrial biomass energy consumption. The data contained in this table are from a survey of manufacturers that is conducted every four years by the EIA.

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	-

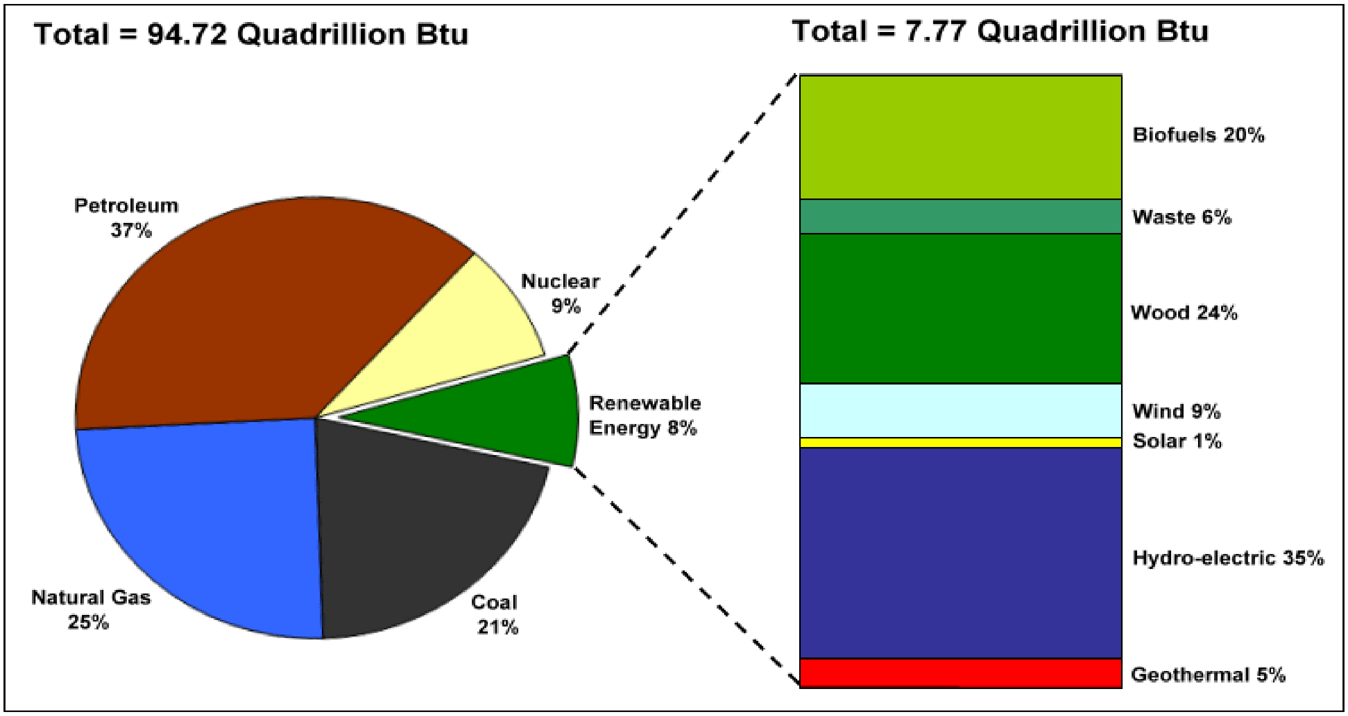
Source:
Renewable Energy Annual, 2008 Edition. Table 1.8 Industrial Biomass Energy Consumption and Electricity Net Generation by Industry and Energy Source, 2008, http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/table1_8.html

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 2009 accounted for half of all renewable energy consumption. In 2009, biomass contributed about 4.1% of the total U.S. energy consumption of about 95 quadrillion Btu. Wood, wood waste, and black liquor from pulp mills is the single largest source, accounting for almost two-thirds of total biomass energy consumption. Wastes (which include municipal solid waste, landfill gas, sludge waste, tires, agricultural by-products, and other secondary and tertiary sources of biomass) accounts for about 12% of total biomass consumption. The remaining share is alcohol fuel derived principally from corn grain.

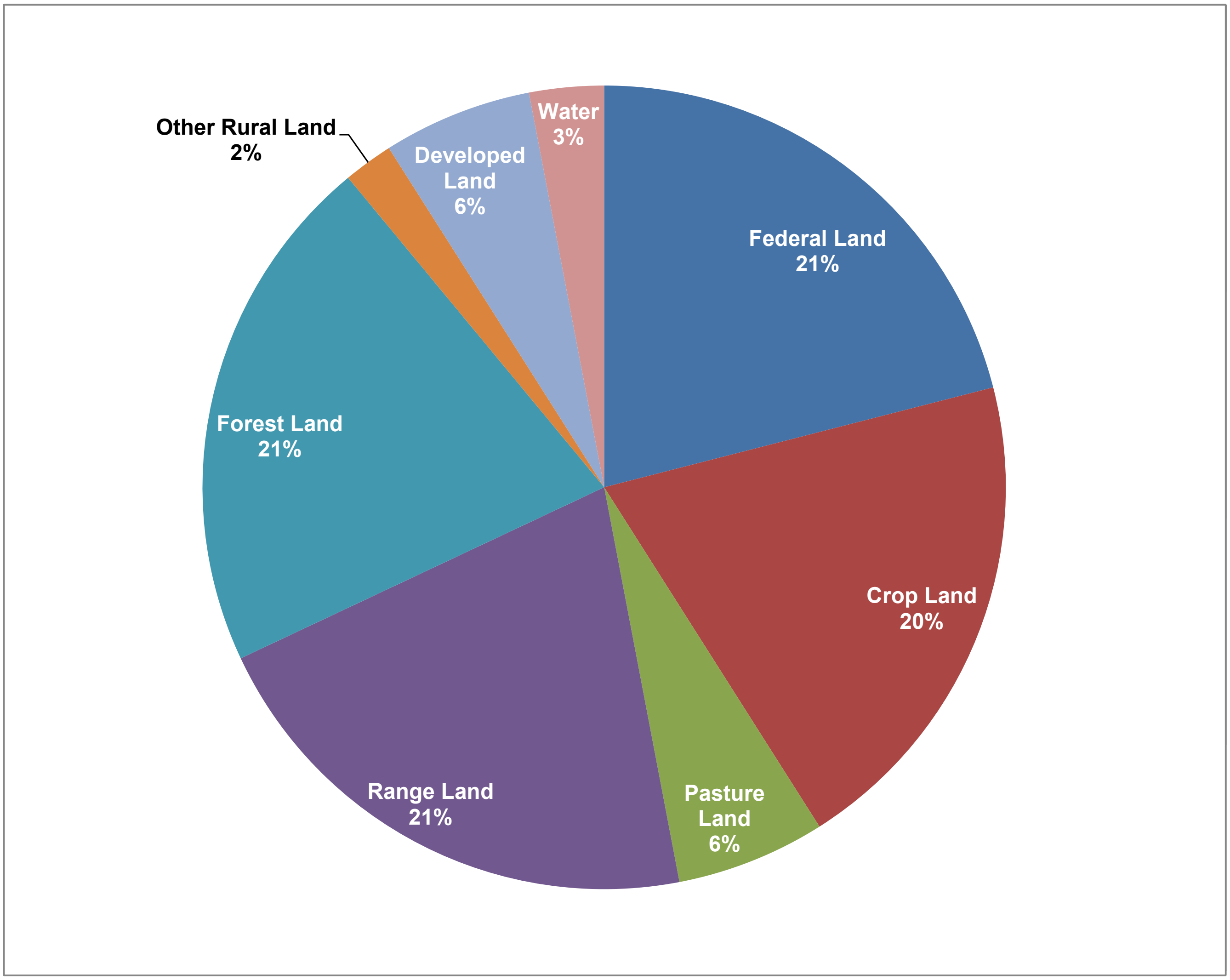
Section: INTRODUCTION
Summary of Biomass Energy Consumption, 2009



Source:
Energy Information Administration, *Monthly Energy Review*, September 2010, 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

The United States has a total surface area if 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/technical/NRI/2007/2007_NRI_Summary.pdf

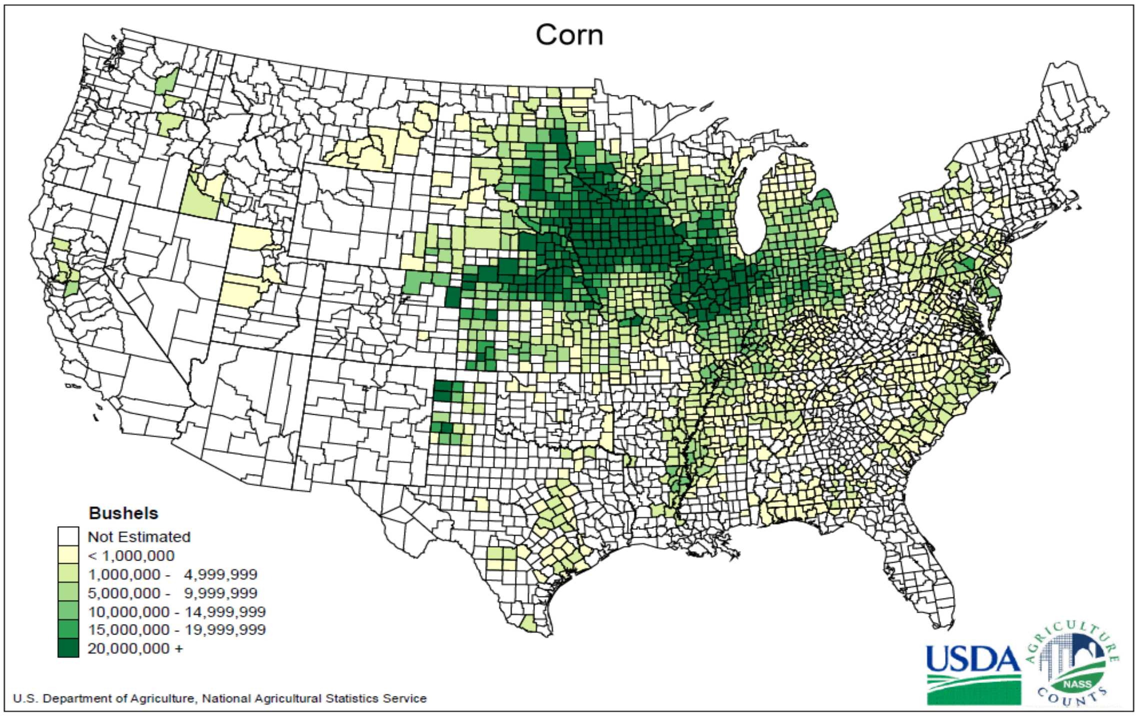
Note:
Cropland includes CRP Land, which is reported separately in the source document.
CRP = Conservation Reserve Program

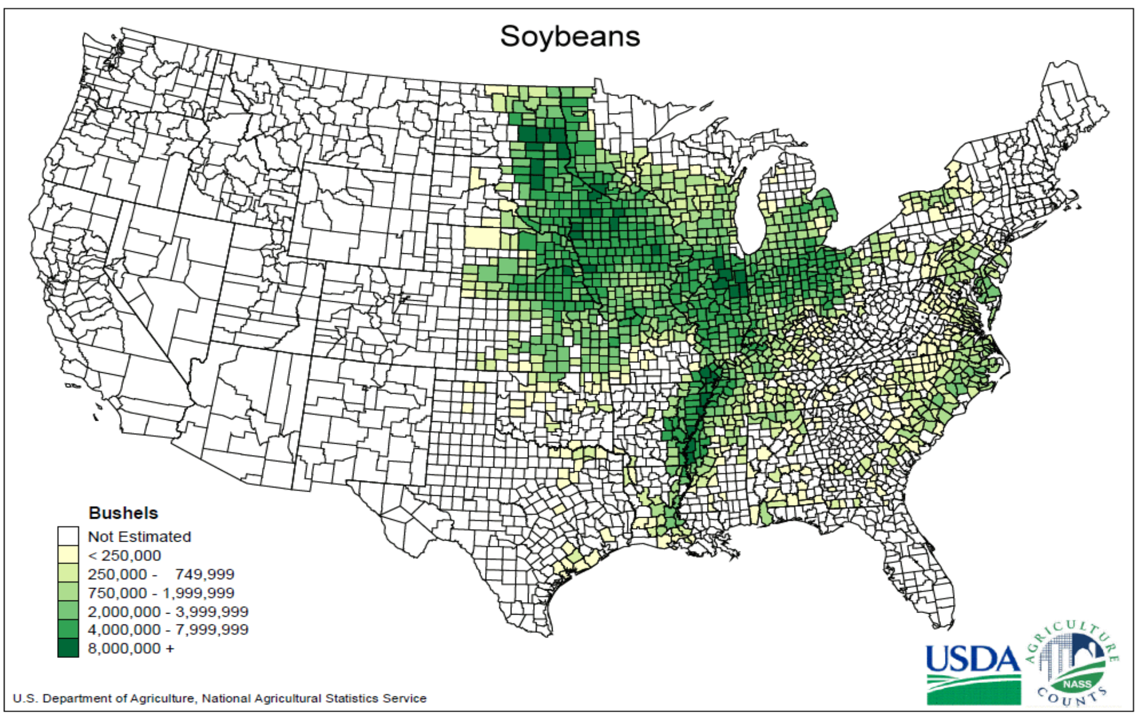
Location of commodity crop production shows where agricultural residues are potentially available for collection and energy crops potentially available for production.

Section: INTRODUCTION

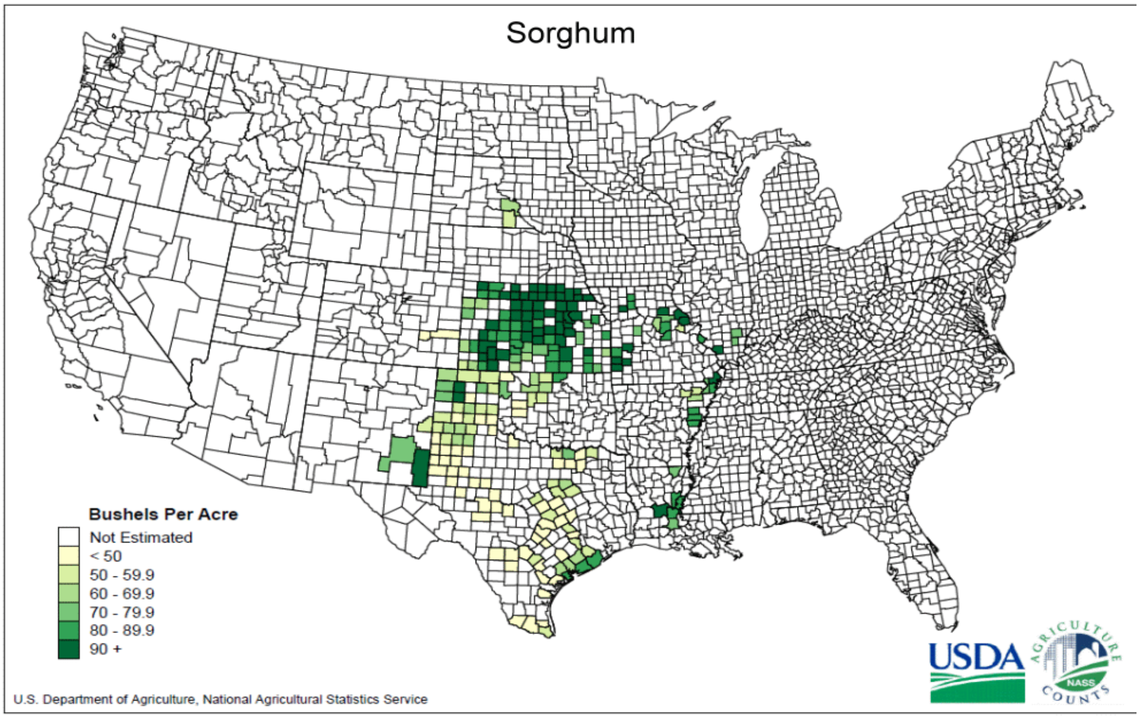
Geographic Locations of Major Crops, 2009[a]

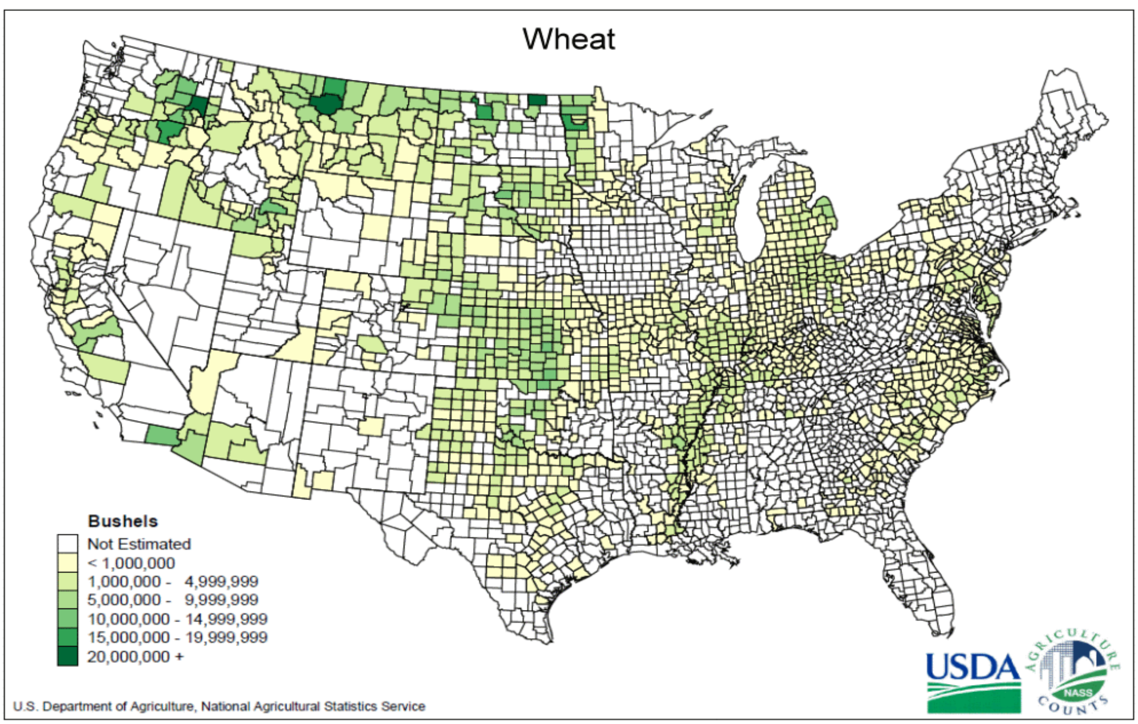
(production acreage by county)





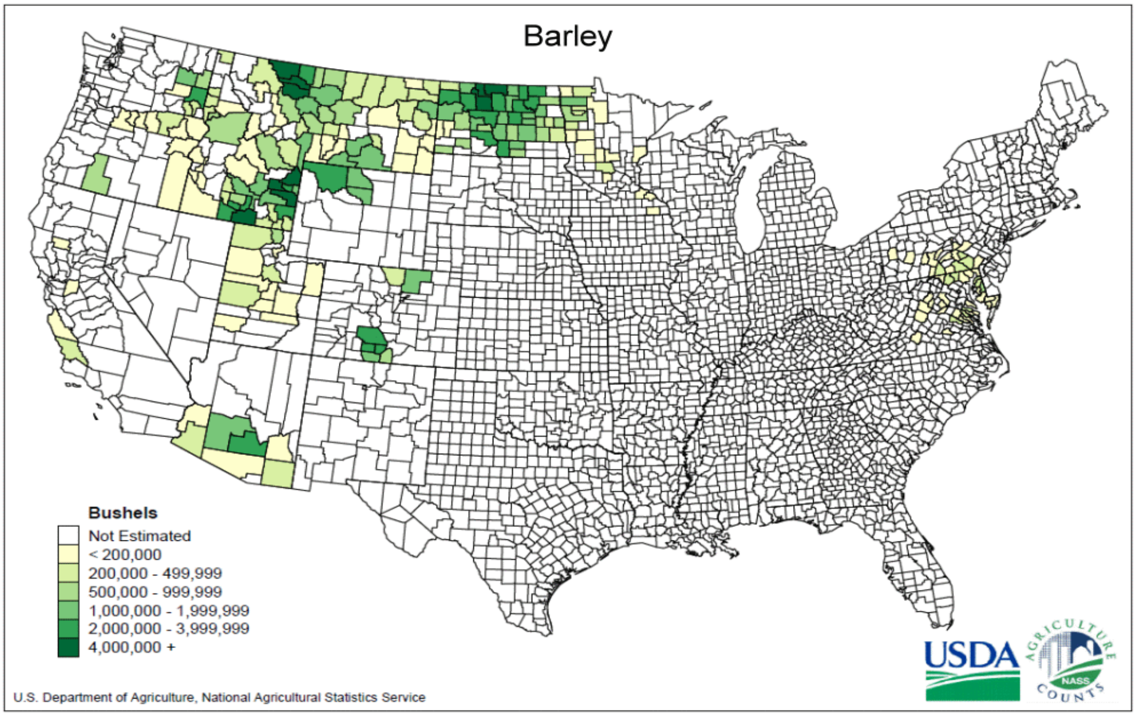
Geographic Locations of Major Crops, 2009[a]
(production acreage by county)

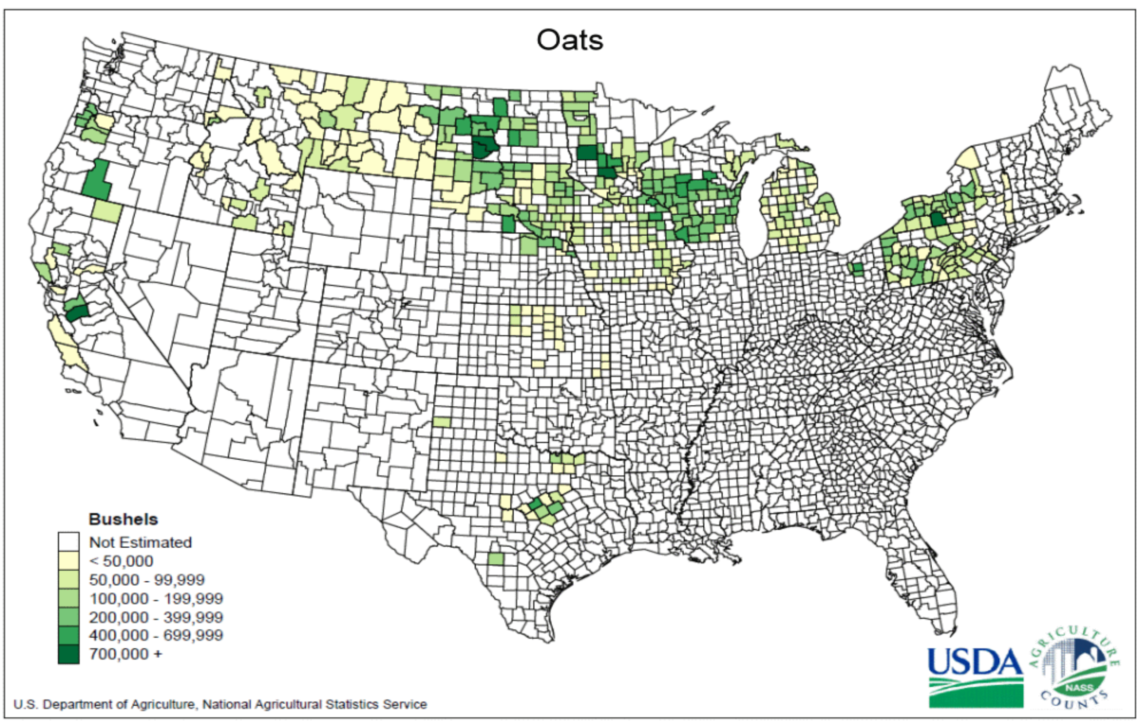




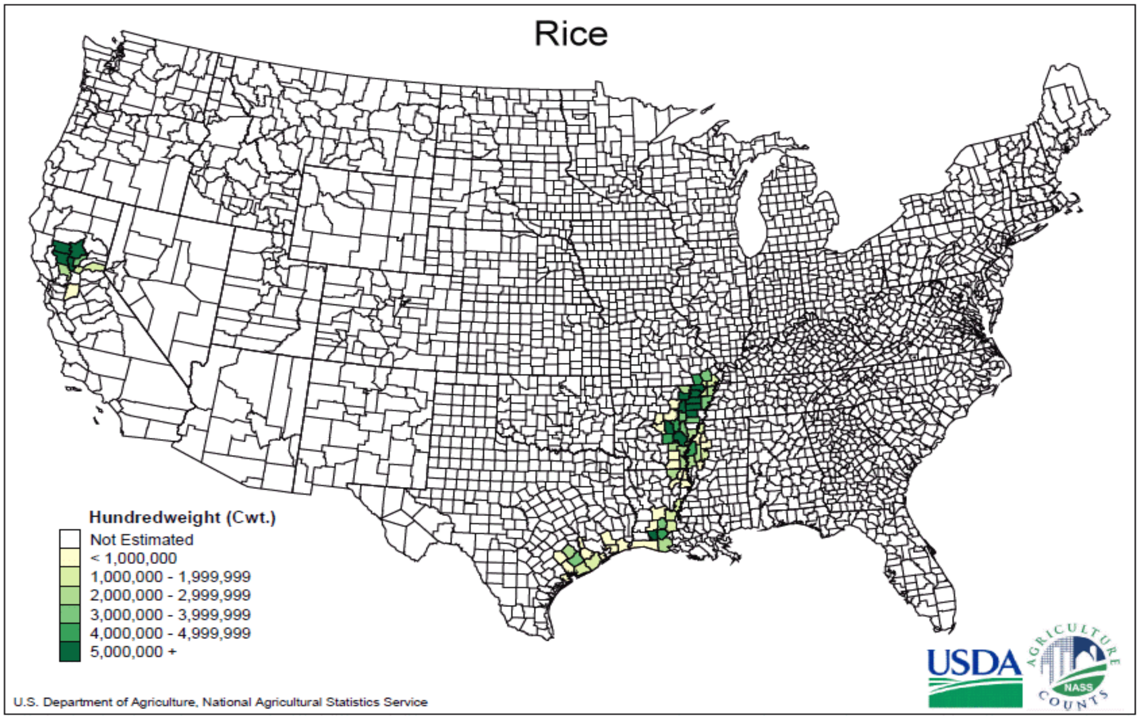
[a] Map for wheat is for 2008.

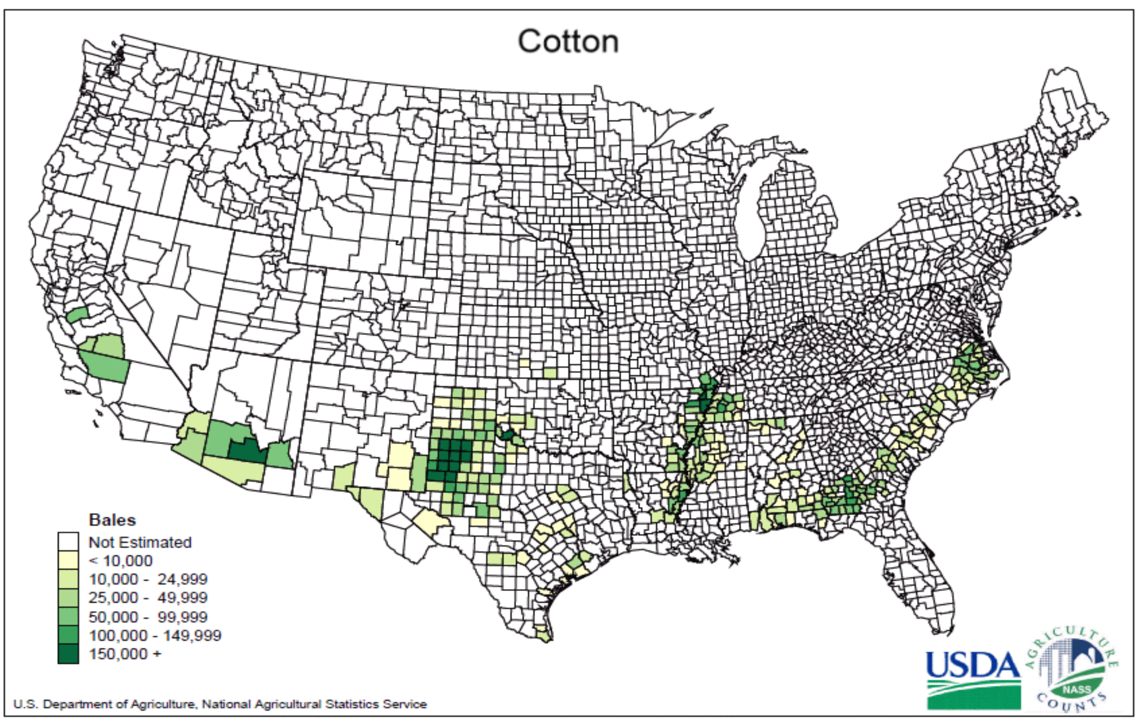
Section: INTRODUCTION
Geographic Locations of Major Crops, 2009[a]
(production acreage by county)





Geographic Locations of Major Crops, 2009[a]
(production acreage by county)



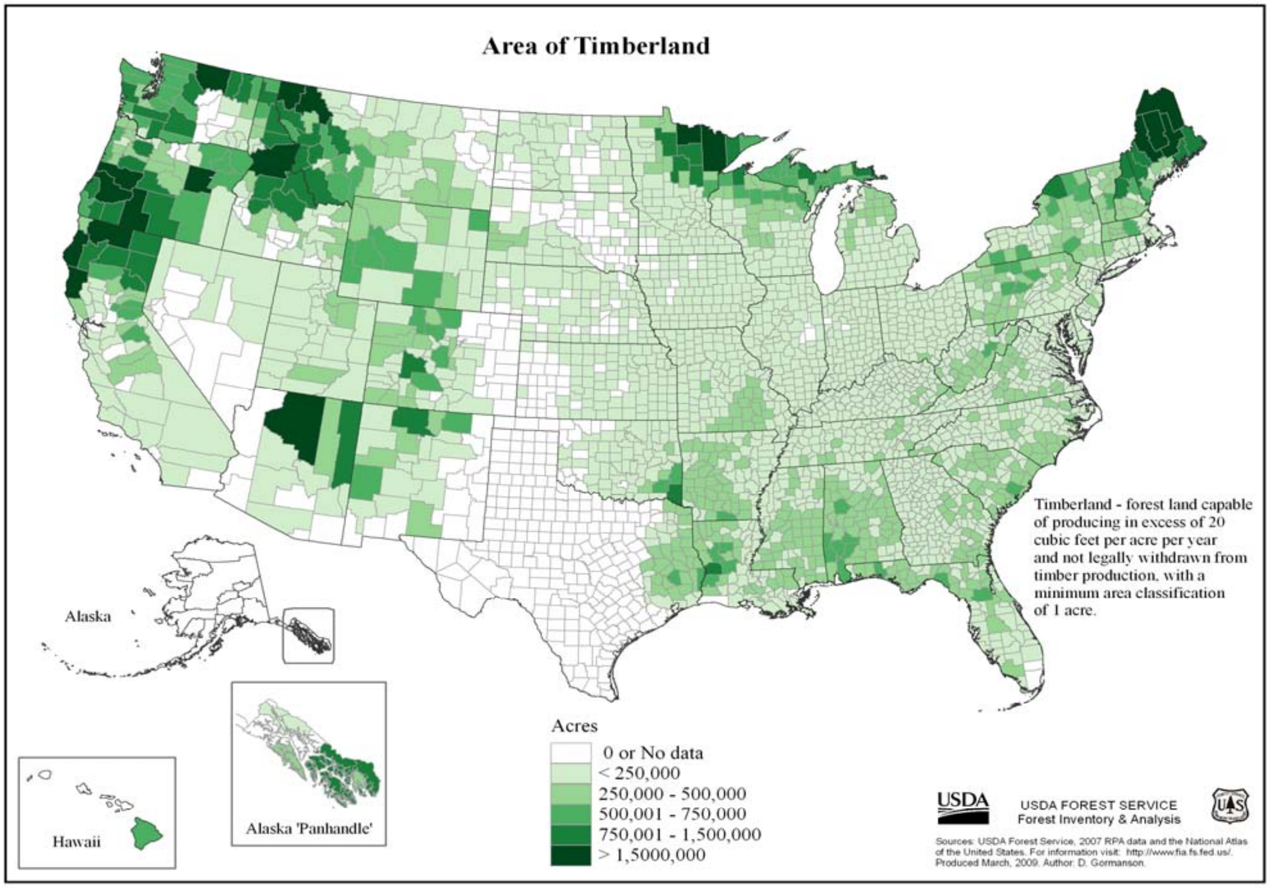


Source:
U.S. Department of Agriculture, National Agricultural Statistics Service
http://www.nass.usda.gov/Charts_and_Maps/A_to_Z/index.asp#h

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.

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.

Cellulosic Biomass Resources

Cellulosic feedstocks such as switchgrass, first came to the attention of many in America when President Bush spoke in his January 31, 2006, State of the Union address of producing biofuels by 2012 using "woodchips, stalks and switchgrass" as the source of cellulosic biomass for producing ethanol. The President also put forward the advanced energy initiative which supported a 22% increase in clean-energy research and set a goal of replacing 75% of the oil imports from the Middle East by 2025. The 2007 State of the Union address re-enforced the concept of using cellulosic biomass for producing ethanol. The president ramped up the goals for alternative fuel use by proposing that the U.S. reduce gasoline consumption by 20% in ten years.

The legislation that was passed in 2007 to support the President's goals, the Energy Independence and Security Act (EISA) of 2007 (H.R. 6), established Renewable Fuel Standards that will require, by 2022, very large supplies of cellulosic biomass in addition to the grains and oils already being used. The potential exists in the U.S. for large supplies since cellulosic biomass can include everything from primary biomass sources of energy crops and forest thinnings or residuals harvested or collected directly from the land, to secondary biomass sources such as sawmill residuals, to tertiary biomass sources of post-consumer residuals that often end up in landfills. Biomass resources also include the gases that result from anaerobic digestion of animal manures or organic materials in landfills.

The estimated potential future availability of agricultural and forestry biomass in the U.S. was reported in 2005 in a joint DOE and USDA document entitled "Biomass as Feedstock For a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply" ; Perlack et al. (2005). The report indicates a technical availability of about 200 million dry tons from the agriculture sector with yields, collection technology and crop management approaches in place in 2001. However scenarios of possible future changes in crop yield, crop management and harvest technology, and in use of perennial energy crops (such as switchgrass) suggests that about 400 to nearly 1 billion dry tons could be technically derived from the agricultural sector later this century. Details on individual crops are provided in the Feedstocks Section of the Biomass Energy Data Book. The ultimate limit for the amount of biomass that can be sustainably produced on agricultural land in the United States depends on land availability. The areas of the country with adequate rainfall and soil quality for production and harvest of energy crops are roughly the same areas where major crops are currently produced in the United States. The major crops (especially corn) are the primary source of lignocellulosic biomass from the agricultural sector. Changes in the way that land is managed will be necessary for increasing biomass resource availability in the U.S. An update of the biomass supply assessment is currently underway including consideration of economic constraints. The current summary tables will be replaced with updated information when they become available.

One of the larger unexploited sources of cellulosic biomass is wood that needs to be removed from forests to reduce the risk of forest fires. Well over 8 billion dry tons of biomass has been identified by the U.S. Forest Service as needing fuel treatment removal (Perlack et al., 2005). The amount of this biomass potentially available for bioenergy uses is estimated to be about 60 million dry tons annually. This estimate takes into consideration factors affecting forest access, residue recovery and the desirability of using some of the recoverable biomass for conventional wood products. The fraction that could be available annually for bioenergy and bioproducts is less than 1% of the total size of the fuel treatment biomass resource. The other large underutilized sources of woodchips are logging residues and urban wood residues. In the case of forest biomass, the relatively high costs of removal, handling, and transportation have not, in the past, compared favorably to their relatively low value as bioenergy resources. Factors affecting the rate at which this source of material will become available for bioenergy includes public opinion toward this type of removal, as well as delivered costs and the extent to which technology is developed for utilizing small diameter wood for products other than bioenergy. The compost market already competes for urban wood resources.

A factor that could greatly affect the amount of wood used for bioenergy, especially of forest fuel treatment removals, is that the definition of "renewable biomass" in EISA 2007 does not include thinnings and residues from federal forests, and some woody feedstocks from private forests except where that biomass is “obtained from the immediate vicinity of buildings, and other areas regularly occupied by people, or of public infrastructure, at risk from wildfire.” While the legislation does not prohibit the use of forest thinnings and fuel reduction treatments from federal forests for bioenergy or bioproducts, it does exclude them from qualifying as feedstocks suitable for meeting the Renewable Fuel Standard targets in EISA 2007.

The Biomass Research and Development Technical Advisory Committee has provided numerous recommendations to DOE, USDA and other Federal Agencies on the research and development needed to ensure that a broad portfolio of diverse domestic feedstocks is available for our nation's energy and chemical supplies. The Executive Summary of the *Roadmap for Bioenergy and Biobased Products in the U.S.* states that significant research breakthroughs are needed in a number of key area including advances in plant science to improve the cost effectiveness of converting biomass to fuel, power, and products. Additionally, it recommends that R&D in geographical information systems will help the U.S. more accurately identify biomass availability. Finally, it recommends a focus on advancements in harvesting methods for both agricultural and forest resources. Additionally, the report *Increasing Feedstock Production for Biofuels: Economic Drivers, Environmental Implications, and the Role of Research* was released in 2008.

In May of 2010, the *National Algal Biofuels Technology Roadmap* was published. This Roadmap describes the current status of algae research, development, and deployment. It also lays the groundwork for identifying challenges that likely need to be overcome for algal biomass to be used in the production of economically viable biofuels. In summary, this Roadmap suggests that many years of both basic and applied science and engineering will likely be needed to achieve affordable, scalable, and sustainable algal-based fuels. The ability to quickly test and implement new and innovative technologies in an integrated process will be a key component to accelerating progress in this area.

Sources:

The White House. 2007 and 2008 State of the Union addresses. http://georgewbush-whitehouse.archives.gov/index.html

The Energy Independence and Security Act of 2007 (H.R.6); final version: http://www.thomas.gov/cgi-bin/query/z?c110:H.R.6:

Perlack, R.D., Wright L.L., Turhollow, A.F., Graham, R.L., Stokes, B.H., and Erbach, D.C., 2005. Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply. DOE/GO-102005-2135 also ORNL/TM-2005/66. A joint U.S. Department of Energy and U.S. Department of Agriculture report available online at: http://www1.eere.energy.gov/biomass/publications.html

Biomass Research and Development Technical Advisory Committee. Roadmap for Bioenergy and Biobased Products in the United States, October 2007. At: http://www1.eere.energy.gov/biomass/pdfs/obp_roadmapv2_web.pdf

Biomass Research and Development Technical Advisory Committee. Increasing Feedstock Production for Biofuels: Economic Drivers, Environmental Implications, and the Role of Research, 2008. Available at: http://www.brdisolutions.com

BIOFUELS

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 2009 production and consumption at nearly 11 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 2008. 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/

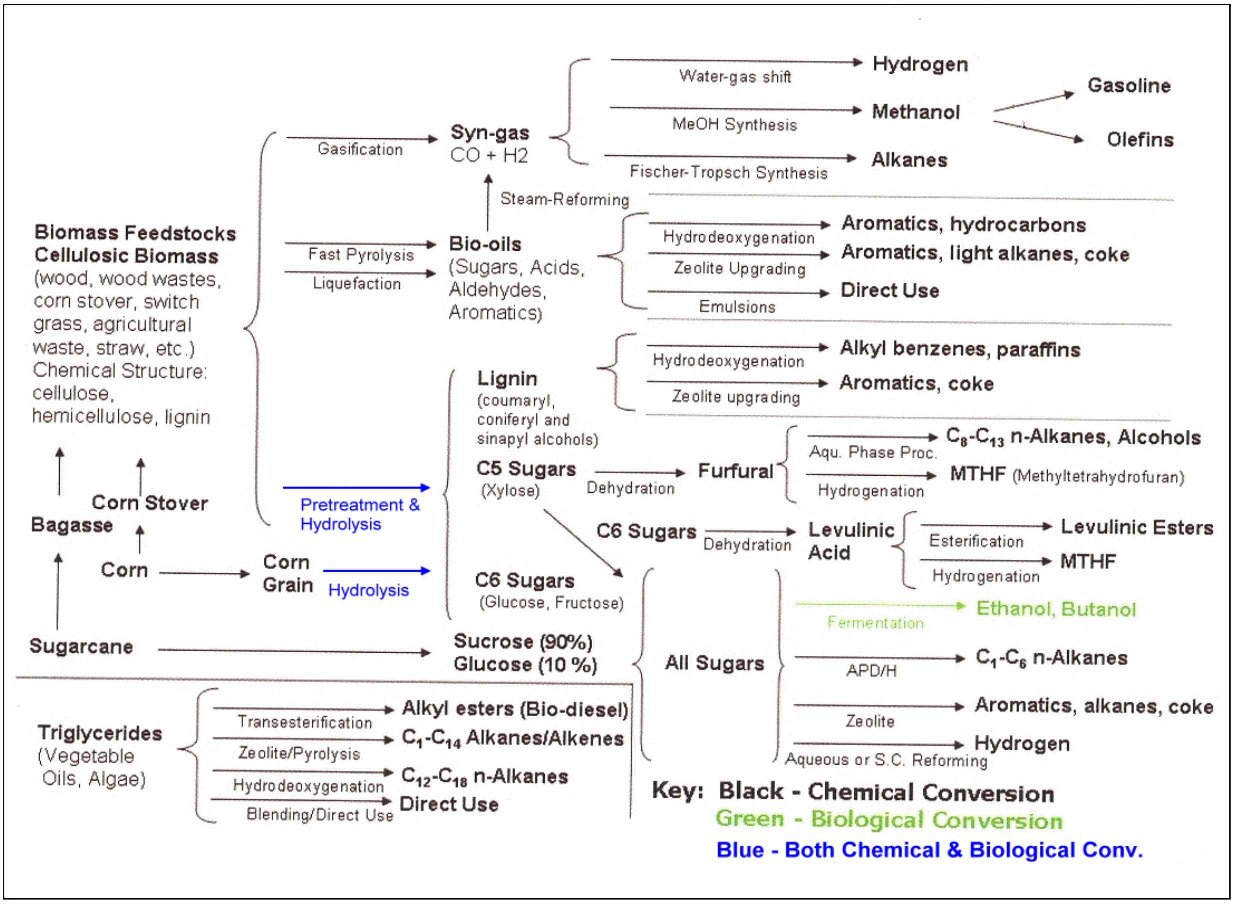
Section: BIOFUELS
Biological and Chemical Catalysts for Biofuels

	Biological Catalysts	Chemical Catalysts
Products	Alcohols	A Wide Range of Hydrocarbon Fuels
Reaction Conditions	Less than 70°C, 1 atm	10-1200°C, 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.

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.

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 2008, more than 6.4 billion 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. 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. and Brazil produced about 89 percent of the world's fuel ethanol in 2008.

Section: BIOFUELS

World Fuel Ethanol Production by Country or Region, 2008

(Millions of gallons, all grades)

Country 2008	
U.S.	9,000.0
Brazil	6,472.2
European Union	733.6
China	501.9
Canada 237.7	
Other	128.4
Thailand	89.8
Colombia	79.29
India	66.0
Australia	26.4
Total 17,335.2	

Source:
Renewable Fuels Association, Industry Statistics, 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.

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

Section: BIOFUELS
U.S. Fuel Ethanol Imports by Country, 2002 - 2007
(millions of gallons)

Country	2002	2003	2004	2005	2006	2007
Brazil	0.0	0.0	90.3	31.2	433.7	188.8
Costa Rica	12	14.7	25.4	33.4	35.9	39.3
El Salvadore	4.5	6.9	5.7	23.7	38.5	73.3
Jamaica	29.0	39.3	36.6	36.3	66.8	75.2
Trinadad & Tobago	0.0	0.0	0.0	10.0	24.3	42.7
Canada	0.0	0.0	0.0	0.0	0.0	5.4
China	0.0	0.0	0.0	0.0	0.0	4.5
Total	**45.5**	**60.9**	**158.0**	**134.6**	**599.2**	**429.2**

Source:
Renewable Fuels Association,
http://www.ethanolrfa.org/pages/statistics

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

Fuel ethanol production has been on the rise in the U.S. since 1980, though production has increased dramatically in recent years. Fuel ethanol production increased over 200% between 2004 and 2009.

Section: BIOFUELS
Historic Fuel Ethanol Production, 1980-2009

Year	Millions of Gallons
1980	175
1981	215
1982	350
1983	375
1984	430
1985	610
1986	710
1987	830
1988	845
1989	870
1990	900
1991	950
1992	1,100
1993	1,200
1994	1,350
1995	1,400
1996	1,100
1997	1,300
1998	1,400
1999	1,470
2000	1,630
2001	1,770
2002	2,130
2003	2,800
2004	3,400
2005	3,904
2006	4,855
2007	6,500
2008	9,000
2009	10,600

Source:
Renewable Fuels Association, Industry Statistics.
http://www.ethanolrfa.org/pages/statistics

Between 1999 and 2010, the number of ethanol plants in the U.S. more than tripled, 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 Production Statistics, 1999-2010

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[b]	24	2,066.0	26
2010	187[a]	13,028.4[b]	15	1,432.0	26

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

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

[a] Operating plants
[b] Capacity including idled capacity

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, 2009

Plant Feedstock	Capacity (million gallons/year)	% of Capacity	No. of Plants	% of Plants
Corn[a]	9,605	91.2%	144	85.2%
Corn, Milo[b]	717	6.8%	14	8.3%
Corn, Wheat	130	1.2%	1	0.6%
Milo	3	0.0%	1	0.6%
Wheat, Milo	50	0.5%	1	0.6%
Cheese Whey	5	0.0%	1	0.6%
Waste Beverages[c]	19	0.2%	5	3.0%
Waste Sugars & Starches[d]	7	0.1%	2	1.2%
Total	**10,536**	**100.0%**	**169**	**100.0%**

Source:

Environmental Protection Agency, Assesment and Standard Division, Office of Transportation and Air Quality, "Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program", May 2009, EPA-420-D-09-001.

[a] Includes one facility processing seed corn, two facilities also operating pilot-level cellulosic ethanol

[b] Includes one facility processing a small amount of molasses in addition to corn and milo.

[c] Includes two facilities processing brewery waste.

[d] Includes one facility processing potato waste that intends to add corn in the future.

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

Ethanol Production Capacity by Plant Energy Source, 2009

Energy Source	Capacity MGY	% of Capacity	No. of Plants	% of Plants	CHP Tech.
Coal[a]	1,868	17.7%	20	11.8%	9
Coal, Biomass	50	0.5%	1	0.6%	0
Natural Gas[b]	8,294	78.7%	142	84.0%	15
Natural Gas, Biomass[c]	113	1.1%	3	1.8%	1
Natural Gas, Landfill Biogas, Wood	110	1.0%	1	0.6%	0
Natural Gas, Syrup	101	1.0%	2	1.2%	0
Total	**10,536**	**100.0%**	**169**	**100.0%**	**25**

Source:

Environmental Protection Agency, Assesment and Standard Division, Office of Transportation and Air Quality, "Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program", May 2009, EPA-420-D-09-001.

[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 one facility that intends to switch to biomass, one facility that intends to burn thin stillage biogas, and two facilities that might switch to coal in the future.

[c]Includes one facility processing bran in addition to natural gas.

With increased blending of ethanol in gasoline, demand for ethanol has continued to rise, requiring greater production capacity. As of November 11, 2010, there were 204 biorefineries producing about 13,118 million gallons of ethanol per year and another nine biorefineries under construction. The Renewable fuels Association tracks the statistics found in the table below and provides plant names, locations and feedstocs 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, November 11, 2010

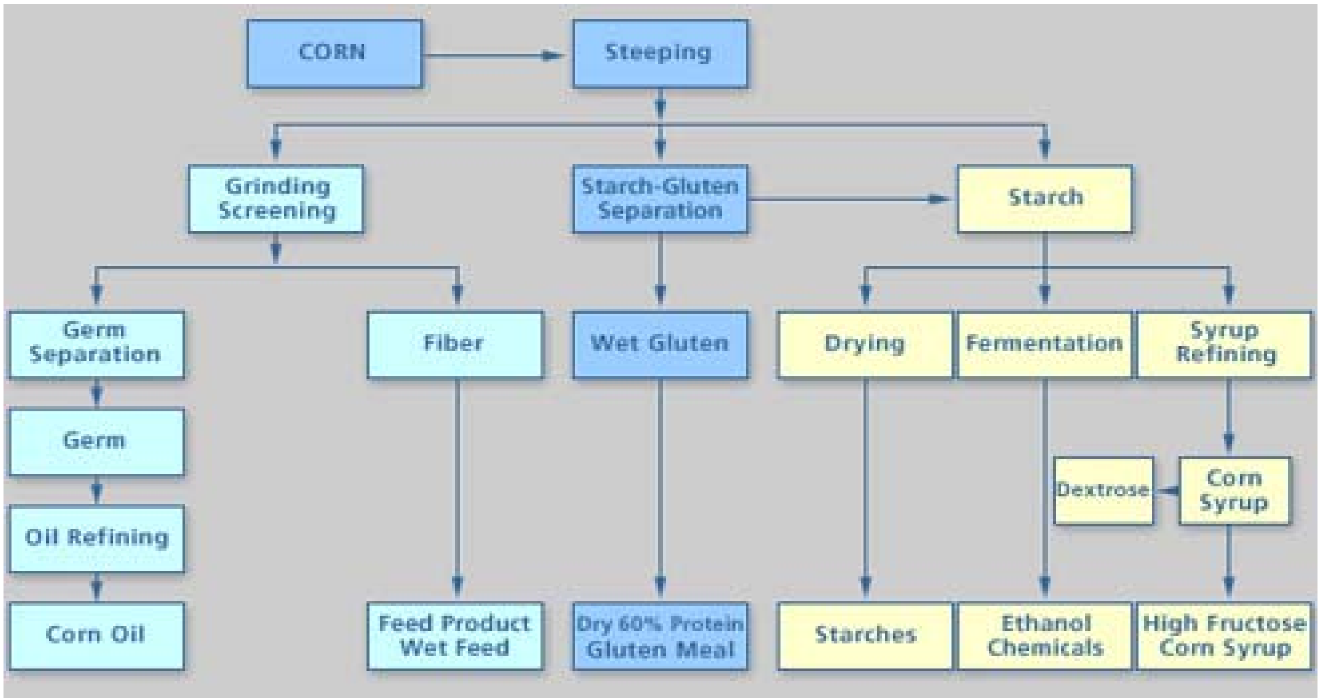
Number of Biorefineries	**Capacity** (mgy)	**Production** (mgy)	**Biorefineries Under Construction**	**Under Construction Capacity** (mgy)
204	13,771.4	13,117.9	9	840

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

Note:
mgy = million gallons per year

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.

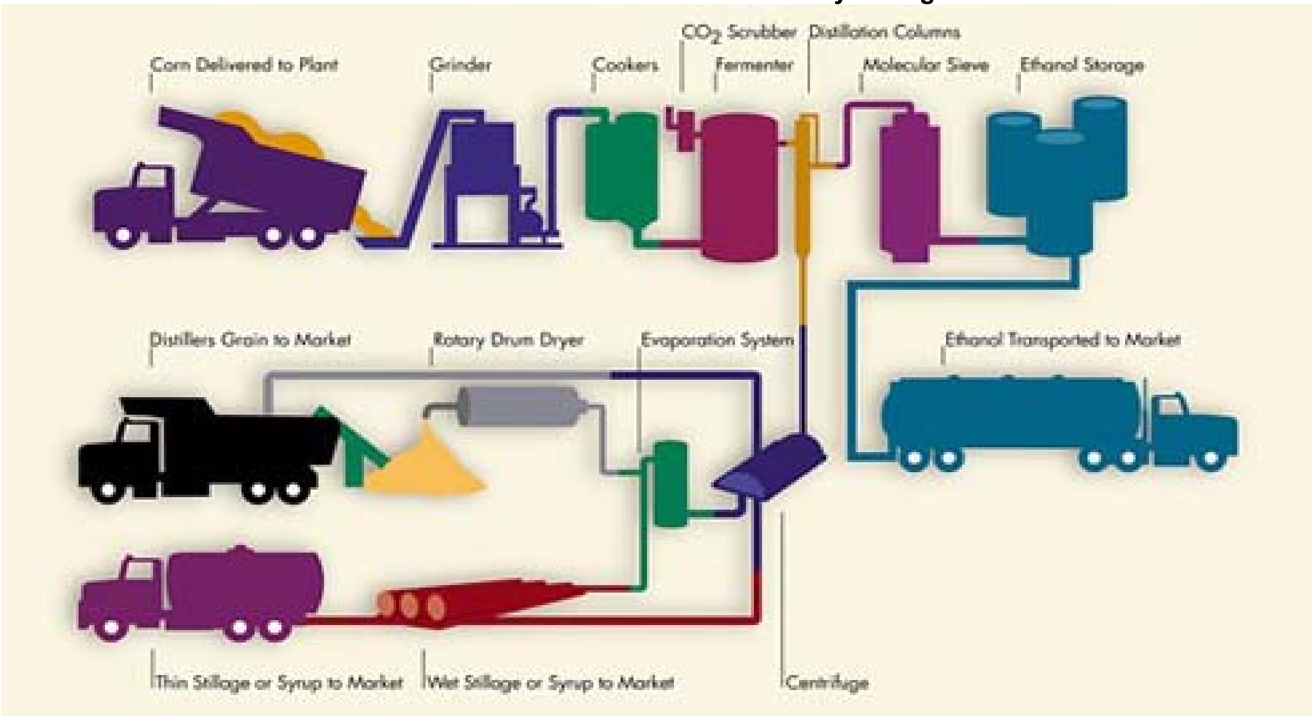
The steeping liquor is concentrated in an evaporator. This concentrated product, heavy steep water, is co-dried with the fiber component and is then sold as corn gluten feed to the livestock industry. Heavy steep water is also sold by itself as a feed ingredient and is used as a component in Ice Ban,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

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 (CO2) 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.

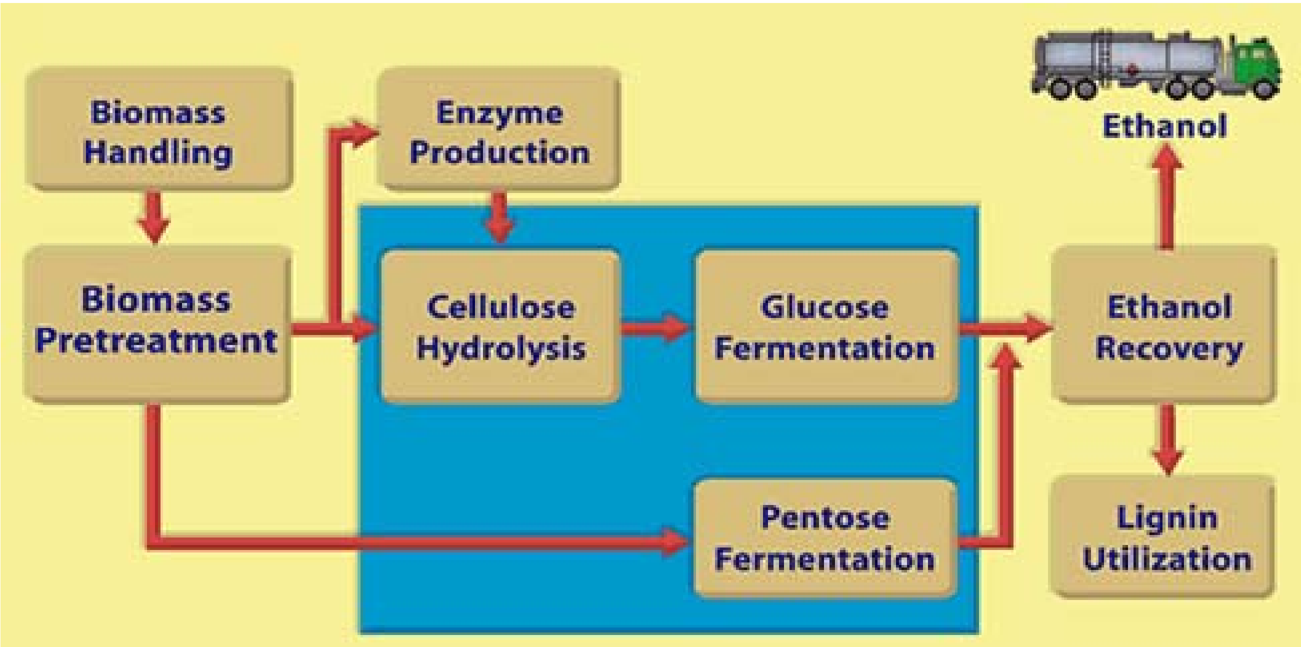
The anhydrous ethanol is blended with about 5% denaturant (such as natural gasoline) to render it undrinkable and thus not subject to beverage alcohol tax. It is then ready for shipment to gasoline terminals or retailers.

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 CO2 released during fermentation is captured and sold for use in carbonating soft drinks and the manufacture of dry ice.

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

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

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, Table B1 "Characteristics of Selected Feedstocks and Fuels."

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, 1995-2008
(Thousands of 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	32,363	1.16%	2,756,663	98.84%	2,789,026
2006	37,435	0.99%	3,729,168	99.01%	3,766,603
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

Source:
U.S. Department of Energy, Energy Information Administration, *Alternatives to Traditional Transportation Fuels*, 2008, Table C1. Washington DC, April 2010, Website: http://www.eia.doe.gov/cneaf/alternate/page/atftables/afv_atf.html

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

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

Section: BIOFUELS

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

Feedstock	Unit	All Dry Mills	Small	Large
Corn	1,000 bu	193,185	103,213	89,972
Sorghum	1,000 bu	10,409	N/A	10,409
Other	1,000 ton	44.9000	N/A	44.9000
Alcohol production:				
Fuel	1,000 gal	548,684	275,900	272,784
Industrial	1,000 gal	1,000	1,000	
Total	1,000 gal	549,684	276,900	272,784
Ethanol yield	Gal/bu	2.6623	2.6828	2.6490
Feedstock costs	Dol./gal	0.8030	0.7965	0.8095
Byproducts credits:				
Distiller’s dried grains	Dol./gal	0.2520	0.2433	0.2610
Carbon dioxide	Dol./gal	0.0060	0.0038	0.0080
Net feedstock costs	Dol./gal	0.5450	0.5494	0.5405
Cash operating expenses:				
Electricity	Dol./gal	0.0374	0.0400	0.0349
Fuels	Dol./gal	0.1355	0.1607	0.1099
Waste management	Dol./gal	0.0059	0.0077	0.0041
Water	Dol./gal	0.0030	0.0044	0.0015
Enzymes	Dol./gal	0.0366	0.0377	0.0365
Yeast	Dol./gal	0.0043	0.0039	0.0046
Chemicals	Dol./gal	0.0229	0.0231	0.0228
Denaturant	Dol./gal	0.0348	0.0356	0.0339
Maintenance	Dol./gal	0.0396	0.0319	0.0474
Labor	Dol./gal	0.0544	0.0609	0.0478
Administrative costs	Dol./gal	0.0341	0.0357	0.0325
Other	Dol./gal	0.0039	0.0035	0.0043
Total	**Dol./gal**	**0.4124**	**0.4451**	**0.3802**
Total cash costs and net feedstock costs	**Dol./gal**	**0.9574**	**0.9945**	**0.9207**

Source:

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

Note: Dol - dollars, bu - bushels, gal - gallons.

The ethanol industry spent $12.5 billion in 2007 on raw materials, other inputs, goods and services to produce an estimated 6.5 billion gallons of ethanol (33% more than 2006). Most of this spending was for corn and other grains used as raw material to make ethanol. An additional $1.6 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 $47.6 billion in additional gross output in the U.S. economy, increased household earnings by nearly $12.3 billion, and created over 238,641 jobs.

Section: BIOFUELS
Economic Contribution of the Ethanol Industry, 2007

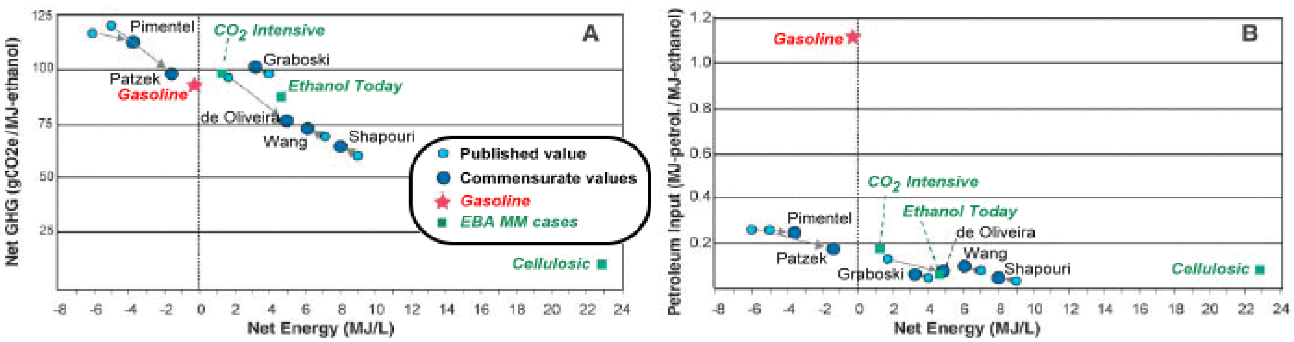
Industry	Purchases (Mil 2007$)	Impact: GDP (Mil 2007$)	Impact: Earnings (Mil 2007$)	Impact: Employment (Jobs)
Construction (labor and other)	$1,706.9	$3,200.1	$1,807.1	42,959
Machinery and equipment	$2,357.1	$3,976.3	$1,844.4	38,318
Plus initial changes:		$4,064.0		
Total $11,240.5			**$3,651.5**	**42,959**
Annual Operations				
Feed Grains (Corn)	$5,700.6	$8,609.3	$3,027.0	84,191
Other Basic Organic Chemicals	$302.1	$553.4	$215.8	4,227
Petroleum Refineries	$444.6	$664.1	$240.9	4,344
Power Generation and Supply	$308.6	$415.8	$184.6	3,464
Natural Gas Distribution	$2,310.1	$3,842.9	$1,510.6	28,052
Water, sewage	$32.6	$46.2	$23.2	507
Facilities Support Services	$167.7	$243.7	$159.0	4,207
Wholesale Trade	$1,463.8	$2,161.9	$1,189.6	25,529
Office Administration Services	$387.0	$601.7	$389.7	8,582
Earnings to households	$252.6	$325.6	$167.0	4,354
Rail Transportation	$916.6	$1,423.5	$719.5	14,364
Water Transportation	$54.7	$96.9	$44.6	940
Truck Transportation	$620.1	$1,044.1	$534.4	12,921
Subtotal $12,961.1		**$20,029.0**	**$8,406.0**	**195,682**
Plus initial changes:				
Value of ethanol production		$13,530.0	$252.6	
Value of co-products		$2,819.5		
Total Annual Operations		**$36,378.6**	**$8,658.6**	**195,682**
Grand Total		**$47,619.1**	**$12,310.1**	**238,641**

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

Section: BIOFUELS
Ethanol Net Energy Balances and Greenhouse Gas Emissions

The net energy balance and greenhouse gas emissions associated with ethanol production have been analyzed by multiple groups. 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.



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.

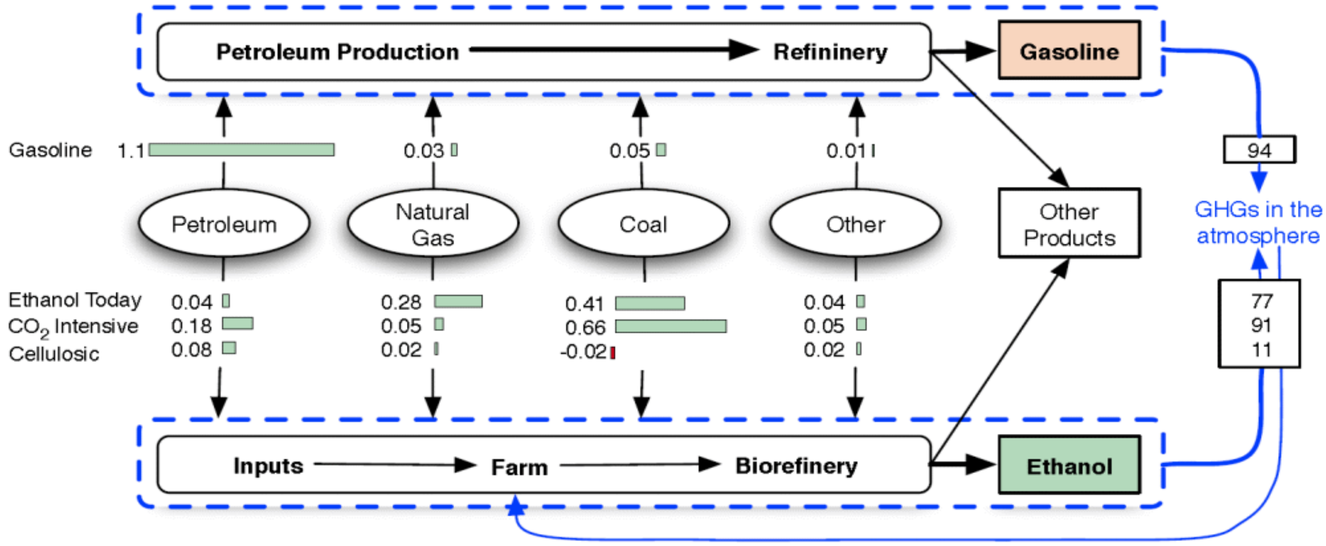
Additional references:

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.

Section: BIOFUELS

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



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

Source:

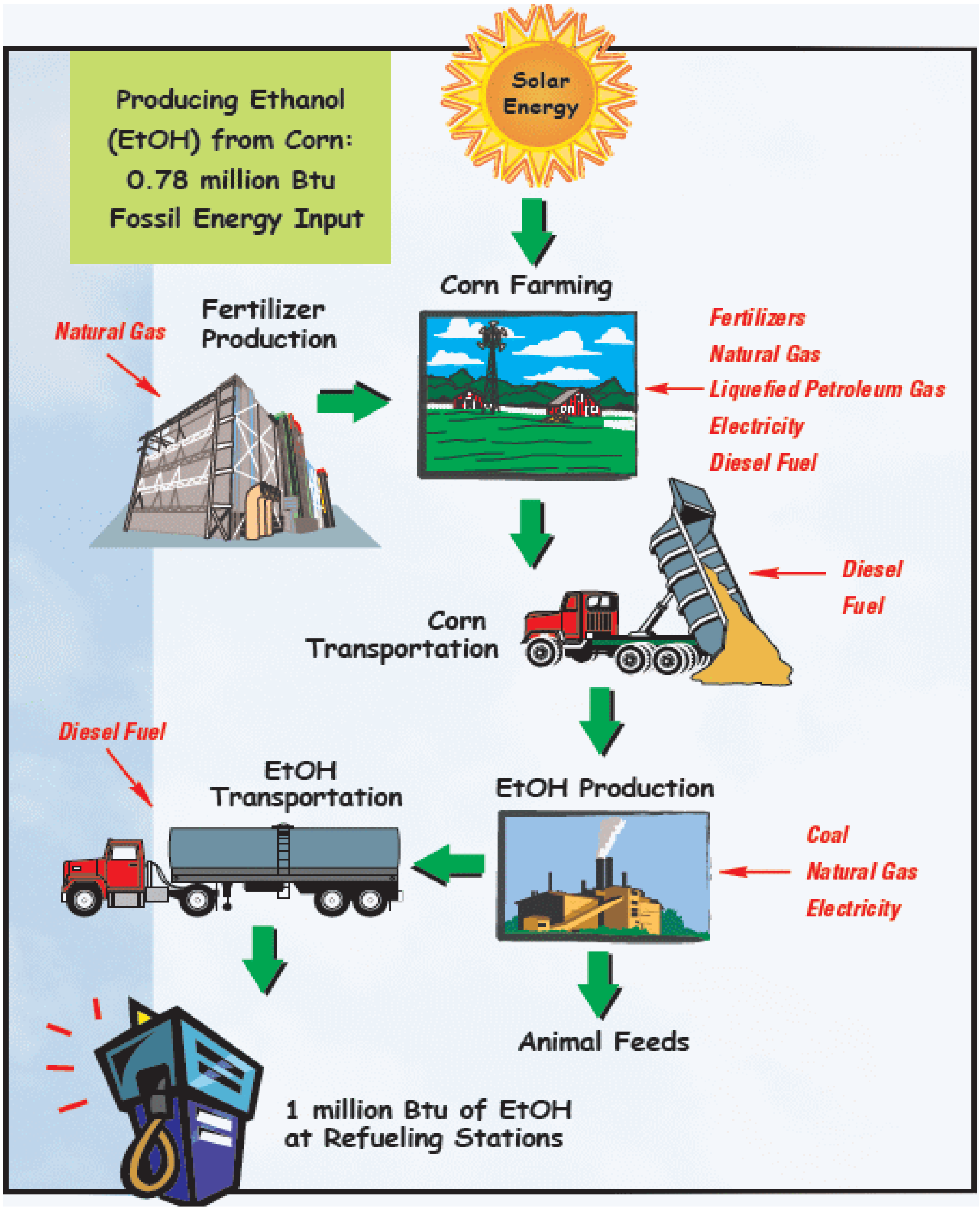
A.E. Farrell, R.J. Plevin, B.T. Turner, A.D. Jones, M. O'Hare, D.M. Kammen. Ethanol Can Contribute To Energy and Environmental Goals. Science, Vol 311, January 27, 2006.

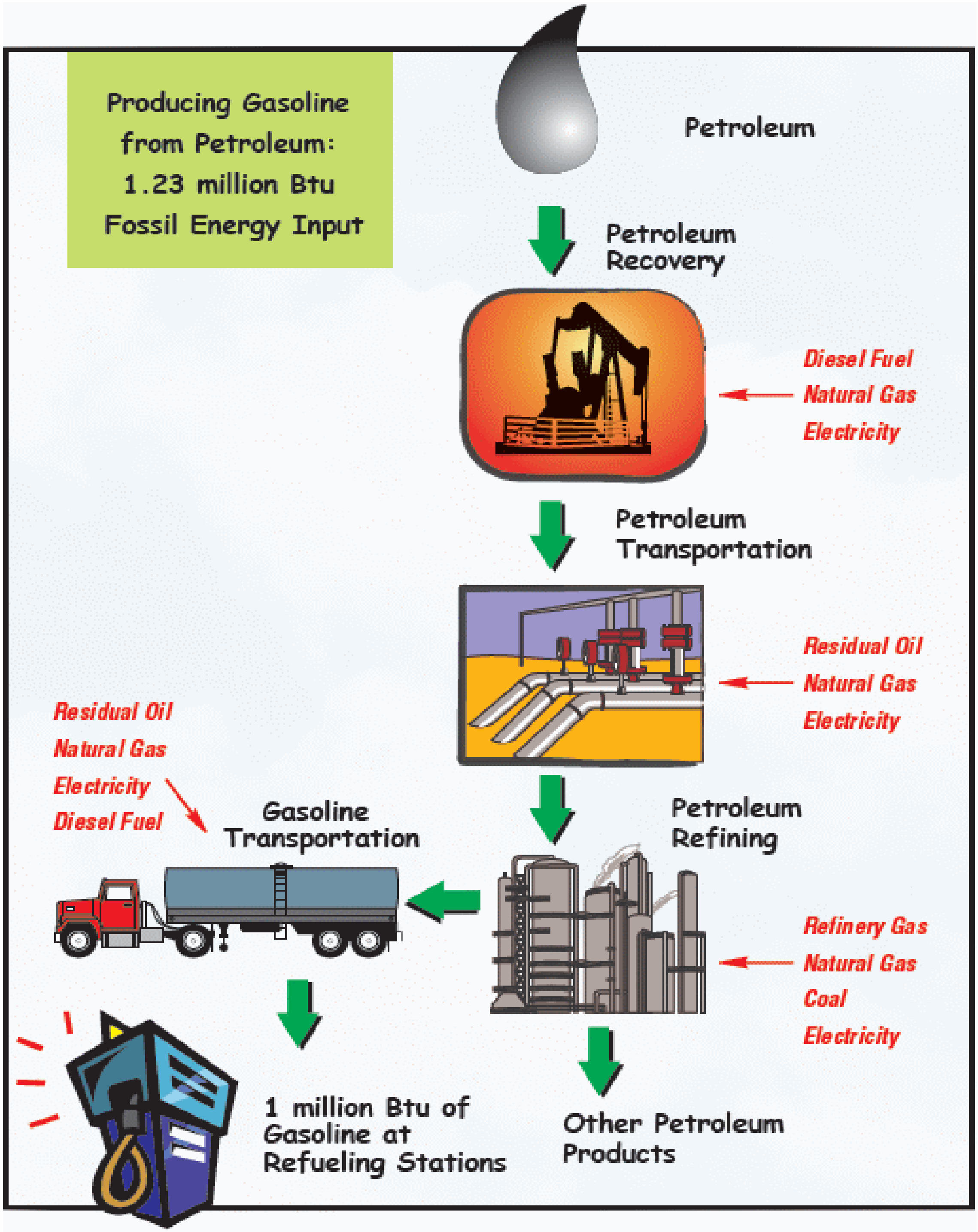
www.science.org

The figure below 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 1.8 version now available. The model allows researchers and analysts to evaluate various vehicle and fuel combinations on a full fuel-cycle basis that includes wells to wheels and the vehicle cycle through material recovery and vehicle disposal.

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

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

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

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

Source:

Figures: Ethanol: The Complete Energy Life-Cycle Picture. Second revised edition, March 2007
http://greet.es.anl.gov/publications

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

	Milling Process		Weighted
Production Process	**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

	Milling process		Weighted
Production Process	**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).

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

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.

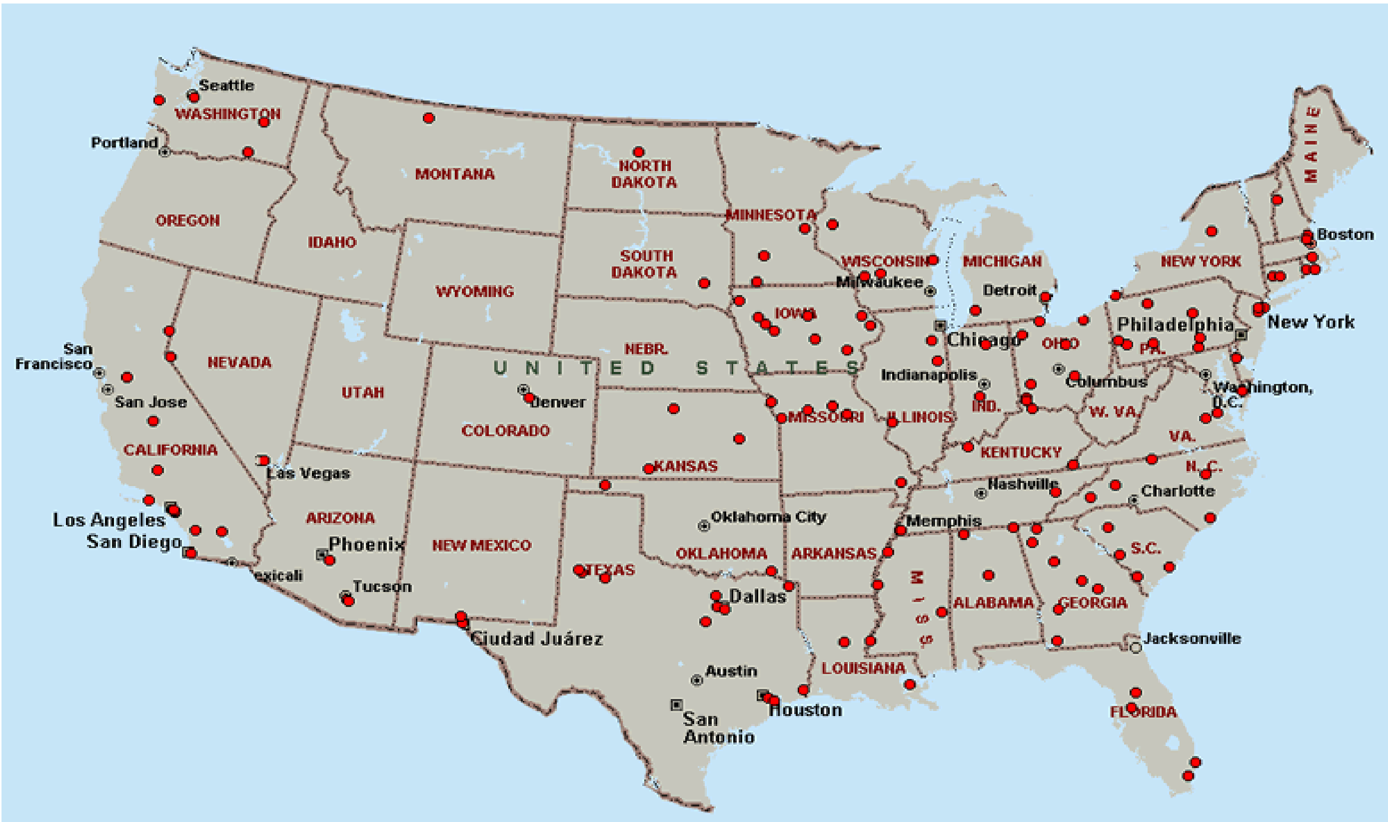
Section: BIOFUELS
World Biodiesel Production by Region and Selected Countries, 2005-2009
(Thousand barrels per day)

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

The plants shown in the map below are all considered active, however, due to the downturn in the economy, many are operating at a reduced or minimal level. The total annual capacity of these plants is approximately 2,737 billion gallons though actual production is currently well below that.

Section: BIOFUELS
Active Commercial Biodiesel Production Facilities



Source:

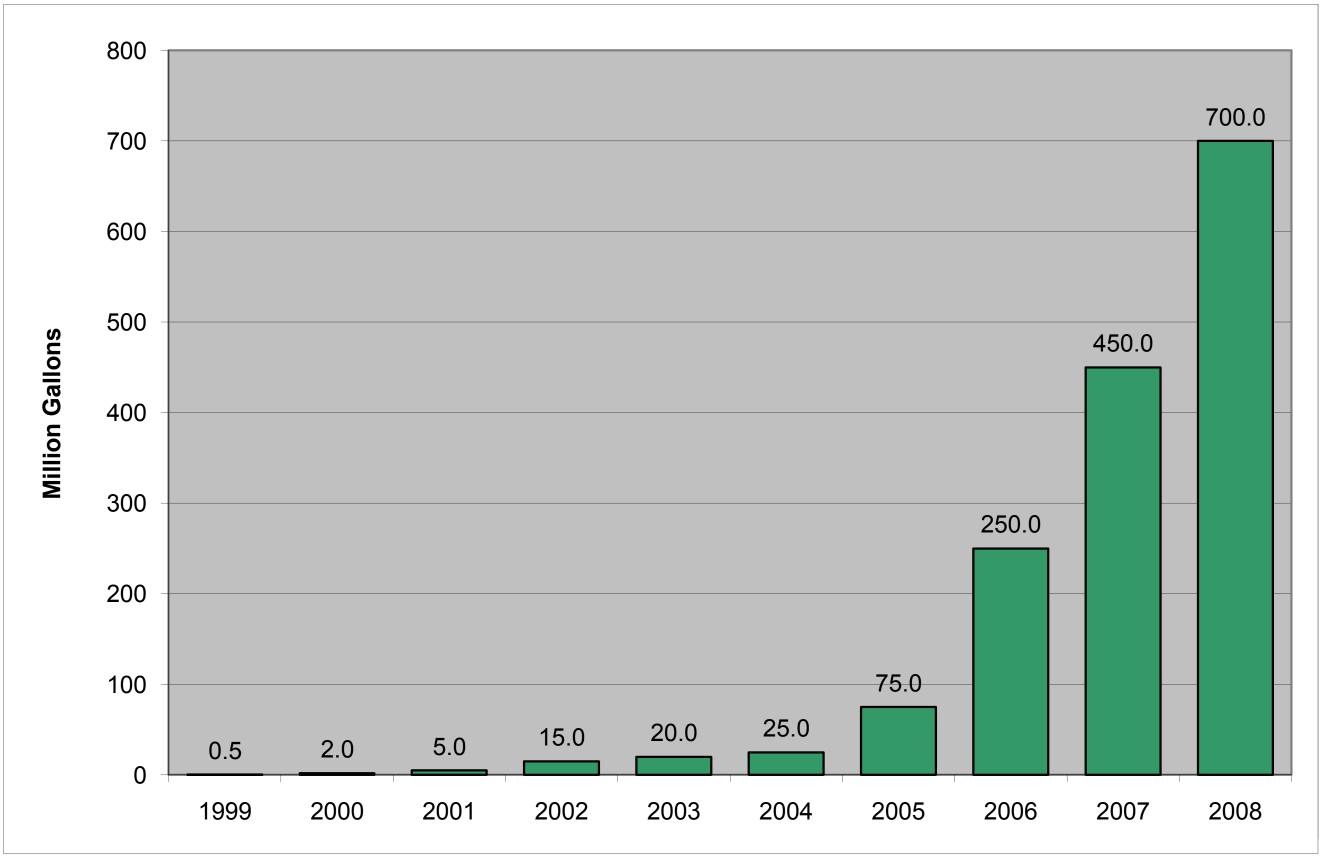
National Biodiesel Board, Biodiesel Fact Sheets, "NBB Member Plant Maps - Active & Under Construction"
http://www.nbb.org/resources/fuelfactsheets/default.shtm

Notes:

In 2008, the National Biodiesel Board began verifying the production statistics of the facilities. For the most current listing of production facilities including company name, state, city, capacity, and primary feedstock used, follow the link listed under source following the map.

The production of biodiesel has been on the rise since 1999, but the most notable growth was between 2004 and 2008 when production increased from 25 million gallons to 700 million gallons.

Section: BIOFUELS
Estimated U.S. Biodiesel Production, 1999-2008



Source:
National Biodiesel Board, Biodiesel Fact Sheets, Biodiesel Production Graph FY99-FY08,
http://www.biodiesel.org/resources/fuelfactsheets/default.shtm

Note: Years refer to fiscal year October 1 through September 30.

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:

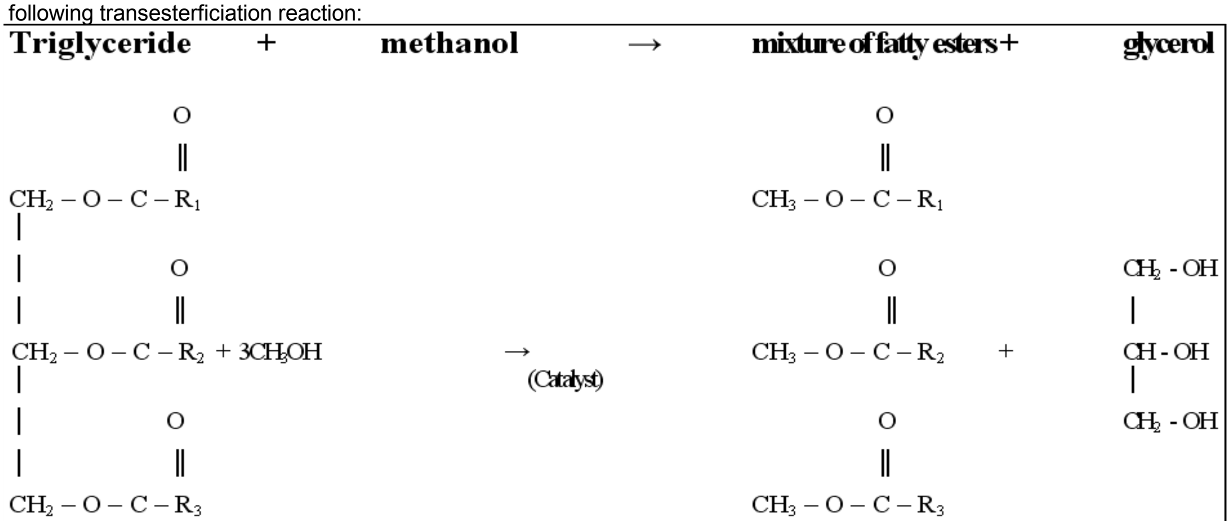
J. Van Gerpen, B. Shanks, and R. Pruszko, D. Clements, and G. Knothe, 2004, "Biodiesel Production Technology," National Renewable Energy Laboratory subcontractor report NREL/SR-510-36244, chapter 1, page 1. Please see this document for a full discussion.

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

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 = $-(CH_2)_7\ CH{=}CH\text{-}CH_2\text{-}CH{=}CH(CH_2)_4CH_3$	18 carbons, 2 double bonds (18:2)
Linolenic:	R = $-(CH_2)_7\ CH{=}CH\text{-}CH_2\text{-}CH{=}CH\text{-}CH_2\text{-}CH{=}CH\text{-}CH_2\text{-}CH_3$	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, and R. Pruszko, D. Clements, and G. Knothe, 2004, "Biodiesel Production Technology," National Renewable Energy Laboratory subcontractor report NREL/SR-510-36244, chapter 1, page 1. Available on-line in DOE's biomass document database. Search by author or title. http://www1.eere.energy.gov/biomass/document_database.html

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

Section: BIOFUELS
Specification for Biodiesel (B100)

Property	ASTM Method	Limits	Units
Calcium and Magnesium, combined	EN 14538	5 max.	ppm(ug/g)
Flash Point (closed cup)	D93	130 min.	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	mm2/sec.
Sulfated Ash	D874	0.020 max.	% mass
Sulfur S 15 Grade	D5453	0.0015 max (15)	% mass (ppm)
Sulfur S 500 Grade	D5453	0.05 max. (500)	% mass (ppm)
Copper Strip Corrosion	D130	No. 3 max.	
Cetane	D613	47 min.	
Cloud Point	D2500	Report	Degrees C
Carbon Residue 100% sample	D4530[a]	0.050 max.	% mass
Acid Number	D664	0.50 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 Filtration	Annex to D6751	360 max.	seconds
For use in temperatures below -12 C	Annex to D6751	200 max.	seconds

Source:
National Biodiesel Board, Biodiesel Fact Sheets, Biodiesel Production & Quality Standards
http://www.biodiesel.org/resources/fuelfactsheets/

Notes: To meet special operating conditions, modifications of individual limiting requirements may be agreed upon between purchaser, seller and manufacturer.

A considerable amount of experience exists in the US with a 20% blend of biodiesel with 80% diesel fuel (B20). Although biodiesel (B100) can be used, blends of over 20% biodiesel with diesel fuel should be evaluated on a case-by-case basis until further experience is available.

Alternate source providing explanations for the various specifications can be found at:

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

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

Section: BIOFUELS
Commercial Biodiesel Production Methods

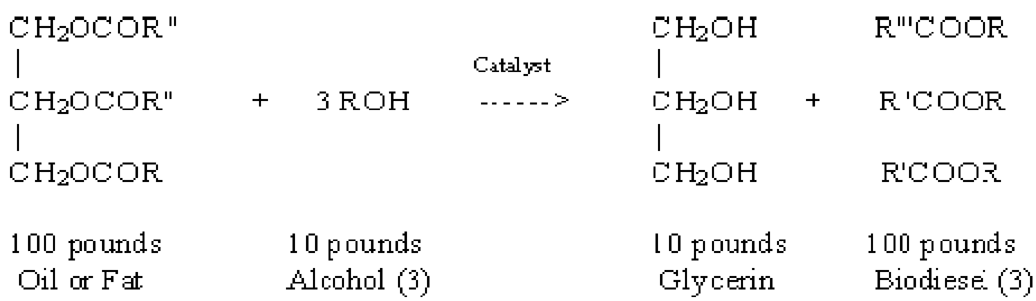
The production processes for biodiesel are well known. There are three basic routes to biodiesel production from oils and fats:

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

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

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/

Note: Testing was performed by the EPA. The full report titled "A comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions" can be found at:
www.epa.gov/otaq/models/biodsl.htm

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

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

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

Section: BIOFUELS
Estimated Impacts from Increased Use of Biodiesel

	Market scenario (percentage change from baseline)		
	Low	**Medium**	**High**
Soybean oil production	0.3	0.8	1.6
Soybean oil price	2.8	7.2	14.1
Soybean meal price	–0.7	–1.7	–3.3
Soybean price	0.4	1.0	2.0
Livestock price (“broilers”)	–0.3	–0.7	–1.4
US net farm income	0.1	0.2	0.3

Source:
International Energy Agency "Biofuels for Transport: An International Perspective," May 2004. Page 96, Table 4.12.

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 400 and 500 degrees Celsius for a very short period of time (less than 2 seconds) and then condensing the resulting vapors within 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 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.

DynaMotive Energy Systems is commercializing a proprietary fast pyrolysis process that converts forest and agricultural residue into liquid bio-oil and char. The company is in the process of launching the 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. Dynamotive is now in the process of building a second 200 ton-per-day plant in Guelph, Ontario.

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 four RTP[tm] facilities in commercial operation; a new facility and a bio-oil refining plant are currently under construction. Three of the commercial facilities are in Wisconsin and one is near Ottawa, Canada. The largest of these facilities, built in 1996, processes about 75 green tons per day of mixed hardwood wastes. Ensyn currently produces about 30 chemical products from RTP[tm] bio-oil with lower value remnant bio-oil used for boiler fuel. Ensyn is just beginning to enter the energy market.

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

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

Output Products by Method of Pyrolysis

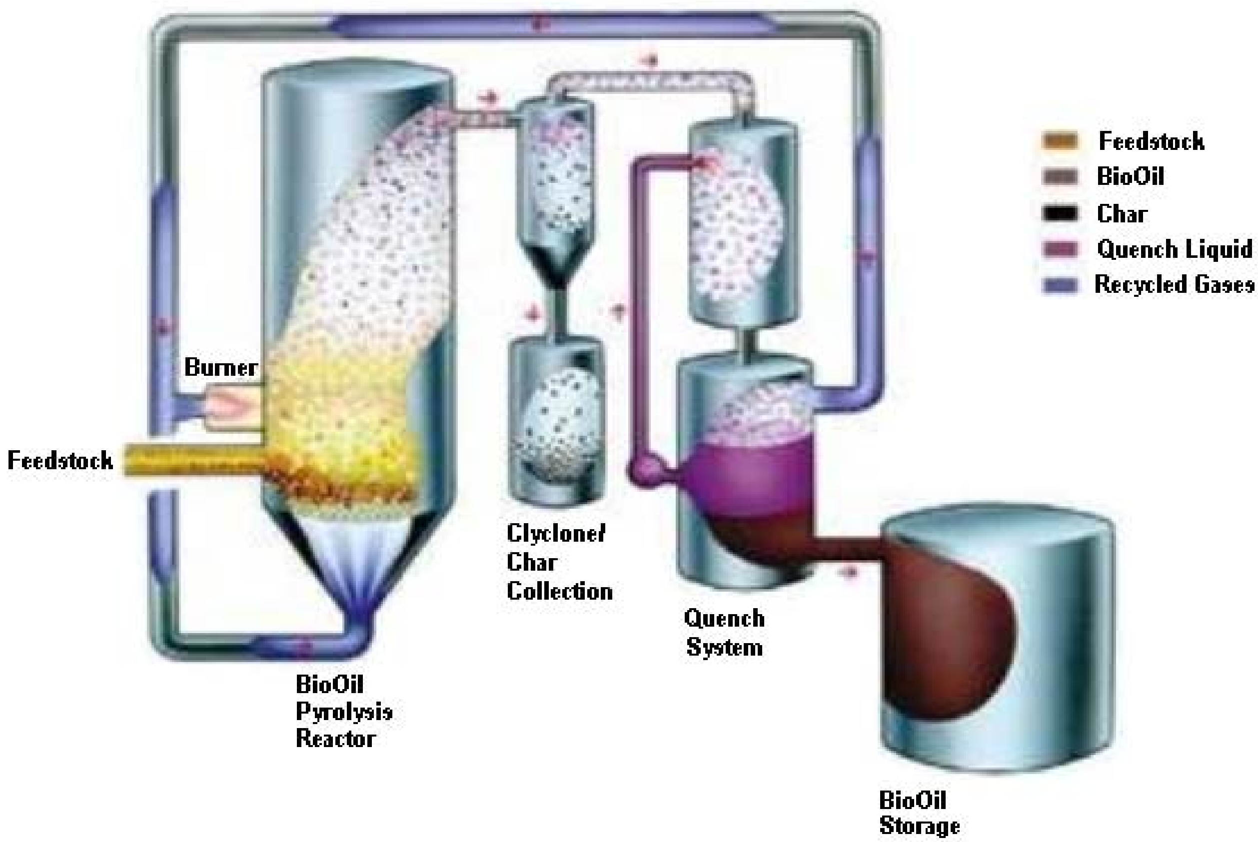
Process	Liquid	Char	Gas
Fast Pyrolysis	75%	12%	13%
Carbonization	30%	35%	35%
Gasification	5%	10%	85%

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

Section: BIOFUELS
Bio-oil Characteristics

Bio-oil Characteristics	Feedstock: Pine 53% Spruce 47% (including bark)	Feedstock: Bagasse
pH	2.4	2.6
Water Content wt%	23.4	20.8
Methanol Insoluable Solids (Lignin content wt%)	24.9	23.5
Solids Content wt%	<0.10	<0.10
Ash Content wt%	<0.02	<0.02
Density kg/L	1.19	1.2
Low Heating MJ/kg	16.4	15.4
Kinematic Viscosity cSt @ 20^{o}C	40.0	50.0
Kinematic Viscosity cSt @ 80^{o}C	6.0	7.0

Source:
http://www.dynamotive.com/industrialfuels/biooil/

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

SOx = Sulfur oxides.
NOx = Nitrogen oxides.
CO_2 = Carbon dioxide.

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

Section: BIOFUELS
Bio-oil Composition

Concentrations wt%	**Feedstock:** Pine 53% Spruce 47% (including bark)	**Bagasse**
Water	23.4	20.8
Methanol Insoluable Solids & Lignin	24.9	23.5
Cellubiosan	1.9	-
Glyoxal	1.9	2.2
Hydroxyacetaldehyde	10.2	10.2
Levoglucosan	6.3	3.0
Formaldehyde	3.0	3.4
Formic Acid	3.7	5.7
Acetic Acid	4.2	6.6
Acetol	4.8	5.8

Source:
http://www.dynamotive.com/industrialfuels/biooil/

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

"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

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

Source:

DynaMotive,

http://www.dynamotive.com/industrialfuels/biooil/

Notes: The exact characteristics of Bio-oil may vary depending on feedstock and processing. The table above is based on the fast pyrolysis method using feedstock composed of 53% pine and 47% spruce including bark. Other companies also produce bio-oil using other conversion processes and feedstocks and the resulting bio-oil properties can vary widely.

N/A = Not Available.

Section: BIOFUELS
Annotated Summary of Biofuel and Biomass Electric Incentives as of December 1, 2010: 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 June 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/la_pubs_factsheets.cfm

This website contains a couple fact sheets that addresses the National Renewable Energy Standard (RES) and U.S. Energy Subsidies.

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.

Section: BIOFUELS
Federal and State Alternative Fuel Incentives, 2010

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	31	29	25	25	27	22	8	2	6	13	6	7
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	5	3	2	2	0	0	1	1	2	0
California	14	11	24	17	23	28	21	3	1	3	4	3
Colorado	8	9	12	9	8	7	3	1	4	1	4	0
Connecticut	5	4	7	5	7	6	5	0	3	2	3	3
Delaware	2	2	2	4	1	2	1	1	0	1	2	1
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	2	1
Hawaii	8	10	5	5	6	8	1	1	0	1	1	0
Idaho	4	2	3	3	2	0	1	1	0	1	0	0
Illinois	19	18	10	9	8	9	5	2	3	3	2	0
Indiana	13	17	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	15	5	4	1	1	0	1	1	1	1	0
Kentucky	8	8	6	4	1	1	1	1	0	1	0	0
Louisiana	6	10	11	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	9	9	7	5	5	5	4	0	0	0	1	1
Michigan	11	11	5	5	6	7	8	0	0	2	1	0
Minnesota	9	11	3	2	4	5	2	2	0	1	2	1
Mississippi	4	4	7	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	3	3	6	5	3	5	4	1	0	1	1	1
New Mexico	14	12	7	6	9	7	2	1	1	1	1	1
New York	10	12	13	8	10	10	4	1	0	1	2	1
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	5	6	3	3	3	2	0	0	1	0	2	0
Oklahoma	11	12	12	9	8	9	3	1	5	0	1	0
Oregon	11	11	6	5	5	8	2	1	2	3	4	5
Pennsylvania	8	7	5	4	4	4	2	0	0	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	9	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	13	10	6	8	6	1	3	0	4	1
Utah	1	1	11	6	5	6	2	0	2	0	2	0
Vermont	5	5	6	4	4	4	3	1	1	3	2	1
Virginia	14	10	12	9	10	10	3	1	3	3	2	1
Washington	18	14	9	8	6	18	6	1	4	2	3	3
West Virginia	5	5	5	5	5	5	1	1	0	1	2	0
Wisconsin	11	8	7	7	6	5	3	2	1	1	3	0
Wyoming	0	1	1	0	0	0	0	0	0	0	0	0
Totals	**438**	**430**	**353**	**285**	**267**	**296**	**138**	**44**	**56**	**66**	**88**	**42**

Source:
U.S. Department of Energy, Energy Efficiency and Renewable Energy, Alternative Fuels Data Center. September 28, 2010.
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

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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 (SO_2), nitrogen oxides (NO_x), 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://www.chem.uu.nl/nws/www/publica/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).

The following table shows EPA data for uncontrolled emissions from the combustion of different fuels. Note that wood compares favorably with the other fuels except for particulate emissions (PM). However, particulates are relatively easy to control and can be captured with cyclones and baghouses.

Section: BIOPOWER
Typical Uncontrolled Emission Factors for Steam Generator Fuels
(Nanograms/Joule and Pounds/Million Btu) Heat Input

	PM		NO_2		SO_2		CO		HC		Trace Metals[e]	
Fuel Type	NG/J	LB/MMbtu	NG/J	LB/MMbtu	NG/J	LB/MMbtu	NG/J	LB/MMbtu	NG/J	LB/MMbtu	NG/J	LB/MMbtu
Coal[a]	1,093	2.540	387	0.90	2450	5.700	13	0.030	2	0.005	4	0.0090
Oil (residual)[b]	96	0.230	[d] 170	[d] 0.39	1,400	3.220	14	0.030	3	0.010	0.07	0.0002
Oil (distillate)[c]	6	0.010	[d] 100	[d] 0.23	220	0.510	16	0.040	3	0.010	-	-
Natural Gas	4	0.010	[d] 100	[d] 0.23	0.3	0.001	7	0.020	1	0.003	0	0
Wood	2,100	4.880	110	0.25	9	0.020	-	-	-	-	-	-
Solid Waste	1,400	3.220	130	0.31	210	0.490	-	-	-	-	-	-

Source:
Federal Register, Tuesday, June 19, 1984, p.25106, Vol. 49, No. 119.

[a] Based on high-sulfur (3.5 percent by weight), high-ash (10.6 percent by weight) coal burned in a spreader stoker coal-fired steam generating unit.
[b] Based on high-sulfur oil (3.0 percent by weight).
[c] Based on low-sulfur oil (0.5 percent by weight.
[d] Assumes no combustion air preheat.
[e] Based on lead to illustrate general level of trace metal emissions.

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:

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

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

Biomass Power Technology Fuel Specifications and Capacity Range

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

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, 2008

Source Sales	MWh	Percentage of total sales	Total MW	MW New Renewable
Wind 3,993,000		83.0%	1,381	1,341
Landfill gas	**343,000**	**7.0%**	**44**	**41**
Other biomass	**202,000**	**4.0%**	**29**	**28**
Solar 9,000		0.2%	7	7
Geothermal 75,000		2.0%	9	9
Hydro 52,000		1.0%	15	14
Unknown	143,000	3.0%	33	-
Total 4,817,000		**100.0%**	**1,517**	**1,440**

Source:
Green Power Marketing in the United States: A Status Report (2008 Data) Table 11
http://www.nrel.gov/docs/fy09osti/46581.pdf

Notes:
MW=megawatt
MWh=megawatt-hour

An estimated 19.5 billion kWh of renewable energy was sold to retail customers by competitive green power and REC marketers in 2008. This figure includes renewable energy from both pre-existing and new sources. In 2008, about 85% 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, 2008

Source MWh	Sales	Percentage of Total Sales	Total MW	MW New Renewable
Wind 13,293,000		68.00%	4,590	4,270
Biomass/Landfill gas	**3,697,000**	**19.00%**	**500**	**420**
Solar 23,000		0.12%	20	20
Geothermal 345,000		2.00%	40	3
Hydro 2,124,000		11.00%	610	130
Unknown	44,000	<1%	10	-
Total 19,526,000		**100.00%**	**5,770**	**4,860**

Source:
Green Power Marketing in the United States: A Status Report (2008 Data) Table 16
http://www.nrel.gov/docs/fy09osti/46581.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 2010)

State	Program Name	Type	Start Date	Premium
AL	Green Power Choice	landfill gas	2006	2.0¢/kWh
AL	Renewable Energy Rate	biomass co-firing (wood)	2003/2000	4.5¢/kWh
AL	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
AZ	EarthWise Energy	central PV, wind, landfill gas, small	1998/2001	3.0¢/kWh
AZ	GreenWatts	landfill gas, PV	2000	10¢/kWh
CA	Green Power for the Grid	wind, landfill gas	2002	1.5¢/kWh
CA	Green Power for a Green LA	wind, landfill gas	1999	3.0¢/kWh
CA	Greenergy	wind, landfill gas, hydro, PV	1997	1.0¢/kWh or $6/month
DE	Renewable Energy Rider	landfill gas	2006	0.2¢/kWh
FL	Green for You	biomass, PV	2002	1.6¢/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	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
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
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	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	Evergreen Renewable Energy	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
KY	Renewable Resources Energy (EnviroWatts	100% biomass	2007	3.65¢/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
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	1.4¢/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
MI	Energy for Tomorrow	wind, landfill gas, hydro	2000	2.04/kWh

Continued on next page

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

State	Program Name	Type	Start Date	Premium
MN	Second Nature	landfill gas, wind	2002	2.0¢/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
MS	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
MO	varies by utility	biomass, wind	2003	2.0¢/kWh-3.5¢/kWh
MO	EnviroWatts	wind, landfill gas	2000	0.9¢/kWh-1.0¢/kWh
NE	Green Power Program	landfill gas, wind	2002	3.0¢/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
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	GoGreen Power	wind, PV, landfill gas, digester gas	2001	2.5¢/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
OR	Blue Sky Usage	wind, biomass, PV	2002	0.78¢/kWh
OR	Blue Sky Habitat	wind, biomass, PV	2002	0.78¢/kWh+2.5¢/mo. donation
OR	Green Power	landfill gas	1998	1.8¢/kWh-2.0¢/kWh
SC	Palmetto Clean Energy (PaCE)	wind, solar, landfill gas	2008	4.0¢/kWh
SC	Green Power Program	landfill gas	2001	3.0¢/kWh
TN	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
TX	GreenChoice	wind, landfill gas	2000/1997	1.85¢/kWh
VT	CVPS Cow Power	biogas	2004	4.0¢/kWh
VT	CooHome/CoolBusiness	wind, biomass	2002	Contribution
VA	Dominion Green Power	biomass, hydro, solar, wind	2009	1.5¢/kWh
WA	Green Power Program	landfill gas, wind, hydro	1999	Contribution
WA	Clallam County PUD Green Power Program	landfill gas	2001	0.69¢/kWh
WA	Green Power	landfill gas	2001	1.05¢/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, biogass	2002	Contribution
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	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	NatureWise	wind, landfill gas, biogas	2002	1.25¢/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% existing small low impact hydro, 34% new landfill gas	—
District of Columbia	PEPCO Energy Services[c]	Green Electricity 100% of usage	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, 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.

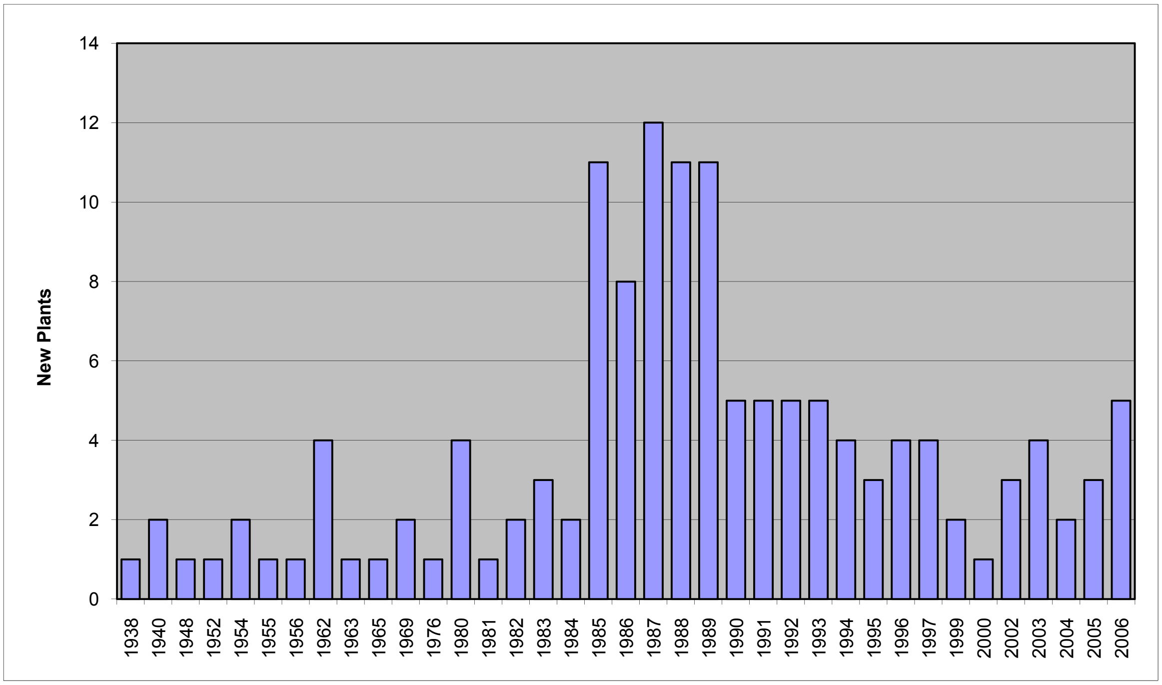
Section: BIOPOWER
National Retail Renewable Energy Certificate Product Offerings, August 2010

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
Native Energy	Renewable 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
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

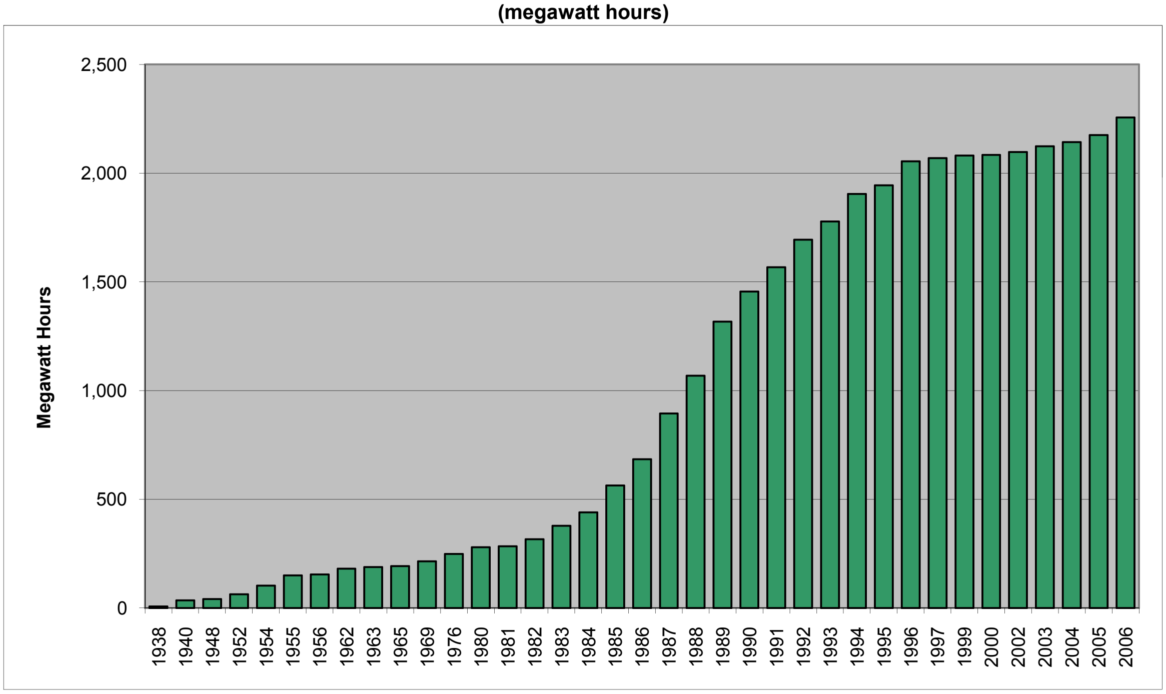
Source:
National Renewable Energy Laboratory, *The Green Power Network*
http://apps3.eere.energy.gov/greenpower/markets/certificates.shtml?page=1

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.

Section: BIOPOWER
New Biomass Power Plants by Year



Biomass Power Plant Capacity by Year
(megawatt hours)



Source:
National Electric Energy System (NEEDS) Database for IPM 2006
http://epa.gov/airmarkets/progsregs/epa-ipm/index.html

Notes:
1. Only years in which new plants were brought online are shown.
2. Power plant capacity based on NEEDS 2006 Data.This was the latest data available at time of publishing this report.

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
Pacific Lumber	G	California	Humboldt	7.50	15,826	Yes	1938
French Island	B	Wisconsin	La Crosse	14.00	10,400	No	1940
French Island	B	Wisconsin	La Crosse	14.00	10,400	No	1940
Berlin Gorham	B	New Hampshire	Coos	5.00	15,826	No	1948
Bay Front	B	Wisconsin	Ashland	22.00	16,190	No	1952
East Millinocket Mill	B	Maine	Penobscot	19.04	15,826	Yes	1954
Bay Front	B	Wisconsin	Ashland	22.00	18,720	No	1954
Schiller	B	New Hampshire	Rockingham	47.20	12,788	No	1955
Medford Operation	G	Oregon	Jackson	3.10	15,826	Yes	1956
Bryant Sugar House	B	Florida	Palm Beach	6.63	15,826	Yes	1962
Bryant Sugar House	B	Florida	Palm Beach	6.63	15,826	Yes	1962
Bryant Sugar House	B	Florida	Palm Beach	6.63	15,826	Yes	1962
Bryant Sugar House	B	Florida	Palm Beach	6.63	15,826	Yes	1962
Stone Container Florence Mill	B	South Carolina	Florence	7.63	15,826	Yes	1963
Medford Operation	G	Oregon	Jackson	4.40	15,826	Yes	1965
Rapids Energy Center	B	Minnesota	Itasca	11.02	10,079	Yes	1969
Rapids Energy Center	B	Minnesota	Itasca	11.02	10,079	Yes	1969
Somerset Plant	B	Maine	Somerset	34.23	15,826	Yes	1976
Century Flooring Co	G	Arkansas	Izard	1.70	15,826	Yes	1980
Forster Strong Mill	G	Maine	Franklin	0.35	15,826	Yes	1980
American Ref-Fuel of Niagara	B	New York	Niagara	9.00	15,826	Yes	1980
Stone Container Hopewell Mill	B	Virginia	Hopewell	20.35	15,826	Yes	1980
Diamond Walnut	G	California	San Joaquin	4.20	15,826	Yes	1981
Plummer Forest Products	G	Idaho	Benewah	5.77	15,000	Yes	1982
S D Warren Somerset	B	Maine	Cumberland	26.88	15,826	No	1982
Tamarack Energy Partnership	G	Idaho	Adams	5.80	9,650	Yes	1983
Snider Industries	G	Texas	Harrison	5.00	15,826	Yes	1983
Kettle Falls Generating Station	G	Washington	Stevens	50.00	11,860	No	1983
Agrilectric Power Partners Ltd	B	Louisiana	Calcasieu	10.90	17,327	No	1984
J C McNeil	B	Vermont	Chittenden	52.00	21,020	No	1984
Wheelabrator Martell	G	California	Amador	15.00	15,826	Yes	1985
Pacific Oroville Power	B	California	Butte	8.25	20,081	No	1985
Pacific Oroville Power	B	California	Butte	8.25	20,081	No	1985
Mt Lassen Power	B	California	Lassen	10.50	19,607	No	1985
Sierra Pacific Susanville	B	California	Lassen	12.60	15,826	Yes	1985
Collins Pine Project	B	California	Plumas	9.80	15,826	Yes	1985
Burney Mountain Power	B	California	Shasta	9.75	18,938	No	1985
Sierra Power	G	California	Tulare	7.00	15,826	Yes	1985
Ultrapower Chinese Station	B	California	Tuolumne	19.80	20,111	No	1985
Biomass One LP	B	Oregon	Jackson	8.50	19,236	Yes	1985
Biomass One LP	B	Oregon	Jackson	14.00	14,427	Yes	1985
Fairhaven Power	B	California	Humboldt	17.30	21,020	No	1986
Sierra Pacific Quincy Facility	B	California	Plumas	14.50	15,826	Yes	1986
Sierra Pacific Quincy Facility	B	California	Plumas	14.50	15,826	Yes	1986
Sierra Pacific Burney Facility	B	California	Shasta	18.00	15,826	Yes	1986
DG Telogia Power	B	Florida	Liberty	12.50	21,020	No	1986
Wheelabrator Sherman Energy Facility	B	Maine	Penobscot	21.00	11,987	Yes	1986
Pinetree Power	B	New Hampshire	Grafton	15.00	15,033	No	1986
Co-Gen LLC	G	Oregon	Grant	6.98	11,987	Yes	1986
Wheelabrator Shasta	B	California	Shasta	17.30	19,254	No	1987
Wheelabrator Shasta	B	California	Shasta	17.30	19,254	No	1987
Wheelabrator Shasta	B	California	Shasta	17.30	19,254	No	1987
Boralex Fort Fairfield	B	Maine	Aroostook	31.00	21,020	No	1987
Indeck West Enfield Energy Center	B	Maine	Penobscot	25.60	21,020	No	1987
Indeck Jonesboro Energy Center	G	Maine	Washington	26.80	9,650	No	1987
Central Michigan University	G	Michigan	Isabella	0.95	15,826	Yes	1987
Hillman Power LLC	B	Michigan	Montmorency	17.80	15,655	No	1987
Pinetree Power Tamworth	B	New Hampshire	Carroll	20.00	14,972	No	1987
Bridgewater Power LP	B	New Hampshire	Grafton	16.00	14,232	No	1987
Hemphill Power & Light	B	New Hampshire	Sullivan	14.13	14,605	No	1987
Co-Gen II LLC	G	Oregon	Douglas	6.98	11,987	Yes	1987
Rio Bravo Fresno	B	California	Fresno	24.30	18,456	No	1988
Pacific Lumber	B	California	Humboldt	8.67	15,826	Yes	1988
Pacific Lumber	B	California	Humboldt	8.67	15,826	Yes	1988
Pacific Lumber	B	California	Humboldt	8.67	15,826	Yes	1988
Greenville Steam	B	Maine	Piscataquis	16.10	13,337	No	1988
Viking Energy of McBain	B	Michigan	Missaukee	16.00	15,982	No	1988
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

Continued on next page

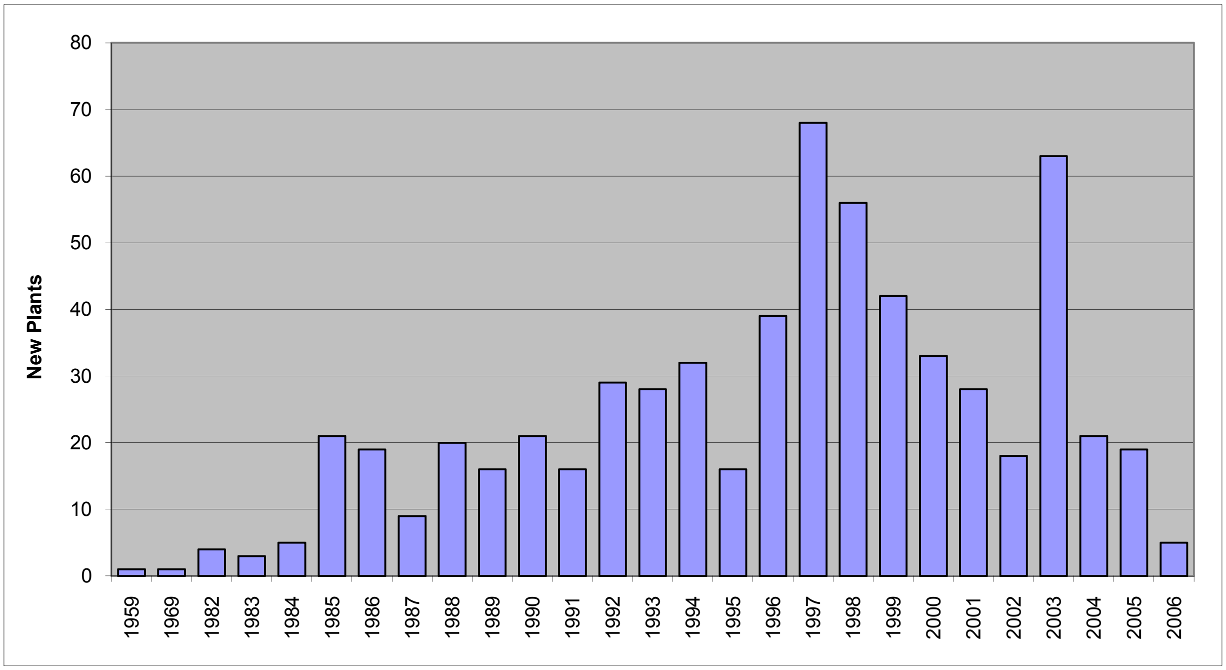
Current Biomass Power Plants
(Continued)

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Whitefield Power & Light	B	New Hampshire	Coos	14.50	13,025	No	1988
Koopers Susquehanna Plant	B	Pennsylvania	Lycoming	11.50	9,650	Yes	1988
Viking Energy of Northumberland	B	Pennsylvania	Northumberland	16.00	13,500	Yes	1988
Wadham Energy LP	B	California	Colusa	25.50	12,637	No	1989
AES Mendota	B	California	Fresno	25.00	17,874	No	1989
HL Power	B	California	Lassen	30.00	14,944	No	1989
Rio Bravo Rocklin	B	California	Placer	24.40	16,645	No	1989
Burney Forest Products	B	California	Shasta	15.50	16,350	Yes	1989
Burney Forest Products	B	California	Shasta	15.50	16,350	Yes	1989
Sierra Pacific Loyalton Facility	B	California	Sierra	14.00	15,826	Yes	1989
Woodland Biomass Power Ltd	B	California	Yolo	25.00	15,302	No	1989
Boralex Stratton Energy	B	Maine	Franklin	45.70	19,601	No	1989
Worcester Energy	G	Maine	Washington	13.00	14,500	No	1989
Viking Energy of Lincoln	B	Michigan	Alcona	16.00	13,646	No	1989
Delano Energy	B	California	Kern	27.00	17,237	No	1990
Tracy Biomass	B	California	San Joaquin	16.46	17,342	No	1990
Jefferson Power LLC	G	Florida	Jefferson	7.50	16,258	No	1990
Somerset Plant	B	Maine	Somerset	42.63	15,826	Yes	1990
Craven County Wood Energy LP	B	North Carolina	Craven	45.00	12,622	No	1990
Alabama Pine Pulp	B	Alabama	Monroe	32.09	15,826	Yes	1991
Potlatch Southern Wood Products	B	Arkansas	Bradley	10.00	15,826	Yes	1991
Mecca Plant	B	California	Riverside	23.50	14,158	No	1991
Mecca Plant	B	California	Riverside	23.50	14,158	No	1991
Port Wentworth	B	Georgia	Chatham	21.60	15,826	Yes	1991
Boralex Beaver Livermore Falls	B	Maine	Androscoggin	34.70	14,309	No	1992
Pinetree Power Fitchburg	B	Massachusetts	Worcester	17.00	15,673	No	1992
Grayling Generating Station	B	Michigan	Crawford	36.20	14,597	No	1992
Lyonsdale Biomass LLC	B	New York	Lewis	19.00	13,230	Yes	1992
Ryegate Power Station	B	Vermont	Caledonia	20.00	21,020	No	1992
Delano Energy	B	California	Kern	22.00	17,237	No	1993
Cadillac Renewable Energy	B	Michigan	Wexford	36.80	15,470	No	1993
Boralex Chateaugay Power Station	B	New York	Franklin	18.00	15,094	No	1993
Sauder Power Plant	G	Ohio	Fulton	3.60	14,900	Yes	1993
Sauder Power Plant	G	Ohio	Fulton	3.60	14,900	Yes	1993
Ridge Generating Station	B	Florida	Polk	47.10	21,020	No	1994
Multitrade of Pittsylvania LP	B	Virginia	Pittsylvania	26.55	13,541	No	1994
Multitrade of Pittsylvania LP	B	Virginia	Pittsylvania	26.55	13,541	No	1994
Multitrade of Pittsylvania LP	B	Virginia	Pittsylvania	26.55	13,541	No	1994
Cox Waste to Energy	G	Kentucky	Taylor	3.00	15,826	Yes	1995
Agrilectric Power Partners Ltd	B	Louisiana	Calcasieu	1.30	17,327	No	1995
Genesee Power Station LP	B	Michigan	Genesee	35.00	21,020	No	1995
Okeelanta Cogeneration	B	Florida	Palm Beach	24.97	13,600	Yes	1996
Okeelanta Cogeneration	B	Florida	Palm Beach	24.97	13,600	Yes	1996
Okeelanta Cogeneration	B	Florida	Palm Beach	24.97	13,600	Yes	1996
Everett Cogen	B	Washington	Snohomish	36.00	19,000	Yes	1996
STEC-S LLC	B	Arkansas	Arkansas	2.00	10,265	Yes	1997
STEC-S LLC	B	Arkansas	Arkansas	2.00	10,265	Yes	1997
Sierra Pacific Lincoln Facility	B	California	Placer	5.60	15,826	Yes	1997
Sierra Pacific Lincoln Facility	B	California	Placer	5.60	15,826	Yes	1997
Sierra Pacific Anderson Facility	G	California	Shasta	4.00	15,826	Yes	1999
Minergy Neenah	G	Wisconsin	Winnebago	6.50	15,826	Yes	1999
Wheelabrator Shasta	G	California	Shasta	3.50	19,254	No	2000
Cox Waste to Energy	G	Kentucky	Taylor	0.30	15,826	Yes	2002
Colville Indian Power & Veneer	G	Washington	Okanogan	5.00	15,826	No	2002
Colville Indian Power & Veneer	G	Washington	Okanogan	7.50	15,826	No	2002
Ware Biomass Cogen	C	Massachusetts	a	7.79	15,826	Yes	2003
Scott Wood	C	Virginia	Amelia	0.80	15,826	No	2003
Scott Wood	C	Virginia	Amelia	2.60	15,826	No	2003
Sierra Pacific Aberdeen	B	Washington	Grays Harbor	16.00	15,826	Yes	2003
Sierra Pacific Lincoln Facility	G	California	Placer	18.00	15,826	Yes	2004
Forster Strong Mill	G	Maine	Franklin	0.50	15,826	Yes	2004
Puente Hills Energy Recovery	C	California	Los Angeles	8.00	8,911	No	2005
Worcester Energy	C	Maine	a	24.56	8,911	No	2005
Blue Spruce Farm Ana	C	Vermont	a	0.26	8,911	No	2005
APS Biomass I	C	Arizona	a	2.85	8,911	No	2006
Buckeye Florida	C	Florida	Taylor	25.00	8,911	No	2006
Ware Cogeneration	C	Massachusetts	a	4.09	8,911	Yes	2006
Central Minn. Ethano	C	Minnesota	a	0.95	8,911	No	2006
Schiller Biomass Con	C	New Hampshire	a	47.50	8,911	No	2006
Fibrominn Biomass Power Plant	C	Minnesota	Swift	55.00	8,911	No	2007

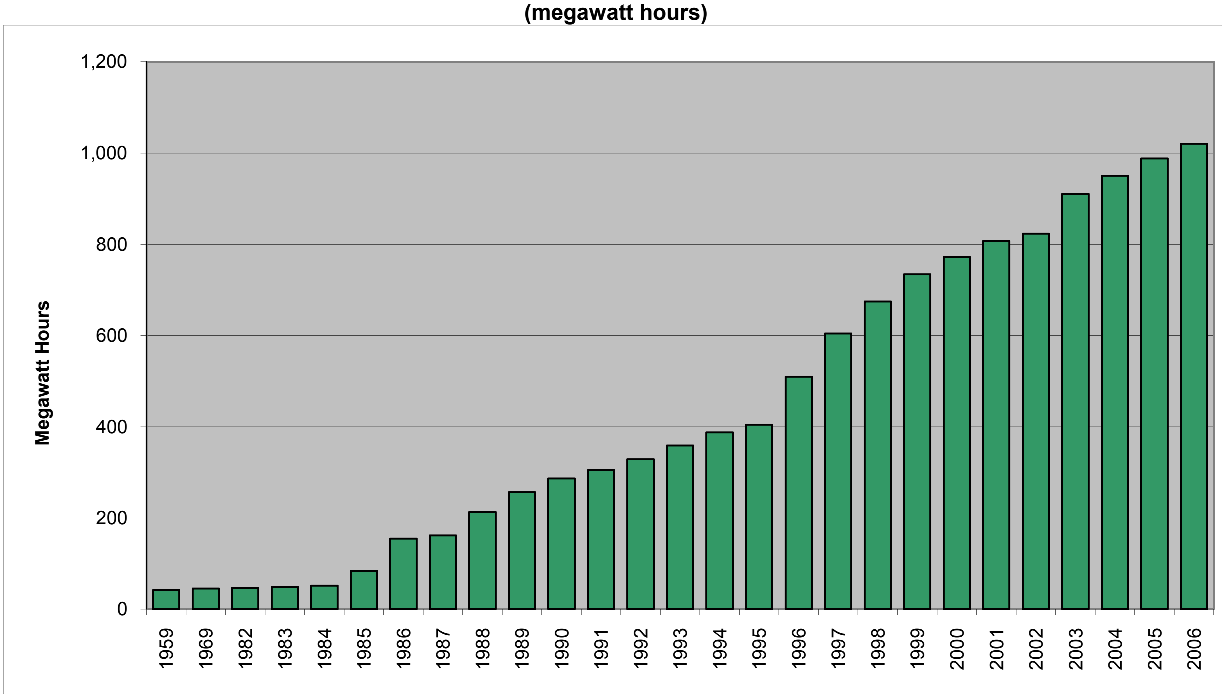
Source:
(National Electric Energy System (NEEDS) Database for IPM 2006. This was the latest data available at time of publishing this report.
http://epa.gov/airmarkets/progsregs/epa-ipm/index.html

[a] Data are not available

Section: BIOPOWER
New Landfill Gas Power Plants by Year



Landfill Gas Power Plant Capacity by Year
(megawatt hours)



Source:
(National Electric Energy System (NEEDS) Database for IPM 2006
http://epa.gov/airmarkets/progsregs/epa-ipm/index.html

Notes:
1. Only years in which new plants were brought online are shown.
2. Power plant capacity based on NEEDS 2006 Data. This was the latest data available at time of publishing this report.

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	14,348	No	1959
Altamont Gas Recovery	G	California	Alameda	2.90	18,748	No	1969
Marsh Road Power Plant	G	California	San Mateo	0.50	18,412	No	1982
Marsh Road Power Plant	G	California	San Mateo	0.50	18,412	No	1982
Marsh Road Power Plant	G	California	San Mateo	0.50	18,412	No	1982
Marsh Road Power Plant	G	California	San Mateo	0.50	18,412	No	1982
Guadalupe Power Plant	G	California	Santa Clara	0.50	13,763	No	1983
Guadalupe Power Plant	G	California	Santa Clara	0.50	13,763	No	1983
Guadalupe Power Plant	G	California	Santa Clara	0.50	13,763	No	1983
Newby Island I	G	California	Santa Clara	0.50	12,991	No	1984
Newby Island I	G	California	Santa Clara	0.50	12,991	No	1984
Newby Island I	G	California	Santa Clara	0.50	12,991	No	1984
Newby Island I	G	California	Santa Clara	0.50	12,991	No	1984
Puente Hills Energy Recovery	G	California	Los Angeles	1.10	36,790	No	1984
American Canyon Power Plant	G	California	Napa	0.70	10,887	No	1985
American Canyon Power Plant	G	California	Napa	0.70	10,887	No	1985
Olinda Landfill Gas Recovery Plant	G	California	Orange	1.70	12,348	No	1985
Olinda Landfill Gas Recovery Plant	G	California	Orange	1.70	12,348	No	1985
Olinda Landfill Gas Recovery Plant	G	California	Orange	1.70	12,348	No	1985
Nove Power Plant	G	California	Contra Costa	2.50	10,205	No	1985
Nove Power Plant	G	California	Contra Costa	2.50	10,205	No	1985
Oxnard	G	California	Ventura	1.70	13,533	No	1985
Oxnard	G	California	Ventura	1.70	13,533	No	1985
Gude	G	Maryland	Montgomery	1.30	14,768	No	1985
Gude	G	Maryland	Montgomery	1.30	14,768	No	1985
Kinsleys Landfill	G	New Jersey	Gloucester	0.50	10,400	No	1985
Kinsleys Landfill	G	New Jersey	Gloucester	0.50	10,400	No	1985
Kinsleys Landfill	G	New Jersey	Gloucester	0.50	10,400	No	1985
Kinsleys Landfill	G	New Jersey	Gloucester	0.50	10,400	No	1985
Lebanon Methane Recovery	G	Pennsylvania	Lebanon	0.60	14,707	No	1985
Lebanon Methane Recovery	G	Pennsylvania	Lebanon	0.60	14,707	No	1985
Metro Gas Recovery	G	Wisconsin	Milwaukee	2.90	17,718	No	1985
Metro Gas Recovery	G	Wisconsin	Milwaukee	2.90	17,718	No	1985
Omega Hills Gas Recovery	G	Wisconsin	Washington	2.90	18,070	No	1985
Omega Hills Gas Recovery	G	Wisconsin	Washington	2.90	18,070	No	1985
Total Energy Facilities	G	California	Los Angeles	4.73	12,917	Yes	1986
Puente Hills Energy Recovery	B	California	Los Angeles	22.50	11,487	No	1986
Puente Hills Energy Recovery	B	California	Los Angeles	22.50	11,487	No	1986
Otay	G	California	San Diego	1.70	12,265	No	1986
Salinas	G	California	Monterey	1.30	18,136	No	1986
Santa Clara	G	California	Santa Clara	1.30	11,259	No	1986
Penrose Power Station	G	California	Los Angeles	1.70	13,169	No	1986
Penrose Power Station	G	California	Los Angeles	1.70	13,169	No	1986
Penrose Power Station	G	California	Los Angeles	1.70	13,169	No	1986
Penrose Power Station	G	California	Los Angeles	1.70	13,169	No	1986
Penrose Power Station	G	California	Los Angeles	1.70	13,169	No	1986
Toyon Power Station	G	California	Los Angeles	1.70	13,200	No	1986
Toyon Power Station	G	California	Los Angeles	1.70	13,200	No	1986
Toyon Power Station	G	California	Los Angeles	1.70	13,200	No	1986
Toyon Power Station	G	California	Los Angeles	1.70	13,200	No	1986
EQ Waste Energy Services	G	Michigan	Wayne	0.50	11,123	Yes	1986
EQ Waste Energy Services	G	Michigan	Wayne	0.30	11,123	Yes	1986
EQ Waste Energy Services	G	Michigan	Wayne	0.30	11,123	Yes	1986
EQ Waste Energy Services	G	Michigan	Wayne	0.30	11,123	Yes	1986
Guadalupe Power Plant	G	California	Santa Clara	1.00	13,763	No	1987
Nove Power Plant	G	California	Contra Costa	2.50	10,205	No	1987
Prince Georges County Brown Station Road	G	Maryland	Prince Georges	0.74	12,917	Yes	1987
Prince Georges County Brown Station Road	G	Maryland	Prince Georges	0.74	12,917	Yes	1987
Prince Georges County Brown Station Road	G	Maryland	Prince Georges	0.74	12,917	Yes	1987
Taylor Energy Partners LP	G	Pennsylvania	Lackawanna	0.50	14,512	No	1987
Taylor Energy Partners LP	G	Pennsylvania	Lackawanna	0.40	14,512	No	1987
Taylor Energy Partners LP	G	Pennsylvania	Lackawanna	0.40	14,512	No	1987
Taylor Energy Partners LP	G	Pennsylvania	Lackawanna	0.40	14,512	No	1987
Palos Verdes Gas to Energy	B	California	Los Angeles	3.00	21,020	No	1988
Palos Verdes Gas to Energy	B	California	Los Angeles	3.00	21,020	No	1988
Settlers Hill Gas Recovery	G	Illinois	Kane	2.90	18,340	No	1988
Lake Gas Recovery	G	Illinois	Cook	2.90	17,932	No	1988
Riverview Energy Systems	G	Michigan	Wayne	2.81	17,800	No	1988
Riverview Energy Systems	G	Michigan	Wayne	2.81	17,800	No	1988
Dunbarton Energy Partners LP	G	New Hampshire	Hillsborough	0.59	10,640	No	1988
Dunbarton Energy Partners LP	G	New Hampshire	Hillsborough	0.59	10,640	No	1988
Al Turi	G	New York	Orange	0.70	15,600	No	1988
Al Turi	G	New York	Orange	0.70	15,600	No	1988
Smithtown Energy Partners LP	G	New York	Suffolk	0.60	21,971	No	1988
Smithtown Energy Partners LP	G	New York	Suffolk	0.60	21,971	No	1988
Onondaga Energy Partners LP	G	New York	Onondaga	0.60	12,543	No	1988
Onondaga Energy Partners LP	G	New York	Onondaga	0.60	12,543	No	1988
Monroe Livingston Gas Recovery	G	New York	Monroe	0.80	13,146	No	1988
Monroe Livingston Gas Recovery	G	New York	Monroe	0.80	13,146	No	1988
Monroe Livingston Gas Recovery	G	New York	Monroe	0.80	13,146	No	1988
Archbald Power Station	B	Pennsylvania	Lackawanna	20.00	21,020	Yes	1988
DFW Gas Recovery	G	Texas	Denton	2.90	18,736	No	1988
DFW Gas Recovery	G	Texas	Denton	2.90	18,736	No	1988
Sycamore San Diego	G	California	San Diego	0.70	10,000	No	1989
Sycamore San Diego	G	California	San Diego	0.70	10,000	No	1989
Newby Island II	G	California	Santa Clara	1.00	10,998	No	1989
Newby Island II	G	California	Santa Clara	1.00	10,998	No	1989
Newby Island II	G	California	Santa Clara	1.00	10,998	No	1989
Coyote Canyon Steam Plant	B	California	Orange	17.00	16,797	No	1989
Altamont Gas Recovery	G	California	Alameda	2.90	18,748	No	1989

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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
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
CID Gas Recovery	G	Illinois	Cook	2.90	19,051	No	1989
CID Gas Recovery	G	Illinois	Cook	2.90	19,051	No	1989
Tazewell Gas Recovery	G	Illinois	Tazewell	0.80	11,786	No	1989
Tazewell Gas Recovery	G	Illinois	Tazewell	0.80	11,786	No	1989
Al Turi	G	New York	Orange	0.70	15,600	No	1989
Stowe Power Production Plant	G	Pennsylvania	Montgomery	2.90	19,515	No	1989
San Marcos	G	California	San Diego	0.70	17,340	No	1990
San Marcos	G	California	San Diego	0.70	17,340	No	1990
Spadra Landfill Gas to Energy	B	California	Los Angeles	8.50	14,888	No	1990
Byxbee Park Sanitary Landfill	G	California	Santa Clara	1.00	10,339	No	1990
Byxbee Park Sanitary Landfill	G	California	Santa Clara	1.00	10,339	No	1990
MM Yolo Power LLC Facility	G	California	Yolo	0.45	23,737	No	1990
MM Yolo Power LLC Facility	G	California	Yolo	0.45	23,737	No	1990
MM Yolo Power LLC Facility	G	California	Yolo	0.45	23,737	No	1990
Lafayette Energy Partners LP	G	New Jersey	Sussex	0.50	17,767	No	1990
Lafayette Energy Partners LP	G	New Jersey	Sussex	0.50	17,767	No	1990
Oceanside Energy	G	New York	Nassau	0.60	12,392	No	1990
Oceanside Energy	G	New York	Nassau	0.60	12,392	No	1990
Oceanside Energy	G	New York	Nassau	0.60	12,392	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	11,832	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	11,832	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	11,832	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	11,832	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	11,832	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	11,832	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	11,832	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	11,832	No	1990
Otay	G	California	San Diego	1.70	12,245	No	1991
Oxnard	G	California	Ventura	1.70	13,533	No	1991
New Milford Gas Recovery	G	Connecticut	Litchfield	3.00	17,053	No	1991
Milam Gas Recovery	G	Illinois	St. Clair	0.80	12,888	No	1991
Milam Gas Recovery	G	Illinois	St. Clair	0.80	12,888	No	1991
Granger Electric Generating Station #2	G	Michigan	Clinton	0.80	12,740	No	1991
Granger Electric Generating Station #2	G	Michigan	Clinton	0.80	12,740	No	1991
Granger Electric Generating Station #2	G	Michigan	Clinton	0.80	12,740	No	1991
High Acres Gas Recovery	G	New York	Monroe	0.80	11,852	No	1991
High Acres Gas Recovery	G	New York	Monroe	0.80	11,852	No	1991
High Acres Gas Recovery	G	New York	Monroe	0.80	11,852	No	1991
High Acres Gas Recovery	G	New York	Monroe	0.80	11,852	No	1991
Stowe Power Production Plant	G	Pennsylvania	Montgomery	2.90	19,515	No	1991
Outagamie County Co-Generation Facility	G	Wisconsin	Outagamie	0.80	12,917	Yes	1991
Outagamie County Co-Generation Facility	G	Wisconsin	Outagamie	0.80	12,917	No	1991
Outagamie County Co-Generation Facility	G	Wisconsin	Outagamie	0.80	12,917	No	1991
Kankakee Gas Recovery	G	Illinois	Kankakee	0.80	11,892	No	1992
Kankakee Gas Recovery	G	Illinois	Kankakee	0.80	11,892	No	1992
Woodland Landfill Gas Recovery	G	Illinois	Kane	0.80	13,196	No	1992
Woodland Landfill Gas Recovery	G	Illinois	Kane	0.80	13,196	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1992
Venice Resources Gas Recovery	G	Michigan	Shiawassee	0.80	16,218	No	1992
Venice Resources Gas Recovery	G	Michigan	Shiawassee	0.80	16,218	No	1992
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	0.80	12,840	No	1992
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	0.80	12,840	No	1992
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	0.80	12,840	No	1992
Chestnut Ridge Gas Recovery	G	Tennessee	Anderson	0.80	14,268	No	1992
Chestnut Ridge Gas Recovery	G	Tennessee	Anderson	0.80	14,268	No	1992
Chestnut Ridge Gas Recovery	G	Tennessee	Anderson	0.80	14,268	No	1992
Chestnut Ridge Gas Recovery	G	Tennessee	Anderson	0.80	14,268	No	1992
I 95 Municipal Landfill Phase I	G	Virginia	Fairfax	0.80	11,031	No	1992
I 95 Municipal Landfill Phase I	G	Virginia	Fairfax	0.80	11,031	No	1992
I 95 Municipal Landfill Phase I	G	Virginia	Fairfax	0.80	11,031	No	1992
I 95 Municipal Landfill Phase I	G	Virginia	Fairfax	0.80	11,031	No	1992
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	1992
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	1992
BKK Landfill	G	California	Los Angeles	4.40	21,020	No	1993
MM Yolo Power LLC Facility	G	California	Yolo	0.60	23,737	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 I	G	California	Sonoma	0.70	13,634	No	1993
BJ Gas Recovery	G	Georgia	Gwinnett	0.80	12,460	No	1993
BJ Gas Recovery	G	Georgia	Gwinnett	0.80	12,460	No	1993
BJ Gas Recovery	G	Georgia	Gwinnett	0.80	12,460	No	1993
Milam Gas Recovery	G	Illinois	St. Clair	0.80	12,888	No	1993
Lake Gas Recovery	G	Illinois	Cook	2.90	17,932	No	1993
Lake Gas Recovery	G	Illinois	Cook	2.90	17,932	No	1993
Chicopee Electric	G	Massachusetts	Hampden	0.90	14,170	No	1993
Chicopee Electric	G	Massachusetts	Hampden	0.90	14,170	No	1993
Granger Electric Generating Station #1	G	Michigan	Clinton	0.80	14,015	No	1993
Granger Electric Generating Station #1	G	Michigan	Clinton	0.80	14,015	No	1993

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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
Lyon Development	G	Michigan	Oakland	0.90	17,641	No	1993
Lyon Development	G	Michigan	Oakland	0.90	17,641	No	1993
Lyon Development	G	Michigan	Oakland	0.90	17,641	No	1993
Lyon Development	G	Michigan	Oakland	0.90	17,641	No	1993
Lyon Development	G	Michigan	Oakland	0.90	17,641	No	1993
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	0.80	12,840	No	1993
I 95 Landfill Phase II	G	Virginia	Fairfax	0.80	10,773	No	1993
I 95 Landfill Phase II	G	Virginia	Fairfax	0.80	10,773	No	1993
I 95 Landfill Phase II	G	Virginia	Fairfax	0.80	10,773	No	1993
I 95 Landfill Phase II	G	Virginia	Fairfax	0.80	10,773	No	1993
Richmond Electric	G	Virginia	Henrico	0.90	14,012	No	1993
Richmond Electric	G	Virginia	Henrico	0.90	14,012	No	1993
Marina Landfill Gas	G	California	Monterey	0.70	12,917	No	1994
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	11,895	No	1994
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	11,895	No	1994
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	11,895	No	1994
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	11,895	No	1994
Prairie View Gas Recovery	G	Indiana	St. Joseph	0.80	10,991	No	1994
Prairie View Gas Recovery	G	Indiana	St. Joseph	0.80	10,991	No	1994
Prairie View Gas Recovery	G	Indiana	St. Joseph	0.80	10,991	No	1994
Prairie View Gas Recovery	G	Indiana	St. Joseph	0.80	10,991	No	1994
Granger Electric Generating Station #1	G	Michigan	Clinton	0.80	14,015	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	11,797	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	11,797	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	11,797	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	11,797	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	11,797	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	11,797	No	1994
Grand Blanc Generating Station	G	Michigan	Genesee	0.80	11,080	No	1994
Grand Blanc Generating Station	G	Michigan	Genesee	0.80	11,080	No	1994
Grand Blanc Generating Station	G	Michigan	Genesee	0.80	11,080	No	1994
Adrian Energy Associates LLC	G	Michigan	Lenawee	0.80	13,171	No	1994
Adrian Energy Associates LLC	G	Michigan	Lenawee	0.80	13,171	No	1994
Adrian Energy Associates LLC	G	Michigan	Lenawee	0.80	13,171	No	1994
Woodlake Sanitary Services	G	Minnesota	Hennepin	1.50	11,749	No	1994
Woodlake Sanitary Services	G	Minnesota	Hennepin	1.50	11,749	No	1994
Woodlake Sanitary Services	G	Minnesota	Hennepin	1.50	11,749	No	1994
EKS Landfill	G	Minnesota	Dakota	1.50	12,381	No	1994
EKS Landfill	G	Minnesota	Dakota	1.50	12,381	No	1994
EKS Landfill	G	Minnesota	Dakota	0.80	12,381	No	1994
Suffolk Energy Partners LP	G	Virginia	Fairfax	0.70	12,500	No	1994
Suffolk Energy Partners LP	G	Virginia	Fairfax	0.70	12,500	No	1994
Suffolk Energy Partners LP	G	Virginia	Fairfax	0.70	12,500	No	1994
Suffolk Energy Partners LP	G	Virginia	Fairfax	0.70	12,500	No	1994
Peoples Generating Station	G	Michigan	Genesee	2.20	9,350	No	1995
C & C Electric	G	Michigan	Calhoun	0.90	13,697	No	1995
C & C Electric	G	Michigan	Calhoun	0.90	13,697	No	1995
C & C Electric	G	Michigan	Calhoun	0.90	13,697	No	1995
Al Turi	G	New York	Orange	0.70	15,600	No	1995
Brookhaven Facility	G	New York	Suffolk	1.20	13,158	No	1995
Brookhaven Facility	G	New York	Suffolk	1.20	13,158	No	1995
Brookhaven Facility	G	New York	Suffolk	1.20	13,158	No	1995
Brookhaven Facility	G	New York	Suffolk	1.20	13,158	No	1995
Coffin Butte	G	Oregon	Benton	2.30	13,151	No	1995
Coffin Butte	G	Oregon	Benton	0.74	13,151	No	1995
Coffin Butte	G	Oregon	Benton	0.74	13,151	No	1995
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,125	No	1995
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,125	No	1995
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,125	No	1995
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,125	No	1995
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
Greene Valley Gas Recovery	G	Illinois	Du Page	2.90	17,551	No	1996
Greene Valley Gas Recovery	G	Illinois	Du Page	2.90	17,551	No	1996
Rockford Electric	G	Illinois	Ogle	0.90	12,317	No	1996
Rockford Electric	G	Illinois	Ogle	0.90	12,317	No	1996
Barre	G	Massachusetts	Worcester	0.40	11,941	No	1996
Barre	G	Massachusetts	Worcester	0.40	11,941	No	1996
Granger Electric Generating Station #2	G	Michigan	Clinton	0.80	12,740	No	1996
Arbor Hills	G	Michigan	Washtenaw	3.80	11,860	No	1996
Arbor Hills	G	Michigan	Washtenaw	3.80	11,860	No	1996
Arbor Hills	G	Michigan	Washtenaw	3.80	11,860	No	1996
Arbor Hills	G	Michigan	Washtenaw	7.60	11,860	No	1996
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
Four Hills Nashua Landfill	G	New Hampshire	Hillsborough	0.46	13,152	No	1996
Four Hills Nashua Landfill	G	New Hampshire	Hillsborough	0.46	13,152	No	1996
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1996
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1996
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1996
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1996
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1996
Salem Energy Systems LLC	G	North Carolina	Forsyth	3.30	16,895	No	1996
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,125	No	1996
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,125	No	1996
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,125	No	1996
Pennsbury	G	Pennsylvania	Bucks	2.67	9,960	No	1996
Pennsbury	G	Pennsylvania	Bucks	2.67	9,960	No	1996

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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
Fairless Hills	B	Pennsylvania	Bucks	20.00	10,265	Yes	1996
Fairless Hills	B	Pennsylvania	Bucks	20.00	10,265	Yes	1996
Sunset Farms	G	Texas	Travis	0.90	12,845	No	1996
Sunset Farms	G	Texas	Travis	0.90	12,845	No	1996
Sunset Farms	G	Texas	Travis	0.90	12,845	No	1996
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	1996
Mallard Ridge Gas Recovery	G	Wisconsin	Walworth	0.80	11,500	No	1996
Mallard Ridge Gas Recovery	G	Wisconsin	Walworth	0.80	11,500	No	1996
Marina Landfill Gas	G	California	Monterey	0.90	12,917	No	1997
Miramar Landfill Metro Biosolids Center	G	California	San Diego	1.56	10,123	Yes	1997
Miramar Landfill Metro Biosolids Center	G	California	San Diego	1.56	10,123	Yes	1997
Miramar Landfill Metro Biosolids Center	G	California	San Diego	1.56	10,123	Yes	1997
Miramar Landfill Metro Biosolids Center	G	California	San Diego	1.56	10,123	Yes	1997
Girvin Landfill	G	Florida	Duval	3.00	13,806	No	1997
Biodyne Peoria	G	Illinois	Peoria	0.80	15,860	No	1997
Biodyne Peoria	G	Illinois	Peoria	0.80	15,860	No	1997
Biodyne Peoria	G	Illinois	Peoria	0.80	15,860	No	1997
Biodyne Peoria	G	Illinois	Peoria	0.80	15,860	No	1997
Biodyne Peoria	G	Illinois	Peoria	0.80	15,860	No	1997
Biodyne Springfield	G	Illinois	Sangamon	0.60	23,000	No	1997
Biodyne Springfield	G	Illinois	Sangamon	0.60	23,000	No	1997
Biodyne Springfield	G	Illinois	Sangamon	0.60	23,000	No	1997
Biodyne Springfield	G	Illinois	Sangamon	0.60	23,000	No	1997
Biodyne Lyons	G	Illinois	Cook	0.90	15,000	No	1997
Biodyne Lyons	G	Illinois	Cook	0.90	15,000	No	1997
Biodyne Lyons	G	Illinois	Cook	0.90	15,000	No	1997
Mallard Lake Electric	G	Illinois	Du Page	3.80	9,800	No	1997
Mallard Lake Electric	G	Illinois	Du Page	3.80	9,800	No	1997
Mallard Lake Electric	G	Illinois	Du Page	3.80	9,800	No	1997
Mallard Lake Electric	G	Illinois	Du Page	7.60	9,800	No	1997
South Barrington Electric	G	Illinois	Du Page	0.80	12,744	No	1997
South Barrington Electric	G	Illinois	Du Page	0.80	12,744	No	1997
Devonshire Power Partners LLC	G	Illinois	Cook	1.00	11,883	No	1997
Devonshire Power Partners LLC	G	Illinois	Cook	1.00	11,883	No	1997
Devonshire Power Partners LLC	G	Illinois	Cook	1.00	11,883	No	1997
Devonshire Power Partners LLC	G	Illinois	Cook	1.00	11,883	No	1997
Devonshire Power Partners LLC	G	Illinois	Cook	1.00	11,883	No	1997
Riveside Resource Recovery LLC	G	Illinois	Will	0.90	12,739	No	1997
Avon Energy Partners LLC	G	Illinois	Cook	0.90	10,367	No	1997
Avon Energy Partners LLC	G	Illinois	Cook	0.90	10,367	No	1997
Avon Energy Partners LLC	G	Illinois	Cook	0.90	10,367	No	1997
KMS Joliet Power Partners LP	G	Illinois	Will	0.43	10,000	No	1997
KMS Joliet Power Partners LP	G	Illinois	Will	0.43	10,000	No	1997
Wheeler Landfill Gas Recovery	G	Indiana	La Porte	0.80	12,270	No	1997
Taunton Landfill	G	Massachusetts	Bristol	0.88	11,754	No	1997
Taunton Landfill	G	Massachusetts	Bristol	0.88	11,754	No	1997
Lowell Landfill	G	Massachusetts	Middlesex	0.78	9,350	No	1997
Lowell Landfill	G	Massachusetts	Middlesex	0.78	9,350	No	1997
East Bridgewater	G	Massachusetts	Plymouth	0.90	13,410	No	1997
East Bridgewater	G	Massachusetts	Plymouth	0.90	13,410	No	1997
East Bridgewater	G	Massachusetts	Plymouth	0.90	13,410	No	1997
East Bridgewater	G	Massachusetts	Plymouth	0.90	13,410	No	1997
East Bridgewater	G	Massachusetts	Plymouth	0.90	13,410	No	1997
East Bridgewater	G	Massachusetts	Plymouth	0.90	13,410	No	1997
Halifax Electric	G	Massachusetts	Plymouth	0.90	13,629	No	1997
Halifax Electric	G	Massachusetts	Plymouth	0.90	13,629	No	1997
Halifax Electric	G	Massachusetts	Plymouth	0.90	13,629	No	1997
Granger Electric Generating Station #2	G	Michigan	Clinton	0.80	12,740	No	1997
Granger Electric Generating Station #1	G	Michigan	Clinton	0.80	14,015	No	1997
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	2.90	17,620	No	1997
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	2.90	17,620	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	9,350	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	9,350	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	9,350	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	9,350	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	9,350	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	9,350	No	1997
O'Brien Biogas IV LLC	G	New Jersey	Middlesex	9.50	19,943	No	1997
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1997
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1997
Lakeview Gas Recovery	G	Pennsylvania	Erie	3.00	12,517	No	1997
Lakeview Gas Recovery	G	Pennsylvania	Erie	3.00	12,517	No	1997
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	11,832	No	1997
Mallard Ridge Gas Recovery	G	Wisconsin	Walworth	0.80	11,500	No	1997
Dane County Landfill #2 Rodefeld	G	Wisconsin	Dane	0.70	12,596	No	1997
Dane County Landfill #2 Rodefeld	G	Wisconsin	Dane	0.70	12,596	No	1997
Marina Landfill Gas	G	California	Monterey	0.90	12,917	No	1998
Visalia Landfill Gas Utilization Project	G	California	Tulare	0.78	15,410	No	1998
Visalia Landfill Gas Utilization Project	G	California	Tulare	0.78	15,410	No	1998
Lopez Landfill Gas Utilization Project	G	California	Los Angeles	2.73	12,698	No	1998
Lopez Landfill Gas Utilization Project	G	California	Los Angeles	2.73	12,698	No	1998
Hartford Landfill Gas Utilization Project	G	Connecticut	Hartford	0.83	12,503	No	1998
Hartford Landfill Gas Utilization Project	G	Connecticut	Hartford	0.83	12,503	No	1998
Hartford Landfill Gas Utilization Project	G	Connecticut	Hartford	0.83	12,503	No	1998
Volusia Landfill Gas Utilization Project	G	Florida	Volusia	1.85	10,333	No	1998
Volusia Landfill Gas Utilization Project	G	Florida	Volusia	1.85	10,333	No	1998
Settlers Hill Gas Recovery	G	Illinois	Kane	2.90	18,340	No	1998
Greene Valley Gas Recovery	G	Illinois	Du Page	2.90	17,551	No	1998
Quad Cities	G	Illinois	Rock Island	0.90	16,840	No	1998

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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
KMS Macon Power	G	Illinois	Macon	0.80	12,917	No	1998
KMS Macon Power	G	Illinois	Macon	0.80	12,917	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,265	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,265	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,265	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,265	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,265	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,265	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,265	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,265	No	1998
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1998
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1998
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1998
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1998
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,388	No	1998
Brent Run Generating Station	G	Michigan	Genesee	0.80	11,472	No	1998
Brent Run Generating Station	G	Michigan	Genesee	0.80	11,472	No	1998
Pine Tree Acres	G	Michigan	Macomb	0.80	10,976	No	1998
Pine Tree Acres	G	Michigan	Macomb	0.80	10,976	No	1998
Pine Tree Acres	G	Michigan	Macomb	0.80	10,976	No	1998
Pine Tree Acres	G	Michigan	Macomb	0.80	10,976	No	1998
Pine Tree Acres	G	Michigan	Macomb	0.80	10,976	No	1998
Balefill Landfill Gas Utilization Project	G	New Jersey	Bergen	1.80	12,611	No	1998
Balefill Landfill Gas Utilization Project	G	New Jersey	Bergen	1.80	12,611	No	1998
Monmouth Landfill Gas to Energy	G	New Jersey	Monmouth	7.37	9,960	No	1998
Al Turi	G	New York	Orange	0.80	15,600	No	1998
Al Turi	G	New York	Orange	0.80	15,600	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,012	No	1998
Albany Landfill Gas Utilization Project	G	New York	Albany	0.90	11,914	No	1998
Albany Landfill Gas Utilization Project	G	New York	Albany	0.90	11,914	No	1998
Modern Landfill Production Plant	G	Pennsylvania	York	3.00	10,820	No	1998
Modern Landfill Production Plant	G	Pennsylvania	York	3.00	10,820	No	1998
Modern Landfill Production Plant	G	Pennsylvania	York	3.00	10,820	No	1998
Prince William County Landfill	G	Virginia	Prince William	0.89	10,206	No	1998
Prince William County Landfill	G	Virginia	Prince William	0.89	10,206	No	1998
Tacoma Landfill Gas Utilization Project	G	Washington	Pierce	0.75	12,917	No	1998
Tacoma Landfill Gas Utilization Project	G	Washington	Pierce	0.75	12,917	No	1998
BKK Landfill	G	California	Los Angeles	4.40	12,597	No	1999
Prima Desheha Landfill	G	California	Orange	2.70	13,752	No	1999
Prima Desheha Landfill	G	California	Orange	2.70	13,752	No	1999
North City Cogen Facility	G	California	San Diego	0.88	12,325	No	1999
North City Cogen Facility	G	California	San Diego	0.88	12,325	No	1999
North City Cogen Facility	G	California	San Diego	0.88	12,325	No	1999
North City Cogen Facility	G	California	San Diego	0.88	12,325	No	1999
Kiefer Landfill	G	California	Sacramento	2.80	12,917	No	1999
Kiefer Landfill	G	California	Sacramento	2.80	12,917	No	1999
Kiefer Landfill	G	California	Sacramento	2.80	12,917	No	1999
Tazewell Gas Recovery	G	Illinois	Tazewell	0.80	11,786	No	1999
Roxana Resource Recovery	G	Illinois	Madison	0.90	10,600	No	1999
Roxana Resource Recovery	G	Illinois	Madison	0.90	10,600	No	1999
Roxana Resource Recovery	G	Illinois	Madison	0.90	10,600	No	1999
Roxana Resource Recovery	G	Illinois	Madison	0.90	10,600	No	1999
Streator Energy Partners LLC	G	Illinois	La Salle	0.90	10,919	No	1999
Brickyard Energy Partners LLC	G	Illinois	Vermilion	0.90	10,793	No	1999
Brickyard Energy Partners LLC	G	Illinois	Vermilion	0.90	10,793	No	1999
Brickyard Energy Partners LLC	G	Illinois	Vermilion	0.90	10,793	No	1999
Dixon/Lee Energy Partners LLC	G	Illinois	Lee	0.90	12,101	No	1999
Dixon/Lee Energy Partners LLC	G	Illinois	Lee	0.90	12,101	No	1999
Dixon/Lee Energy Partners LLC	G	Illinois	Lee	0.90	12,101	No	1999
Dixon/Lee Energy Partners LLC	G	Illinois	Lee	0.90	12,101	No	1999
KMS Joliet Power Partners LP	G	Illinois	Will	0.43	10,000	No	1999
Deercroft Gas Recovery	G	Indiana	La Porte	0.80	12,030	No	1999
Deercroft Gas Recovery	G	Indiana	La Porte	0.80	12,030	No	1999
Deercroft Gas Recovery	G	Indiana	La Porte	0.80	12,030	No	1999
Deercroft Gas Recovery	G	Indiana	La Porte	0.80	12,030	No	1999
HMDC Kingsland Landfill	G	New Jersey	Bergen	0.90	13,406	No	1999
HMDC Kingsland Landfill	G	New Jersey	Bergen	0.90	13,406	No	1999
Blackburn Landfill Co-Generation	G	North Carolina	Catawba	1.00	10,433	Yes	1999
Blackburn Landfill Co-Generation	G	North Carolina	Catawba	1.00	10,433	Yes	1999
Charlotte Motor Speedway	G	North Carolina	Cabarrus	4.30	14,303	No	1999
Cuyahoga Regional Landfill	G	Ohio	Cuyahoga	1.80	10,374	No	1999
Cuyahoga Regional Landfill	G	Ohio	Cuyahoga	1.80	10,374	No	1999
P.E.R.C.	G	Washington	Pierce	0.75	17,782	No	1999
P.E.R.C.	G	Washington	Pierce	0.75	17,782	No	1999
P.E.R.C.	G	Washington	Pierce	0.75	17,782	No	1999
Roosevelt Biogas 1	G	Washington	Klickitat	2.10	10,000	No	1999
Roosevelt Biogas 1	G	Washington	Klickitat	2.10	10,000	No	1999
Roosevelt Biogas 1	G	Washington	Klickitat	2.10	10,000	No	1999
Roosevelt Biogas 1	G	Washington	Klickitat	2.10	10,000	No	1999
Tajiguas Landfill	G	California	Santa Barbara	2.70	11,332	No	2000
CSL Gas Recovery	G	Florida	Broward	2.20	11,860	No	2000
Upper Rock Energy Partners LLC	G	Illinois	Rock Island	0.90	10,828	No	2000
Upper Rock Energy Partners LLC	G	Illinois	Rock Island	0.90	10,828	No	2000
Upper Rock Energy Partners LLC	G	Illinois	Rock Island	0.90	10,828	No	2000

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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
Countyside Genco LLC	G	Illinois	Lake	1.30	12,917	No	2000
Countyside Genco LLC	G	Illinois	Lake	1.30	12,917	No	2000
Countyside Genco LLC	G	Illinois	Lake	1.30	12,917	No	2000
Countyside Genco LLC	G	Illinois	Lake	1.30	12,917	No	2000
Countyside Genco LLC	G	Illinois	Lake	1.30	12,917	No	2000
Countyside Genco LLC	G	Illinois	Lake	1.30	12,917	No	2000
KMS Joliet Power Partners LP	G	Illinois	Will	0.43	10,000	No	2000
Randolph Electric	G	Massachusetts	Norfolk	0.90	14,779	No	2000
Randolph Electric	G	Massachusetts	Norfolk	0.90	14,779	No	2000
Randolph Electric	G	Massachusetts	Norfolk	0.90	14,779	No	2000
Fall River Electric	G	Massachusetts	Bristol	0.90	18,550	No	2000
Fall River Electric	G	Massachusetts	Bristol	0.90	18,550	No	2000
Fall River Electric	G	Massachusetts	Bristol	4.40	13,219	No	2000
Grand Blanc Generating Station	G	Michigan	Genesee	0.80	11,080	No	2000
MM Nashville	G	Tennessee	Davidson	0.80	11,399	No	2000
MM Nashville	G	Tennessee	Davidson	0.80	11,399	No	2000
Roosevelt Biogas 1	G	Washington	Klickitat	2.10	10,000	No	2000
Metro Gas Recovery	G	Wisconsin	Milwaukee	0.80	13,749	No	2000
Metro Gas Recovery	G	Wisconsin	Milwaukee	0.80	13,749	No	2000
Metro Gas Recovery	G	Wisconsin	Milwaukee	0.80	13,749	No	2000
Metro Gas Recovery	G	Wisconsin	Milwaukee	0.80	13,749	No	2000
Winnebago County Landfill Gas	G	Wisconsin	Winnebago	0.90	9,350	No	2000
Winnebago County Landfill Gas	G	Wisconsin	Winnebago	0.90	9,350	No	2000
Winnebago County Landfill Gas	G	Wisconsin	Winnebago	0.90	9,350	No	2000
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	2000
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	2000
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	2000
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	2000
Tri Cities	G	Arizona	Maricopa	0.80	11,992	No	2001
Tri Cities	G	Arizona	Maricopa	0.80	11,992	No	2001
Tri Cities	G	Arizona	Maricopa	0.80	11,992	No	2001
Tri Cities	G	Arizona	Maricopa	0.80	11,992	No	2001
Tri Cities	G	Arizona	Maricopa	0.80	11,992	No	2001
RCWMD Badlands Landfill Gas Project	G	California	Riverside	1.00	12,917	No	2001
Biodyne Beecher	G	Illinois	Will	4.20	12,536	No	2001
Morris Genco LLC	G	Illinois	Grundy	1.30	12,917	No	2001
Morris Genco LLC	G	Illinois	Grundy	1.30	12,917	No	2001
Morris Genco LLC	G	Illinois	Grundy	1.30	12,917	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	11,220	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	11,220	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	11,220	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	11,220	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	11,220	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	11,220	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	11,220	No	2001
Green Knight Energy Center	G	Pennsylvania	Northampton	2.40	18,426	No	2001
Green Knight Energy Center	G	Pennsylvania	Northampton	2.40	18,426	No	2001
Green Knight Energy Center	G	Pennsylvania	Northampton	2.40	18,426	No	2001
Horry Land Fill Gas Site	G	South Carolina	Horry	1.10	10,523	No	2001
Horry Land Fill Gas Site	G	South Carolina	Horry	1.10	10,523	No	2001
Omega Hills Gas Recovery	G	Wisconsin	Washington	3.00	18,070	No	2001
Superior Glacier Ridge Landfill	G	Wisconsin	Dodge	0.90	12,917	No	2001
Superior Glacier Ridge Landfill	G	Wisconsin	Dodge	0.90	12,917	No	2001
Berlin	G	Wisconsin	Green Lake	0.79	10,583	No	2001
Berlin	G	Wisconsin	Green Lake	0.80	10,583	No	2001
Berlin	G	Wisconsin	Green Lake	0.79	10,583	No	2001
Marina Landfill Gas	G	California	Monterey	0.90	12,917	No	2002
Altamont Gas Recovery	G	California	Alameda	1.30	10,500	No	2002
Altamont Gas Recovery	G	California	Alameda	1.30	10,500	No	2002
Quad Cities	G	Illinois	Rock Island	1.00	16,840	No	2002
Brent Run Generating Station	G	Michigan	Genesee	0.80	12,917	No	2002
Elk City Station	G	Nebraska	Douglas	0.80	12,064	No	2002
Elk City Station	G	Nebraska	Douglas	0.80	12,064	No	2002
Elk City Station	G	Nebraska	Douglas	0.80	12,064	No	2002
Elk City Station	G	Nebraska	Douglas	0.80	12,064	No	2002
HMDC Kingsland Landfill	G	New Jersey	Bergen	0.90	13,406	No	2002
Blackburn Landfill Co-Generation	G	North Carolina	Catawba	0.90	10,433	Yes	2002
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	2002
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	2002
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	2002
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	12,475	No	2002
Ridgeview	G	Wisconsin	Manitowoc	0.80	11,054	No	2002
Ridgeview	G	Wisconsin	Manitowoc	0.80	11,054	No	2002
Ridgeview	G	Wisconsin	Manitowoc	0.80	11,054	No	2002
Colton Landfill	G	California	San Bernardino	1.27	12,173	No	2003
Mid Valley Landfill	G	California	San Bernardino	1.27	12,168	No	2003
Mid Valley Landfill	G	California	San Bernardino	1.27	12,168	No	2003
Milliken Landfill	G	California	San Bernardino	1.07	12,166	No	2003
Milliken Landfill	G	California	San Bernardino	1.07	12,166	No	2003
Bradley	C	California	Los Angeles	6.18	12,917	No	2003
Acme Landfill	C	California	Contra Costa	0.27	12,917	No	2003
California Street	C	California	San Bernardino	0.95	12,917	No	2003
South West Landfill	G	Florida	Alachua	0.80	9,413	No	2003
South West Landfill	G	Florida	Alachua	0.80	9,413	No	2003
South West Landfill	G	Florida	Alachua	0.80	9,413	No	2003
Taylor County Landfill	C	Georgia	Taylor	3.80	12,917	No	2003
Bavarian LFGTE	G	Kentucky	Boone	0.80	11,489	No	2003
Bavarian LFGTE	G	Kentucky	Boone	0.80	11,489	No	2003
Bavarian LFGTE	G	Kentucky	Boone	0.80	11,489	No	2003
Bavarian LFGTE	G	Kentucky	Boone	0.80	11,489	No	2003
Green Valley LFGTE	G	Kentucky	Greenup	0.80	11,826	No	2003
Green Valley LFGTE	G	Kentucky	Greenup	0.80	11,826	No	2003
Green Valley LFGTE	G	Kentucky	Greenup	0.80	11,826	No	2003
Laurel Ridge LFGTE	G	Kentucky	Laurel	0.80	11,021	No	2003
Laurel Ridge LFGTE	G	Kentucky	Laurel	0.80	11,021	No	2003
Laurel Ridge LFGTE	G	Kentucky	Laurel	0.80	11,021	No	2003
Laurel Ridge LFGTE	G	Kentucky	Laurel	0.80	11,021	No	2003

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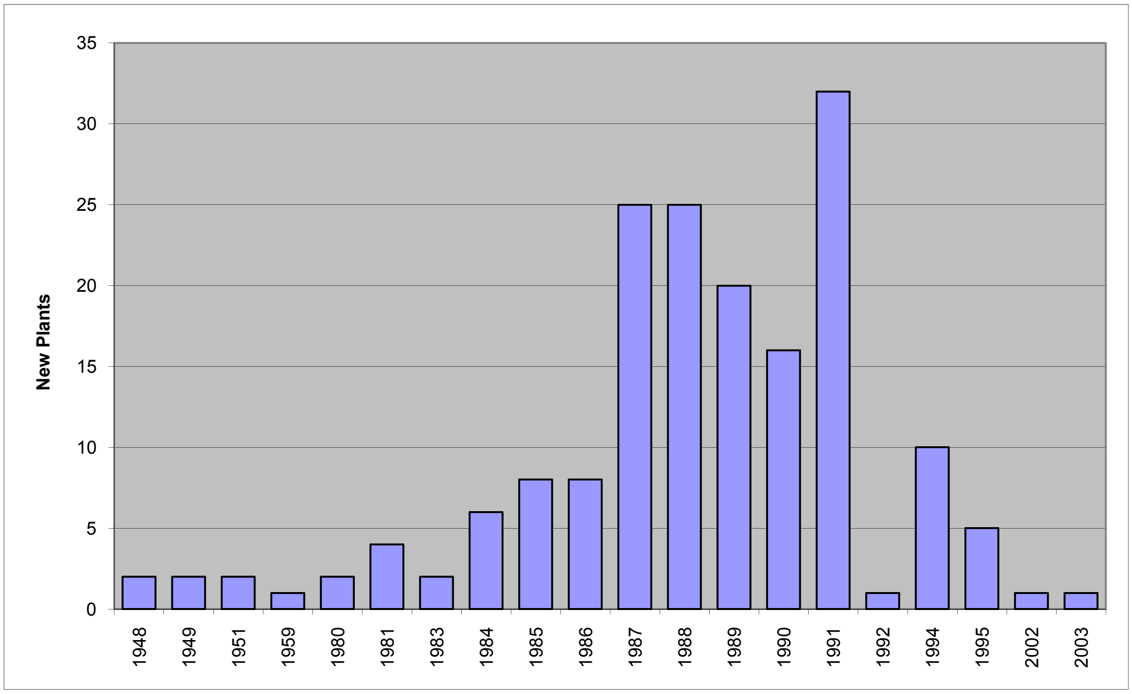
Current Landfill Gas Power Plants
(Continued)

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
PG Cnty Brown Station Road II	G	Maryland	Prince Georges	0.98	12,917	No	2003
PG Cnty Brown Station Road II	G	Maryland	Prince Georges	0.98	12,917	No	2003
PG Cnty Brown Station Road II	G	Maryland	Prince Georges	0.98	12,917	No	2003
PG Cnty Brown Station Road II	G	Maryland	Prince Georges	0.98	12,917	No	2003
Chicopee II LFG	C	Massachusetts	a	5.42	12,917	No	2003
Plainville LFG	C	Massachusetts	a	5.32	12,917	No	2003
Grand Blanc Generating Station	G	Michigan	Genesee	0.80	11,080	No	2003
Pine Tree Acres	G	Michigan	Macomb	0.80	10,976	No	2003
Pine Tree Acres	G	Michigan	Macomb	0.80	10,976	No	2003
Ontario LFGTE	G	New York	Ontario	0.80	10,500	No	2003
Ontario LFGTE	G	New York	Ontario	0.80	10,500	No	2003
Ontario LFGTE	G	New York	Ontario	0.80	10,500	No	2003
Ontario LFGTE	G	New York	Ontario	0.80	10,500	No	2003
Horry Land Fill Gas Site	G	South Carolina	Horry	1.10	10,523	No	2003
Reliant Energy Renewables Atascosita	G	Texas	Harris	1.70	10,518	No	2003
Reliant Energy Renewables Atascosita	G	Texas	Harris	1.70	10,518	No	2003
Reliant Energy Renewables Atascosita	G	Texas	Harris	1.70	10,518	No	2003
Reliant Energy Renewables Atascosita	G	Texas	Harris	1.70	10,518	No	2003
Reliant Energy Renewables Atascosita	G	Texas	Harris	1.70	10,518	No	2003
Reliant Baytown	G	Texas	Chambers	1.00	10,535	No	2003
Reliant Baytown	G	Texas	Chambers	1.00	10,535	No	2003
Reliant Baytown	G	Texas	Chambers	1.00	10,535	No	2003
Reliant Baytown	G	Texas	Chambers	1.00	10,535	No	2003
Reliant Bluebonnet	G	Texas	Harris	1.00	11,043	No	2003
Reliant Bluebonnet	G	Texas	Harris	1.00	11,043	No	2003
Reliant Bluebonnet	G	Texas	Harris	1.00	11,043	No	2003
Reliant Bluebonnet	G	Texas	Harris	1.00	11,043	No	2003
Reliant Coastal Plains	G	Texas	Galveston	1.70	10,353	No	2003
Reliant Coastal Plains	G	Texas	Galveston	1.70	10,353	No	2003
Reliant Coastal Plains	G	Texas	Galveston	1.70	10,353	No	2003
Reliant Coastal Plains	G	Texas	Galveston	1.70	10,353	No	2003
Reliant Conroe	G	Texas	Montgomery	1.00	11,168	No	2003
Reliant Conroe	G	Texas	Montgomery	1.00	11,168	No	2003
Reliant Conroe	G	Texas	Montgomery	1.00	11,168	No	2003
Reliant Security	G	Texas	Liberty	1.70	9,910	No	2003
Reliant Security	G	Texas	Liberty	1.70	9,910	No	2003
Reliant Security	G	Texas	Liberty	1.70	9,910	No	2003
Tessman Road LFG - A	C	Texas	Bexar	2.47	12,917	No	2003
Hutchins LFG	C	Texas	Dallas	2.47	12,917	No	2003
Ridgeview	G	Wisconsin	Manitowoc	0.80	11,054	No	2003
Sonoma Central Landfill Phase III	G	California	Sonoma	0.70	12,917	No	2004
Sonoma Central Landfill Phase III	G	California	Sonoma	0.70	12,917	No	2004
Simi Valley	C	California	Ventura	2.57	12,917	No	2004
Brickyard Recycling	C	Illinois	Vermilion	0.19	12,917	No	2004
Des Plaines Landfill	C	Illinois	Cook	3.80	12,917	No	2004
Westchester Landfill	C	Illinois	Cook	3.33	12,917	No	2004
Twiss Street (Westfi	C	Massachusetts	a	0.46	12,917	No	2004
Dairyland PPA Landfi	C	Minnesota	a	2.85	12,917	No	2004
Atlantic City Landfi	C	New Jersey	a	1.44	12,917	No	2004
Troy	C	New York	Rensselaer	0.76	12,917	No	2004
Broome County	C	New York	Broome	0.67	12,917	No	2004
Ontario County SLF	C	New York	Ontario	3.04	12,917	No	2004
Johnston LFG (MA RPS	C	Rhode Island	a	2.50	12,917	No	2004
Central LF	C	Rhode Island	a	2.38	12,917	No	2004
Charles County Landf	C	Virginia	Charles City	4.56	12,917	No	2004
Fauquier County Land	C	Virginia	Fauquier	1.80	12,917	No	2004
Shoosmith Landfill	C	Virginia	Chesterfield	4.56	12,917	No	2004
Dane County Landfill #2 Rodefeld	G	Wisconsin	Dane	0.80	11,000	No	2004
Seven Mile Creek LFG	G	Wisconsin	Eau Claire	0.98	10,123	No	2004
Seven Mile Creek LFG	G	Wisconsin	Eau Claire	0.98	10,123	No	2004
Seven Mile Creek LFG	G	Wisconsin	Eau Claire	0.98	10,123	No	2004
Owl Creek-Richmond C	C	Georgia	Richmond	3.80	13,648	No	2005
New Paris Pike LF	C	Indiana	Pike	1.52	13,648	No	2005
Pearl Hollow Landfil	C	Kentucky	Hardin	2.28	13,648	No	2005
Crapo Hill Landfill	C	Massachusetts	a	3.04	13,648	No	2005
Glendale	C	Massachusetts	a	1.14	13,648	No	2005
Atlantic County Util	C	New Jersey	Atlantic	1.52	13,648	No	2005
IGENCO (Upton)	C	Pennsylvania	Franklin	5.80	13,648	No	2005
Lanchester	C	Pennsylvania	Lancaster	0.88	13,648	No	2005
Pine Hurst Acres	C	Pennsylvania	Northumberland	0.05	13,648	No	2005
Brookside Dairy	C	Pennsylvania	Indiana	0.13	13,648	No	2005
Wanner's Pride	C	Pennsylvania	Lancaster	0.15	13,648	No	2005
Rolling Hills	C	Pennsylvania	Berks	2.00	13,648	No	2005
Lee County Landfill	C	South Carolina	Lee	1.90	13,648	No	2005
Lee County Landfill	C	South Carolina	Lee	1.90	13,648	No	2005
Lee County Landfill	C	South Carolina	Lee	1.90	13,648	No	2005
Davis County	C	Utah	Davis	0.95	13,648	No	2005
Coventry LFG	C	Vermont	a	4.56	13,648	No	2005
Rodefeld Landfill Ga	C	Wisconsin	Dane	3.80	13,648	No	2005
Double S Dairy Diges	C	Wisconsin	Green Lake	0.38	13,648	No	2005
Los Reales LFG Expan	C	Arizona	a	1.90	13,648	No	2006
Dekalb County Landfi	C	Georgia	De Kalb	3.04	13,648	No	2006
Harrisburg Facility	C	Pennsylvania	Dauphin	20.82	13,648	No	2006
Lee County Landfill	C	South Carolina	Lee	1.90	13,648	No	2006
Texas Mandate Landfill Gas	C	Texas	a	5.00	13,648	No	2006
Lee County Solid Waste Energy	C	Florida	Lee	18.60	13,648	No	2007

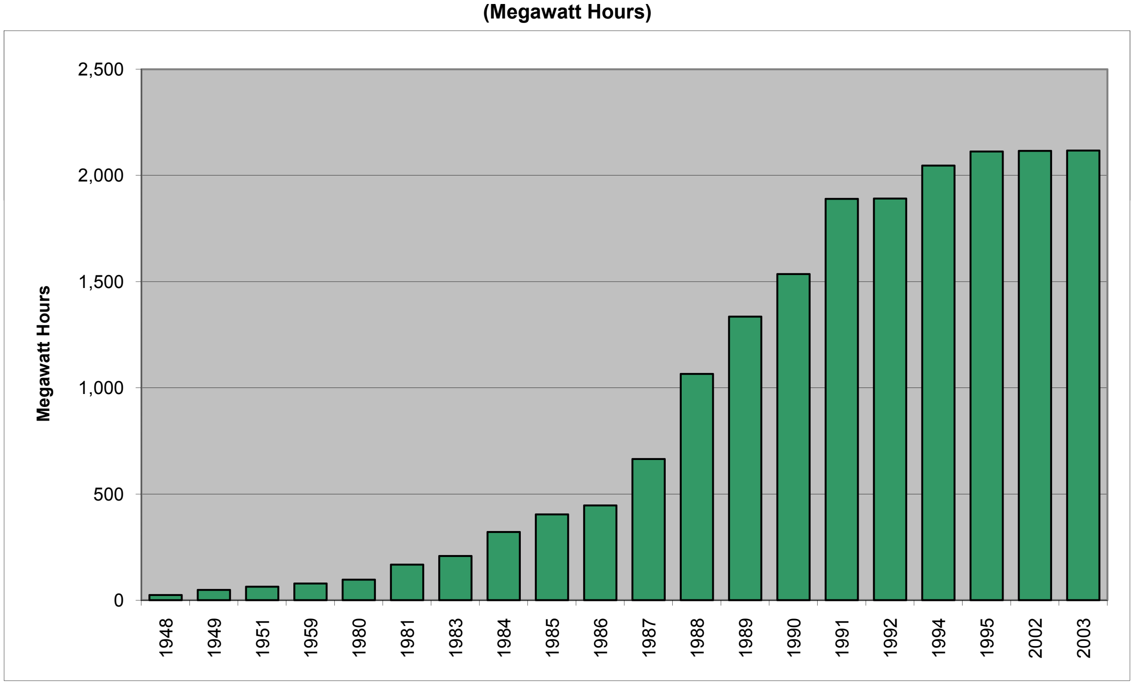
Source:
National Electric Energy System (NEEDS) Database for IPM 2006. This was the latest data available at time of publishing this report.
http://epa.gov/airmarkets/progsregs/epa-ipm/index.html

[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 2006. This was the latest data available at time of publishing this report.
http://epa.gov/airmarkets/progsregs/epa-ipm/index.html

Notes:
1. Only years in which new plants were brought online are shown.
2. Power plant capacity based on NEEDS 2006 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
Wilmarth	B	Minnesota	Blue Earth	12.00	18,268	No	1948
Wilmarth	B	Minnesota	Blue Earth	12.00	18,268	No	1948
Red Wing	B	Minnesota	Goodhue	12.00	16,876	No	1949
Red Wing	B	Minnesota	Goodhue	12.00	16,876	No	1949
Elk River	B	Minnesota	Sherburne	7.80	14,800	No	1951
Elk River	B	Minnesota	Sherburne	7.50	14,800	No	1951
Elk River	B	Minnesota	Sherburne	14.50	14,800	No	1959
American Ref-Fuel of Niagara	B	New York	Niagara	9.00	11,987	Yes	1980
American Ref-Fuel of Niagara	B	New York	Niagara	9.00	11,987	Yes	1980
Miami Dade County Resource Recovery	B	Florida	Miami-Dade	17.91	21,020	No	1981
Miami Dade County Resource Recovery	B	Florida	Miami-Dade	17.91	21,020	No	1981
Miami Dade County Resource Recovery	B	Florida	Miami-Dade	17.91	21,020	No	1981
Miami Dade County Resource Recovery	B	Florida	Miami-Dade	17.91	21,020	No	1981
Pinellas County Resource Recovery	B	Florida	Pinellas	20.55	16,170	Yes	1983
Pinellas County Resource Recovery	B	Florida	Pinellas	20.55	16,170	Yes	1983
Wheelabrator Baltimore Refuse	B	Maryland	Baltimore City	20.43	9,650	Yes	1984
Wheelabrator Baltimore Refuse	B	Maryland	Baltimore City	20.43	9,650	Yes	1984
Wheelabrator Baltimore Refuse	B	Maryland	Baltimore City	20.43	9,650	Yes	1984
Wheelabrator Westchester	B	New York	Westchester	17.00	17,567	No	1984
Wheelabrator Westchester	B	New York	Westchester	17.00	17,567	No	1984
Wheelabrator Westchester	B	New York	Westchester	17.00	17,567	No	1984
McKay Bay Facility	B	Florida	Hillsborough	4.50	21,020	No	1985
McKay Bay Facility	B	Florida	Hillsborough	4.50	21,020	No	1985
McKay Bay Facility	B	Florida	Hillsborough	4.50	21,020	No	1985
McKay Bay Facility	B	Florida	Hillsborough	4.50	21,020	No	1985
Wheelabrator North Andover	B	Massachusetts	Essex	16.50	19,214	No	1985
Wheelabrator North Andover	B	Massachusetts	Essex	16.50	19,214	No	1985
Wheelabrator Saugus	B	Massachusetts	Essex	16.00	18,019	No	1985
Wheelabrator Saugus	B	Massachusetts	Essex	16.00	18,019	No	1985
Commerce Refuse To Energy	B	California	Los Angeles	7.00	16,788	No	1986
Pinellas County Resource Recovery	B	Florida	Pinellas	17.00	16,170	Yes	1986
Southernmost Waste To Energy	G	Florida	Monroe	2.30	17,330	No	1986
Oswego County Energy Recovery	G	New York	Oswego	1.67	17,330	Yes	1986
Oswego County Energy Recovery	G	New York	Oswego	1.67	17,330	Yes	1986
Covanta Marion Inc.	B	Oregon	Marion	5.75	11,987	Yes	1986
Covanta Marion Inc.	B	Oregon	Marion	5.75	11,987	Yes	1986
Wasatch Energy Systems Energy	G	Utah	Davis	1.40	11,987	Yes	1986
Covanta Bristol Energy	B	Connecticut	Hartford	6.60	16,715	No	1987
Covanta Bristol Energy	B	Connecticut	Hartford	6.60	16,715	No	1987
Bay Resource Management Center	B	Florida	Bay	5.00	19,140	No	1987
Bay Resource Management Center	B	Florida	Bay	5.00	19,140	No	1987
Hillsborough County Resource Recovery	B	Florida	Hillsborough	8.67	20,245	No	1987
Hillsborough County Resource Recovery	B	Florida	Hillsborough	8.67	20,245	No	1987
Hillsborough County Resource Recovery	B	Florida	Hillsborough	8.67	20,245	No	1987
Maine Energy Recovery	B	Maine	York	9.00	15,226	No	1987
Maine Energy Recovery	B	Maine	York	9.00	15,226	No	1987
Penobscot Energy Recovery	B	Maine	Penobscot	10.60	17,330	No	1987
Penobscot Energy Recovery	B	Maine	Penobscot	10.60	17,330	No	1987
Wheelabrator Millbury Facility	B	Massachusetts	Worcester	20.00	15,079	No	1987
Wheelabrator Millbury Facility	B	Massachusetts	Worcester	20.00	15,079	No	1987
Olmsted Waste Energy	G	Minnesota	Olmsted	1.30	17,330	Yes	1987
Olmsted Waste Energy	G	Minnesota	Olmsted	1.40	17,330	Yes	1987
Wheelabrator Claremont Facility	G	New Hampshire	Sullivan	4.50	21,020	No	1987
Dutchess County Resource Recovery	B	New York	Dutchess	3.60	13,117	Yes	1987
Dutchess County Resource Recovery	B	New York	Dutchess	3.60	13,117	Yes	1987
Covanta Alexandria/Arlington Energy	B	Virginia	Alexandria	9.67	17,330	No	1987
Covanta Alexandria/Arlington Energy	B	Virginia	Alexandria	9.67	17,330	No	1987
Covanta Alexandria/Arlington Energy	B	Virginia	Alexandria	9.67	17,330	No	1987
SPSA Waste To Energy Power Plant	B	Virginia	Portsmouth	11.63	17,330	Yes	1987
SPSA Waste To Energy Power Plant	B	Virginia	Portsmouth	11.63	17,330	Yes	1987
SPSA Waste To Energy Power Plant	B	Virginia	Portsmouth	11.63	17,330	Yes	1987
SPSA Waste To Energy Power Plant	B	Virginia	Portsmouth	11.63	17,330	Yes	1987
Covanta Stanislaus Energy	B	California	Stanislaus	9.00	18,297	No	1988
Covanta Stanislaus Energy	B	California	Stanislaus	9.00	18,297	No	1988
Southeast Resource Recovery	B	California	Los Angeles	9.32	18,340	Yes	1988
Southeast Resource Recovery	B	California	Los Angeles	9.32	18,340	Yes	1988
Southeast Resource Recovery	B	California	Los Angeles	9.32	18,340	Yes	1988
Covanta Wallingford Energy	B	Connecticut	New Haven	2.80	21,020	No	1988
Covanta Wallingford Energy	B	Connecticut	New Haven	2.80	21,020	No	1988
Covanta Wallingford Energy	B	Connecticut	New Haven	2.80	21,020	No	1988
Wheelabrator Bridgeport	B	Connecticut	Fairfield	20.42	15,666	No	1988
Wheelabrator Bridgeport	B	Connecticut	Fairfield	20.42	15,666	No	1988
Wheelabrator Bridgeport	B	Connecticut	Fairfield	20.42	15,666	No	1988
Covanta Mid-Connecticut Energy	B	Connecticut	Hartford	37.60	19,402	No	1988
Covanta Mid-Connecticut Energy	B	Connecticut	Hartford	37.60	19,402	No	1988
Covanta Mid-Connecticut Energy	B	Connecticut	Hartford	37.60	17,330	No	1988
Regional Waste Systems	B	Maine	Cumberland	5.75	19,483	No	1988
Regional Waste Systems	B	Maine	Cumberland	5.75	19,483	No	1988
Pioneer Valley Resource Recovery	G	Massachusetts	Hampden	7.50	21,020	No	1988
SEMASS Resource Recovery	B	Massachusetts	Plymouth	26.67	17,961	No	1988
SEMASS Resource Recovery	B	Massachusetts	Plymouth	26.67	17,961	No	1988
SEMASS Resource Recovery	B	Massachusetts	Plymouth	26.67	17,961	No	1988
Greater Detroit Resource Recovery	B	Michigan	Wayne	21.20	17,330	Yes	1988
Greater Detroit Resource Recovery	B	Michigan	Wayne	21.20	17,330	Yes	1988
Greater Detroit Resource Recovery	B	Michigan	Wayne	21.20	17,330	Yes	1988
Covanta Warren Energy	B	New Jersey	Warren	5.00	18,843	No	1988
Covanta Warren Energy	B	New Jersey	Warren	5.00	18,843	No	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
North County Regional Resource	B	Florida	Palm Beach	21.75	17,862	No	1989
North County Regional Resource	B	Florida	Palm Beach	21.75	17,862	No	1989
Covanta Haverhill	B	Massachusetts	Essex	21.39	15,734	No	1989
Covanta Haverhill	B	Massachusetts	Essex	21.39	15,734	No	1989
Kent County Waste to Energy Facility	B	Michigan	Kent	7.85	9,650	Yes	1989
Kent County Waste to Energy Facility	B	Michigan	Kent	7.85	9,650	Yes	1989
Covanta Hennepin Energy	B	Minnesota	Hennepin	16.85	15,894	No	1989
Covanta Hennepin Energy	B	Minnesota	Hennepin	16.85	15,894	No	1989
Wheelabrator Concord Facility	B	New Hampshire	Merrimack	7.00	18,592	No	1989
Wheelabrator Concord Facility	B	New Hampshire	Merrimack	7.00	18,592	No	1989
American Ref-Fuel of Hempstead	B	New York	Nassau	22.57	16,566	No	1989
American Ref-Fuel of Hempstead	B	New York	Nassau	22.57	17,330	No	1989
American Ref-Fuel of Hempstead	B	New York	Nassau	22.57	17,330	No	1989
Covanta Babylon Energy	B	New York	Suffolk	7.18	21,020	No	1989
Covanta Babylon Energy	B	New York	Suffolk	7.18	21,020	No	1989
York County Resource Recovery	B	Pennsylvania	York	9.33	20,113	No	1989
York County Resource Recovery	B	Pennsylvania	York	9.33	20,113	No	1989
York County Resource Recovery	B	Pennsylvania	York	9.33	20,113	No	1989
Charleston Resource Recovery Facility	B	South Carolina	Charleston	4.75	17,330	Yes	1989
Charleston Resource Recovery Facility	B	South Carolina	Charleston	4.75	17,330	Yes	1989
Covanta Lake County Energy	B	Florida	Lake	6.25	20,026	No	1990
Covanta Lake County Energy	B	Florida	Lake	6.25	20,026	No	1990
American Ref-Fuel of Essex	B	New Jersey	Essex	10.00	11,500	No	1990
American Ref-Fuel of Essex	B	New Jersey	Essex	10.00	11,500	No	1990
American Ref-Fuel of Essex	B	New Jersey	Essex	40.00	11,500	No	1990
Wheelabrator Gloucester LP	B	New Jersey	Gloucester	6.00	19,829	No	1990
Wheelabrator Gloucester LP	B	New Jersey	Gloucester	6.00	19,829	No	1990
MacArthur Waste to Energy Facility	B	New York	Suffolk	2.30	21,020	No	1990
MacArthur Waste to Energy Facility	B	New York	Suffolk	2.30	17,330	No	1990
Lancaster County Resource Recovery	B	Pennsylvania	Lancaster	10.80	17,820	No	1990
Lancaster County Resource Recovery	B	Pennsylvania	Lancaster	10.80	17,820	No	1990
Lancaster County Resource Recovery	B	Pennsylvania	Lancaster	10.80	17,820	No	1990
Covanta Fairfax Energy	B	Virginia	Fairfax	19.75	17,055	No	1990
Covanta Fairfax Energy	B	Virginia	Fairfax	19.75	17,055	No	1990
Covanta Fairfax Energy	B	Virginia	Fairfax	19.75	17,055	No	1990
Covanta Fairfax Energy	B	Virginia	Fairfax	19.75	17,055	No	1990
American Ref-Fuel of SE CT	B	Connecticut	New London	6.00	18,528	No	1991
American Ref-Fuel of SE CT	B	Connecticut	New London	6.00	18,528	No	1991
Pasco Cnty Solid Waste Resource	B	Florida	Pasco	8.67	21,020	No	1991
Pasco Cnty Solid Waste Resource	B	Florida	Pasco	8.67	21,020	No	1991
Pasco Cnty Solid Waste Resource	B	Florida	Pasco	8.67	21,020	No	1991
Wheelabrator South Broward	B	Florida	Broward	19.30	17,997	No	1991
Wheelabrator South Broward	B	Florida	Broward	19.30	17,997	No	1991
Wheelabrator South Broward	B	Florida	Broward	19.30	17,997	No	1991
Wheelabrator North Broward	B	Florida	Broward	18.67	18,534	No	1991
Wheelabrator North Broward	B	Florida	Broward	18.67	18,534	No	1991
Wheelabrator North Broward	B	Florida	Broward	18.67	18,534	No	1991
Camden Resource Recovery Facility	B	New Jersey	Camden	10.00	20,835	No	1991
Camden Resource Recovery Facility	B	New Jersey	Camden	10.00	20,835	No	1991
Camden Resource Recovery Facility	B	New Jersey	Camden	10.00	20,835	No	1991
Wheelabrator Hudson Falls, LLC	B	New York	Washington	5.75	9,650	No	1991
Wheelabrator Hudson Falls, LLC	B	New York	Washington	5.75	9,650	No	1991
Huntington Resource Recovery Facility	B	New York	Suffolk	8.33	18,674	No	1991
Huntington Resource Recovery Facility	B	New York	Suffolk	8.33	18,674	No	1991
Huntington Resource Recovery Facility	B	New York	Suffolk	8.33	18,674	No	1991
New Hanover County WASTEC	B	North Carolina	New Hanover	0.57	9,650	Yes	1991
New Hanover County WASTEC	B	North Carolina	New Hanover	0.57	9,650	Yes	1991
New Hanover County WASTEC	B	North Carolina	New Hanover	0.57	9,650	Yes	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,675	No	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,675	No	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,675	No	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,675	No	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,675	No	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,675	No	1991
Montenay Montgomery LP	B	Pennsylvania	Montgomery	14.00	17,330	No	1991
Montenay Montgomery LP	B	Pennsylvania	Montgomery	14.00	17,330	No	1991
Wheelabrator Spokane	B	Washington	Spokane	13.00	18,657	No	1991
Wheelabrator Spokane	B	Washington	Spokane	13.00	18,657	No	1991
MMWAC Resource Recovery Facility	G	Maine	Androscoggin	2.10	17,330	No	1992
Lee County Solid Waste Energy	B	Florida	Lee	19.50	15,175	No	1994
Lee County Solid Waste Energy	B	Florida	Lee	19.50	15,175	No	1994
Union County Resource Recovery	B	New Jersey	Union	12.50	17,339	No	1994
Union County Resource Recovery	B	New Jersey	Union	12.50	17,339	No	1994
Union County Resource Recovery	B	New Jersey	Union	12.50	17,339	No	1994
Onondaga County Resource Recovery	B	New York	Onondaga	10.00	17,330	No	1994
Onondaga County Resource Recovery	B	New York	Onondaga	10.00	17,330	No	1994
Onondaga County Resource Recovery	B	New York	Onondaga	10.00	17,330	No	1994
Wheelabrator Falls	B	Pennsylvania	Bucks	24.05	15,195	No	1994
Wheelabrator Falls	B	Pennsylvania	Bucks	24.05	15,195	No	1994
Wheelabrator Lisbon	B	Connecticut	New London	6.50	16,839	No	1995
Wheelabrator Lisbon	B	Connecticut	New London	6.50	16,839	No	1995
Montgomery County Resource Recovery	B	Maryland	Montgomery	18.00	17,172	No	1995
Montgomery County Resource Recovery	B	Maryland	Montgomery	18.00	17,172	No	1995
Montgomery County Resource Recovery	B	Maryland	Montgomery	18.00	17,172	No	1995
New Hanover County WASTEC	G	North Carolina	New Hanover	1.90	9,650	Yes	2002
Perham Incinerator	G	Minnesota	Otter Tail	1.20	17,330	No	2003

Source:
National Electric Energy System (NEEDS) Database for IPM 2006. This was the latest data available at time of publishing this report.
http://epa.gov/airmarkets/progsregs/epa-ipm/index.html

Section: BIOPOWER

Total Net Generation of Electricity by State from Wood and Wood Waste, 2007

(Thousand Kilowatt hours)

State	Wood/Wood Waste[a]	Percent of all Renewables	Total from all Renewables
Alabama	3,783,882	47.68%	7,936,734
Alaska	22	0.00%	1,302,453
Arkansas	1,580,803	32.52%	4,860,497
California	3,407,416	6.53%	52,173,008
Connecticut	1676	0.15%	1,093,100
Florida	1,929,798	43.30%	4,457,264
Georgia	3,362,097	59.49%	5,651,610
Idaho	480,582	4.97%	9,674,539
Iowa	16	0.00%	3,870,121
Kentucky	370,210	17.35%	2,134,210
Louisiana	2,898,371	76.14%	3,806,525
Maine	3,847,566	48.43%	7,945,147
Maryland	203,097	9.00%	2,255,678
Massachusetts	119,157	5.85%	2,037,706
Michigan	1,692,202	45.90%	3,686,736
Minnesota	727,455	15.86%	4,586,460
Mississippi	1,488,348	99.66%	1,493,365
Missouri	120	0.01%	1,233,635
Montana	110,945	1.11%	9,971,057
New Hampshire	970,456	40.63%	2,388,501
New York	492,261	1.76%	28,027,639
North Carolina	1,585,374	34.05%	4,656,377
Ohio	399,378	47.23%	845,579
Oklahoma	276,133	5.32%	5,194,860
Oregon	842,565	2.35%	35,815,732
Pennsylvania	619,567	12.96%	4,782,178
South Carolina	1,895,432	53.36%	3,551,946
Tennessee	868,110	14.69%	5,910,127
Texas	914,164	7.66%	11,932,049
Vermont	453,038	40.81%	1,110,153
Virginia	1,792,326	47.00%	3,813,835
Washington	1,116,380	1.35%	82,559,749
Wisconsin	785,079	27.59%	2,845,600
Total 39,014,026		**12.06%**	**323,604,170**

Source:
Energy Information Administration, *Renewable Energy Annual 2008*, Table 1.17
http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea_sum.html

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

[a] Black liquor, and wood/woodwaste solids and liquids.

Section: BIOPOWER

Net Summer Capacity of Plants Cofiring Biomass and Coal by State and Plant Name, 2008 (Megawatts)

State	Company Name	Plant Name	County	Biomass/ Coal Cofiring Capacity	Total Plant Capacity
Alabama	DTE Energy Services	Mobile Energy Services LLC	Mobile	73	73
Alabama	Georgia-Pacific Corp	Georgia Pacific Naheola Mill	Choctaw	29	73
Alabama	International Paper Co	International Paper Prattville Mill	Autauga	43	78
Arkansas	Domtar Industries Inc	Ashdown	Little River	128	128
Arizona	Tucson Electric Power Co	H Wilson Sundt Generating Station	Pima	156	472
California	Air Products Energy Enterprise	Stockton Cogen	San Joaquin	54	54
Deleware	Conectiv Delmarva Gen Inc	Edge Moor	New Castle	260	718
Florida	International Paper Co-Pensacola	International Paper Pensacola	Escambia	76	76
Florida	Jefferson Smurfit Corp	Jefferson Smurfit Fernandina Beach	Nassau	50	80
Florida	Stone Container Corp-Panama City	Stone Container Panama City Mill	Bay	22	36
Georgia	Georgia Pacific CSO LLC	Georgia Pacific Cedar Springs	Early	90	90
Georgia	International Paper Co-Augusta	International Paper Augusta Mill	Richmond	79	79
Georgia	Riverwood Intl USA Inc	Riverwood International Macon Mill	Bibb	35	40
Georgia	SP Newsprint Company	Dublin Mill	Laurens	44	84
Georgia	SP Newsprint Company	SP Newsprint	Laurens	-	-
Hawaii	Hawaiian Com & Sugar Co Ltd	Hawaiian Comm & Sugar Puunene Mill	Maui	46	46
Iowa	Ames City of	Ames Electric Services Power Plant	Story	105	105
Iowa	University of Iowa	University of Iowa Main Power Plant	Johnson	21	23
Kentucky	East Kentucky Power Coop, Inc	H L Spurlock	Mason	268	1,103
Lousiana	International Paper Co	International Paper Louisiana Mill	Morehouse	63	63
Maryland	NewPage Corporation	Luke Mill	Allegany	60	60
Maine	NewPage Corporation	Rumford Cogeneration	Oxford	85	85
Maine	S D Warren Co.- Westbrook	S D Warren Westbrook	Cumberland	56	65
Maine	Verso Bucksport LLC	Verso Paper	Hancock	93	250
Michigan	Decorative Panels International, Inc.	Decorative Panels Intl	Alpena	7	7
Michigan	NewPage Corporation	Escanaba Paper Company	Delta	77	100
Michigan	S D Warren Co	S D Warren Muskegon	Muskegon	37	37
Michigan	TES Filer City Station LP	TES Filer City Station	Manistee	60	60
Minnesota	Willmar Municipal Utilities	Willmar	Kandiyohi	16	23
Minnesota	Minnesota Power Inc	Rapids Energy Center	Itasca	29	29
Minnesota	Minnesota Power Inc	M L Hibbard	St Louis	59	59
Missouri	Anheuser-Busch Inc	Anheuser Busch St Louis	St Louis City	26	26
Missouri	University of Missouri-Columbia	University of Missouri Columbia	Boone	18	77
Mississippi	Weyerhaeuser Co	Weyerhaeuser Columbus MS	Lowndes	123	123
North Carolina	Carlyle/Riverstone Renewable Energy	Coastal Carolina Clean Power	Duplin	27	27
North Carolina	Corn Products Intl Inc	Corn Products Winston Salem	Forsyth	7	7
North Carolina	Domtar Paper Company LLC	Domtar Paper Co LLC Plymouth NC	Martin	146	146
North Carolina	Primary Energy of North Carolina LLC	Primary Energy Roxboro	Person	56	56
New York	AES Greenidge	AES Greenidge LLC	Yates	104	156
New York	AES Hickling LLC	AES Hickling LLC	Steuben	-	-
New York	AES Jennison LLC	AES Jennison LLC	Chenango	-	-
New York	Black River Generation LLC	Black River Generation	Jefferson	55	55
New York	Niagara Generation LLC	WPS Power Niagara	Niagara	50	50
Pennsylvania	Domtar LLC	Johnsonburg Mill	Elk	49	49
Pennsylvania	P H Glatfelter Co	P H Glatfelter	York	-	-
South Carolina	International Paper Co-Eastover	International Paper Eastover Facility	Richland	46	103
South Carolina	Smurfit-Stone Container Enterprises Inc	Stone Container Florence Mill	Florence	75	103
South Carolina	South Carolina Electric&Gas Co	Cogen South	Charleston	90	90
Virginia	GP Big Island LLC	Georgia Pacific Big Island	Bedford	7	7
Virginia	International Paper	International Paper Franklin Mill	Isle of Wight	89	108
Virginia	MeadWestvaco Corp	Covington Facility	Covington	102	102
Virginia	Smurfit-Stone Container Enterprises Inc	Stone Container Hopewell Mill	Hopewell City	41	41
Wisconsin	Flambeau River Papers	Flambeau River Papers	Price	5	5
Wisconsin	Fox Valley Energy Center LLC	Fox Valley Energy Center	Winnebago	7	7
Wisconsin	Madison Gas & Electric Co	Blount Street	Dane	97	187
Wisconsin	Manitowoc Public Utilities	Manitowoc	Manitowoc	116	126
Wisconsin	Mosinee Paper Corp	Mosinee Paper	Marathon	-	-
Wisconsin	NewPage Corporation	Biron Mill	Wood	22	62
Wisconsin	NewPage Corporation	Whiting Mill	Portage	4	4
Wisconsin	NewPage Corporation	Wisconsin Rapids Pulp Mill	Wood	67	67
Wisconsin	NewPage Corporation	Niagara Mill	Marinette	12	25
Wisconsin	Northern States Power Co	Bay Front	Ashland	44	73
Wisconsin	State of Wisconsin	Waupun Correctional Central Heating Plant	Dodge	1	1
Wisconsin	State of Wisconsin	Univ of Wisc Madison Charter Sreet Plant	Dane	6	6
Wisconsin	Thilmany LLC	International Paper Kaukauna Mill	Outagamie	45	45
Wisconsin	Wausau Paper Specialty Products LLC	Mosinee Paper	Marathon	18	21
Total				**3,772**	**6,147**

Source: U.S. Energy Information Administration, Renewable Energy Trends in Consumption and Electricity, 2008 Edition, Table 1.9
http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends.html

Note:
- = No data reported.

Section: BIOPOWER
Coal Displacement Calculation, 2009

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)	31,663,210	2,440,946	7,024,987	77,194,856	1,378,947	608,393
(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)	99,853,099,056	19,244,418,264	49,231,108,896	298,849,328,414	2,717,904,537	1,300,403,534
(E) Conversion Efficiency (Btu/kWh)	9,854	9,854	9,854	9,854	9,854	9,854
(F) Total Output (Million Btu)	983,952,438	189,634,498	485,123,347	2,944,861,282	26,782,231	12,814,176
(G) Coal Heat Rate (Btu per short ton)	20,213,000	20,213,000	20,213,000	20,213,000	20,213,000	20,213,000
(H) Coal (short tons)	48,679,189	9,381,809	24,000,561	145,691,450	1,325,000	633,957

Sources: Capacity, EIA, Annual Energy Outlook 2010, DOE/EIA-0383 (2010) Washington, D.C., May 11, 2010, Table A.16, Reference Case.
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 2010, DOE/EIA-0383 (2010), Washington, D.C., May 11, 2010, Table G1, Fossil-Fueled Steam-Electric Plants heat rate.

Renewable Energy Impacts Calculation, 2009

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)	31,663,210	2,440,946	7,024,987	77,194,856	1,378,947	608,393
(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)	99,853,099,056	19,244,418,264	49,231,108,896	298,849,328,414	2,717,904,537	1,300,403,534
(E) Competing Heat Rate (Btu/kWh)	9,854	9,854	9,854	9,854	9,854	9,854
(F) Annual Output (Trillion Btu)	984.0	189.6	485.1	2,944.9	26.8	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)	17.544	3.172	8.328	54.635	0.100	0.128

Sources: Capacity, EIA, Annual Energy Outlook 2010, DOE/EIA-0383 (2010) Washington, D.C., May 11, 2010, Table A.16, Reference Case
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, 2009

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)	31,663,210	2,440,946	7,024,987	77,194,856	1,378,947	608,393
(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)	99,853,099,056	19,244,418,264	49,231,108,896	298,849,328,414	2,717,904,537	1,300,403,534
(E) Average Annual Household Electricity Consumption (kWh)	12,081	12,081	12,081	12,081	12,081	12,081
(F) Number of Households	8,265,459	1,592,980	4,075,164	24,737,610	224,978	107,642

Sources:
Capacity, EIA, Annual Energy Outlook 2010, DOE/EIA-0383 (2010) Washington, D.C., May 11, 2010, Reference Case Table A.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 2010, DOE/EIA-0383 (2010) Washington, D.C., May 11, 2010, Reference Case Table 4.

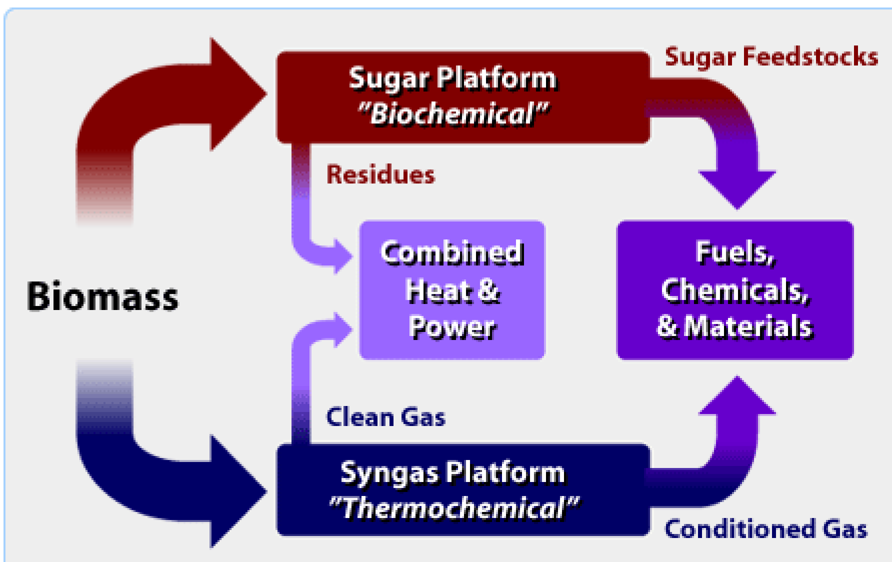
BIOREFINERIES

Contents	Data Type
Brief Overview	**Text**
Lignocellulosic Biorefineries by Scale and Stage of Development	Table
Lignocellulosic Biorefineries by State	Table
Major DOE Biofuels Project Locations	*Figure-Map*
Fuels, Tecnololgies and Feedstocks in Planned Biorefineries as of 2008	Table
Federal and State Investments in Lignocellulosic Biorefineries as of 2008	Table
State and Private Investment in Biorefineries for Biofuels and Bioproducts	Table
Recently Completed U.S. Department of Energy Biorefinery Projects	Table

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 November 2010, the Renewable Fuels Association listed 204 operating ethanol biorefineries with a total production capacity of 13,771 million gallon per year (MGY). New construction and expansion would add another 840 MGY. Distillers grains, a high-value, protein rich product being used for livestock feed is the major co-product of the existing dry-mill 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. History was made in 2007 with the ground breaking for construction of the first commercial-scale lignocellulosic ethanol biorefinery in the U.S. The Range Fuels facility near Soperton, Georgia will use initially use wood residues from timber harvesting to produce ethanol and other products. 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. Three pulp production facilities were included among the 9 awarded funding in 2008 for building small-scale prototype biorefineries to test new ideas.

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. Several other biorefinery platforms are included among the medium and small-scale projects being cost-shared by the U.S. Department of Energy, state funding, and private investment.



Source: National Renewable Energy Laboratory, Biomass Program, September 2009.
http://www.nrel.gov/biomass/biorefinery.html

As of July 2008, there were 55 cellulosic biorefineries either completed, under construction or in the planning stage in a total of 31 states across the country. Altogether they create an expected capacity of 629 million gallons per year (MGY) and a potential expansion to 995 MGY. Most of the demonstration and commercial scale facilities are scheduled to start operation in 2009 or 2010.

Section: BIOREFINERIES
Lignocellulosic Biorefineries by Scale and Stage of Development

	Commercial Scale[a]	Demonstration Scale[b]	Pilot Scale[c]
Completed	-	2	3
Under Construction	1	3	5
Planning Status	21	14	6
Total	**22**	**19**	**14**

Lignocellulosic Biorefineries by State

Alabama (2)	Indiana (2)	Minnesota (1)	Pennsylvania (3)
Arkansas (1)	Iowa (1)	Missouri (1)	South Carolina (1)
California (2)	Kansas (1)	Montana (1)	South Dakota (1)
Colorado (3)	Kentucky (1)	Nebraska (1)	Tennessee (2)
Connecticut (1)	Louisiana (2)	Nevada (1)	Washington (1)
Florida (6)	Maine (1)	New York (3)	Wisconsin (3)
Georgia (1)	Maryland (1)	North Carolina (2)	Wyoming (1)
Hawaii (1)	Michigan (1)	Oregon (2)	

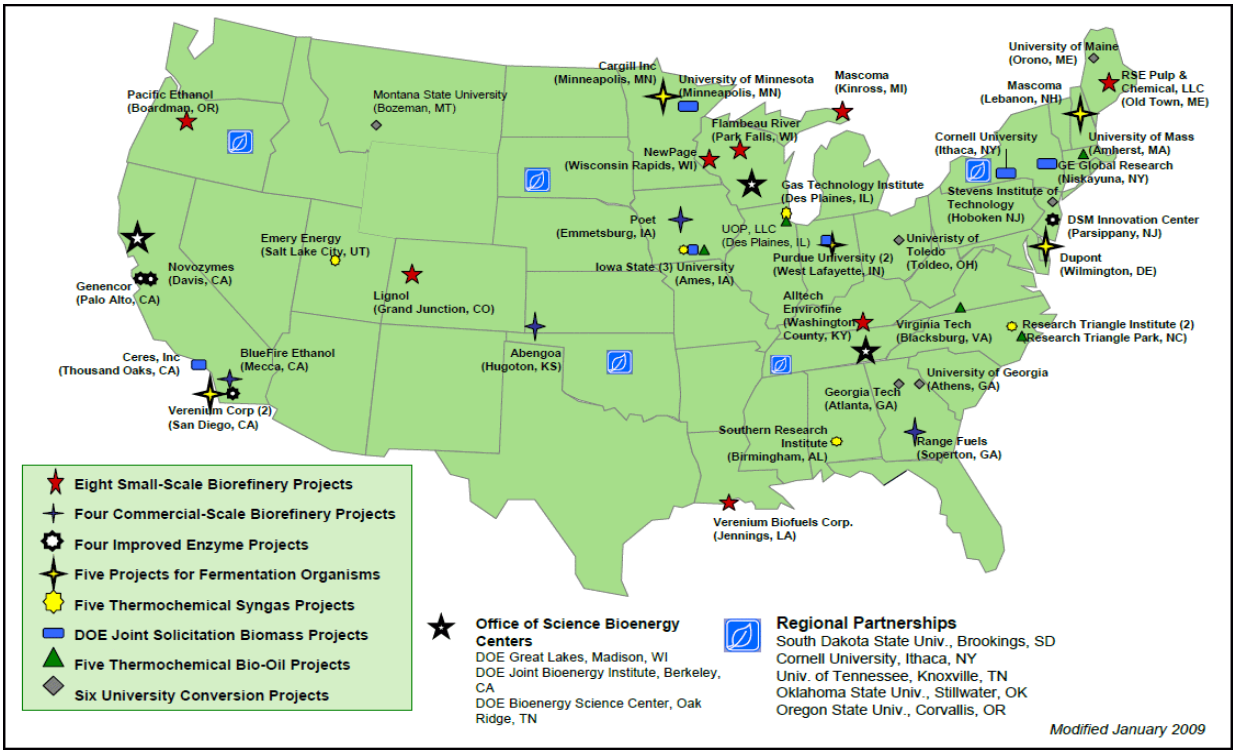
Source:

The information for these two tables is wholly 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). The EESI Fact Sheet provides many references for information summarized above.

Note: Four facilities have not disclosed their location.

[a] Commercial scale: uses at least 700 tons of feedstock per day to produce 10-20 MGY of biofuel.
[b] Demonstration scale: uses approximately 70 tons of feedstock per day, yielding at least 1 MGY.
[c] Pilot scale facilities are generally smaller and are used to develop new methods and technologies.

Section: BIOREFINERIES
Major DOE Biorefinery Project Locations



Source:
U.S. Department of Energy, Energy Efficiency and Renewable Energy, Biomass Program, January 2009
http://www1.eere.energy.gov/biomass/pdfs/biofuels_project_locations.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

Federal and State Investments in Lignocellulosic Biorefineries as of 2008

The following companies were awarded DOE contracts in February 2007 totaling $385 million in federal investment over four years. All projects are cost-shared by the private industry partner and other investors and some projects also receive state support.

Company Name	Location	Size MGY*	Products	Feedstocks
Range Fuels[a]	Soperton, GA	40.0	Ethanol, methanol	Wood residues and crops
BlueFire Ethanol, Inc	Corona, CA	19.0	Ethanol	green & wood wastes diverted from landfills
Abengoa Bioenergy	Hugoton, KS	11.4	Ethanol & power	Ag residues & switchgrass
Poet, LLC[a]	Emmitsburg, IA	125.0	Ethanol; 25% cellulosic	Corn fiber, cobs, stalks

The following companies were awarded DOE contracts in January, April, and July 2008 for small scale biorefinery projects totaling $240 in Federal investment over four years.

Company Name	Location	Size MGY*	Products	Feedstocks
ICM Incorporated	St. Joseph, MO	1.5	Ethanol & other	Corn fiber & stover switchgrass, sorghum
Ecofin, LLC	Nicholasville, KY	1.0	Ethanol & other	Corn cobs
Mascoma Corp.[b]	Vonore, TN	2.0	Ethanol & other	Corn cobs & switchgrass
Pacific Ethanol	Boardman, OR	2.7	Ethanol & other	Wood & crop residues
Verenium Corp[c]	Jennings, LA	1.5	Ethanol & other	Ag & wood residues & energy crops
Lignol Innovations, Inc	Commerce City, CO	2.0	Ethanol, lignin, furfural	Wood residues
New Page (formerly Stora Enso, N America)	Wisconsin Rapids, WI	5.5	Fischer-Tropsch liquids	Mill and forest residues
RSE Pulp & Chemical, LLC	Old Town, ME	2.2	Ethanol & other	Hemicelluloses extract from wood
Flambeau River Biofuels, LLC	Park Falls, WI	6.0	Fischer-Tropsch liquids, heat	Mill and forest residues

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 more detail from the DOE Biomass Program website.

Notes:

MGY = Million gallons per year.

[a] Listed on www.ethanolrfa.org website as under construction.

[b] Dupont Danisco Cellulosic Ethanol, LLC has replaced Mascoma Corporation as the technology partner on the Vonore, TN project.

[c] Listed on www.ethanolrfa.org website as operational.

State and Private Investment in Biorefineries for Biofuels and Bioproducts

The following companies are currently planning demonstration or commercial facilities and have received significant state grants or other substantial private financial investments.

Company Name	Location & status	Size	Products	Feedstocks
AE Biofuels[a]	Butte, MT (operating)	Very small	Ethanol	Grasses, Ag residues, sugar sources
Citrus Energy, LLC (2007 grant)	Clewiston, FL (planning)	4 million gallons per year	Ethanol	Citrus peels
Mascoma Corp[b]	Vonore, TN	2 million gallons per year	Ethanol & other	Corn cobs & switchgrass
Liberty Industries (2008 grant)	Hosford, FL (planning)	7 million gallons per year + 5.4 Mega Watts	Ethanol, electricity	Forest residues, mill wastes, ag residues & other
KL Process Design Group[c]	Upton, WY (operating)	1.5 million gallons per year	Ethanol , protein, syrup, lignin	Forest residues (mostly pine)
SunOpta, Inc	Little Fall, MN (planning)	10 million gallons per year + 50 Mega Watts (in future)	Ethanol, electricity	Wood chips
Coskata	Madison, PA (testing)	Lab demonstration	Ethanol	Municipal Waste
Catalyst Renewables Corp	Lyonsdale, NY (operating)	19 Mega Watts	Electricity	Forest Resources
Gulf Coast Energy (2008 grant)	Mossy Head, FL (planning)	Not Available	Ethanol , methanol, Biodiesel	Wood residues, chicken fat & soybean oil
Southeast Biofuels, LLC (2008 – grant)	Auburndale, FL (planning)	Small demo 8 (future goal)	Ethanol	Citrus peels
Florida Crystals Corp/U. of Florida (2007 grant)	Okeelanta, FL (planning)	1 to 2 million gallons per year	Ethanol	Sugarcane bagasse
ZeaChem, Inc	Boardman, OR (planning)	1.5 million gallons per year	Ethanol & chemicals	Tree crop residues
Poet, LLC	Scotland, SD	9 million gallons per year	Ethanol	Corn cobs

Source:

The list of state and private supported biorefinery projects was 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 more detail derived from examining state and company websites.

[a] AE Biofuels demonstration facility opened Aug 11, 2008.

[b] Dupont Danisco Cellulosic Ethanol, LLC has replaced Mascoma Corporation as the technology partner on the Vonore, TN project. This project received both substantial and state and Federal support.

[c] The KL Process Design Group began operaton using wood waste in January 2008.

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™ 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, December 2010, 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

Total Municipal Solid Waste Wood Residues	*Figure-Map*
Landfill Gas	
Landfill Gas Projects and Candidate Landfills by State, October 2010	Table
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, 1996-2008

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[b]	4,234	3,767	63.6	239,498	5.15	1,208,173

Source: U.S. Department of Agriculture, *2009 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, 2006-2008

	Area planted[a]			Area harvested			Yield per harvested acre			Production		
	2006	**2007**	**2008[b]**	**2006**	**2007**	**2008[b]**	**2006**	**2007**	**2008[b]**	**2006**	**2007**	**2008[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	25	33	42	22	31	40	115	110	120	2,530	3,410	4800
California	90	85	90	65	40	55	55	64	55	3,575	2,560	3025
Colorado 47		60	80	42	58	72	115	120	120	4,830	6,960	8640
Delaware	27	21	25	24	19	22	80	78	80	1,920	1,482	1760
Idaho	530	570	600	510	550	580	84	78	86	42,840	42,900	49880
Kansas	24	20	17	18	13	10	27	52	37	486	676	370
Kentucky	15	10	8	14	3	7	88	37	88	1,232	111	616
Maine	18	18	20	17	17	19	50	65	55	850	1105	1045
Maryland	50	45	45	32	30	35	87	82	90	2,784	2,460	3150
Michigan	15	14	12	14	13	10	49	51	46	686	663	460
Minnesota	105	130	130	90	110	110	60	54	65	5,400	5,940	7,150
Montana	770	900	860	620	720	740	50	44	51	31,000	31,680	37,740
Nevada	4	3	3	2	1	1	100	90	100	200	90	100
New Jersey	3	3	3	2	2	2	57	68	71	114	136	142
New York	17	13	13	12	11	9	55	49	52	660	539	468
North Carolina	24	22	21	17	14	14	80	49	71	1,360	686	994
North Dakota	1,100	1,470	1650	995	1,390	1,540	49	56	56	48,755	77,840	86,240
Ohio	5	4	6	4	3	5	68	53	72	272	159	360
Oregon	55	63	60	42	53	45	58	53	50	2,436	2,809	2,250
Pennsylvania	55	55	60	46	42	55	81	73	75	3,726	3,066	4,125
South Dakota	55	56	63	14	29	43	40	40	41	560	1,160	1,763
Utah	40	38	40	30	22	27	76	81	85	2,280	1,782	2,295
Virginia	58	48	63	42	30	36	77	71	85	3,234	2,130	3,060
Washington	200	235	190	190	225	185	63	62	57	11,970	13,950	10,545
Wisconsin	50	40	43	30	23	30	54	57	54	1,620	1,311	1,620
Wyoming	70	62	90	57	53	75	85	85	92	4,845	4,505	6,900
US	**3,452**	**4,018**	**4234**	**2,951**	**3,502**	**3,767**	**61.1**	**60**	**63.6**	**180,165**	**210,110**	**239,498**

Source:
U.S. Department of Agriculture, *2009 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

Section: FEEDSTOCKS

Barley Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2008-2009[a]
(dollars per planted acre)

Item	United States		Northern Great Plains		Basin and Range		Fruitful Rim		Northern Crescent		Heartland	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Gross value of production												
Primary product: Barley grain	289.19	294.58	262.58	255.00	265.53	270.92	380.87	440.08	295.36	265.21	230.46	206.58
Secondary product: Barley silage, straw, grazing	13.51	11.94	6.45	5.59	13.34	11.56	19.08	16.53	87.27	75.62	21.43	18.57
Total, gross value of production	**302.70**	**306.52**	**269.03**	**260.59**	**278.87**	**282.48**	**399.95**	**456.61**	**382.63**	**340.83**	**251.89**	**225.15**
Operating costs:												
Seed	14.44	14.09	12.02	11.64	15.82	15.32	18.99	18.38	19.07	18.47	15.81	15.31
Fertilizer [b]	55.24	60.13	44.60	48.02	67.04	72.18	74.37	80.08	59.96	64.56	53.63	57.75
Chemicals	13.83	15.06	13.55	14.77	13.61	14.85	17.36	18.93	3.20	3.49	5.59	6.10
Custom operations[c]	9.24	9.36	7.06	7.11	8.26	8.32	13.70	13.79	18.37	18.50	15.03	15.14
Fuel, lube, and electricity	29.27	19.58	19.07	12.64	28.36	18.79	59.14	39.20	25.11	16.64	18.87	12.51
Repairs	18.04	18.41	16.87	17.20	18.31	18.67	22.72	23.16	11.53	11.75	11.42	11.64
Purchased irrigation water	2.69	3.07	0.81	0.90	4.17	4.60	6.89	7.60	2.44	2.69	0.67	0.74
Interest on operating inputs	1.19	0.20	0.95	0.16	1.29	0.22	1.77	0.29	1.16	0.20	1.00	0.17
Total, operating costs	**143.94**	**139.90**	**114.93**	**112.44**	**156.86**	**152.95**	**214.94**	**201.43**	**140.84**	**136.30**	**122.02**	**119.36**
Allocated overhead:												
Hired labor	3.94	4.06	2.30	2.35	3.24	3.31	9.28	9.48	2.53	2.58	2.52	2.57
Opportunity cost of unpaid labor	25.52	26.41	20.77	21.23	32.46	33.17	31.44	32.12	34.93	35.70	26.05	26.62
Capital recovery of machinery and equipment	90.14	96.17	87.97	93.87	90.37	96.42	104.11	111.09	59.28	63.25	58.52	62.44
Opportunity cost of land (rental rate)	66.16	76.55	43.43	49.39	85.13	96.79	113.04	128.53	64.53	73.37	70.42	80.08
Taxes and insurance	10.78	12.08	11.13	12.49	10.73	12.05	11.03	12.38	6.15	6.90	7.13	8.01
General farm overhead	10.26	10.47	9.60	9.78	10.14	10.34	12.41	12.66	9.55	9.73	8.67	8.84
Total, allocated overhead	**206.80**	**225.74**	**175.20**	**189.11**	**232.07**	**252.08**	**281.31**	**306.26**	**176.97**	**191.53**	**173.31**	**188.56**
Total, costs listed	**350.74**	**365.64**	**290.13**	**301.55**	**388.93**	**405.03**	**496.25**	**507.69**	**317.81**	**327.83**	**295.33**	**307.92**
Value of production less total costs listed	-48.04	-59.12	-21.10	-40.96	-110.06	-122.55	-96.30	-51.08	64.82	13.00	-43.44	-82.77
Value of production less operating costs	158.76	166.62	154.10	148.15	122.01	129.53	185.01	255.18	241.79	204.53	129.87	105.79
Supporting information:												
Yield (bushels per planted acre)	55.40	62.41	50.40	60.00	48.90	52.10	74.10	81.80	57.80	51.10	45.10	39.20
Price (dollars per bushel at harvest)	5.22	4.72	5.21	4.25	5.43	5.20	5.14	5.38	5.11	5.19	5.11	5.27
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	[c]	[c]	66	66
Spring barley (percent of acres)	97	97	100	100	99	99	91	91	52	52	100	100
Winter barley (percent of acres)	[c]	[c]	0	0	[c]	[c]	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	[c]	[c]	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.

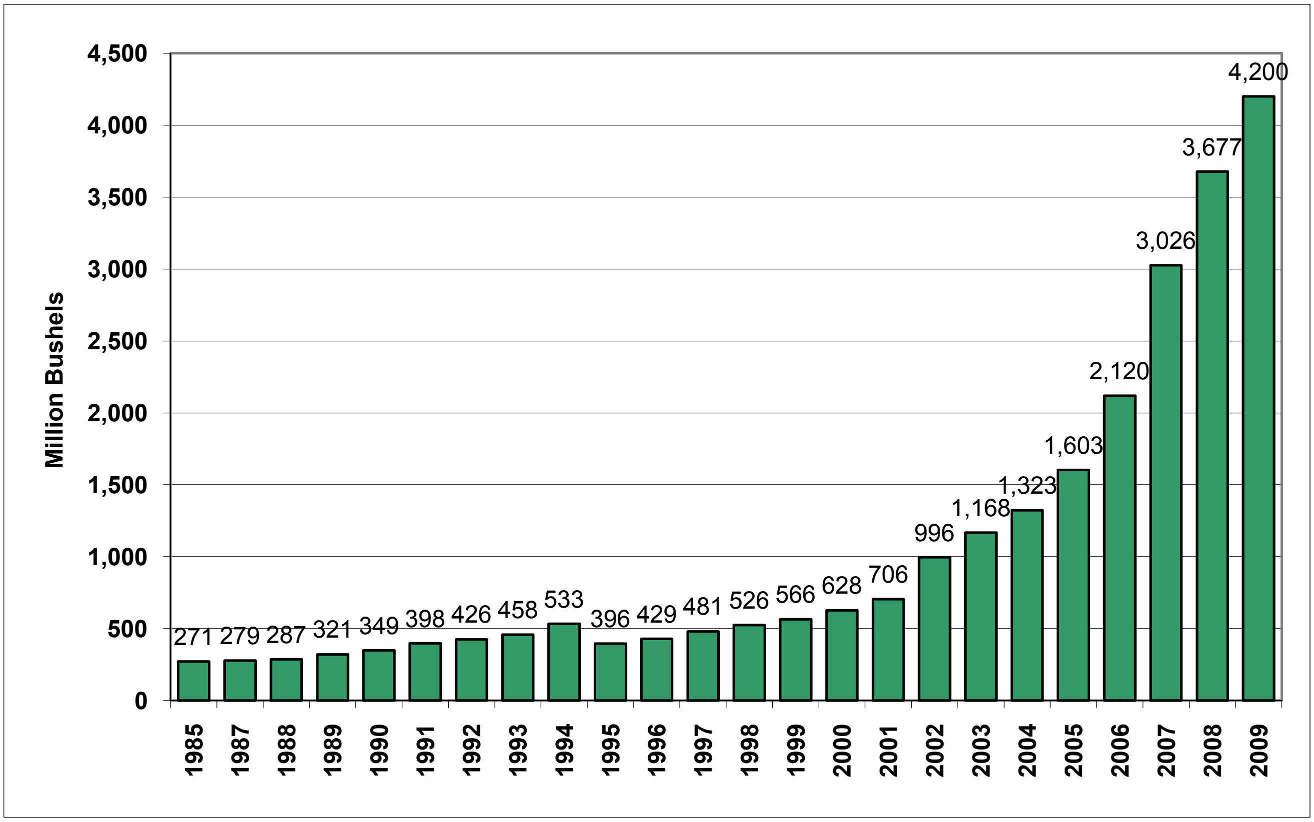
Section: FEEDSTOCKS
Corn Baseline Projections, 2008 - 2019

Item	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/2019	2019/2020
Area (million acres):												
Planted acres	86.0	86.4	88.0	90.0	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.0
Harvested acres	78.6	79.3	80.8	82.8	82.3	82.3	82.3	82.3	82.3	82.3	82.3	81.8
Yields (bushels per acre):												
Yield/harvested acre	153.9	162.9	160.4	162.4	164.4	166.4	168.4	170.4	172.4	174.4	176.4	178.4
Supply and use (million bushels):												
Beginning stocks	1,624	1,674	1,625	1,480	1,610	1,590	1,550	1,520	1,470	1,450	1,460	1,505
Production	12,101	12,921	12,960	13,445	13,530	13,695	13,860	14,025	14,190	14,355	14,520	14,595
Imports	14	10	15	15	15	15	15	15	15	15	15	15
Supply	13,739	14,605	14,600	14,940	15,155	15,300	15,425	15,560	15,675	15,820	15,995	16,115
Feed & residual	5,254	5,400	5,275	5,275	5,300	5,325	5,400	5,500	5,575	5,650	5,725	5,800
Food, seed, & industrial	4,953	5,480	5,695	5,855	6,015	6,150	6,205	6,265	6,300	6,335	6,365	6,400
Ethanol for fuel	3,677	4,200	4,400	4,550	4,700	4,825	4,875	4,925	4,950	4,975	5,000	5,025
Domestic	10,207	10,880	10,970	11,130	11,315	11,475	11,605	11,765	11,875	11,985	12,090	12,200
Exports	1,858	2,100	2,150	2,200	2,250	2,275	2,300	2,325	2,350	2,375	2,400	2,425
Total use	12,065	12,980	13,120	13,330	13,565	13,750	13,905	14,090	14,225	14,360	14,490	14,625
Ending stocks	1,674	1,625	1,480	1,610	1,590	1,550	1,520	1,470	1,450	1,460	1,505	1,490
Stocks/use ratio, percent	13.9	12.5	11.3	12.1	11.7	11.3	10.9	10.4	10.2	10.2	10.4	10.2
Prices (dollars per bushel):												
Farm price	4.06	3.55	3.90	3.75	3.70	3.70	3.70	3.70	3.70	3.70	3.65	3.65
Loan rate	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
Variable costs of production (dollars):												
Per acre	295.89	255.22	253.51	265.60	272.16	277.73	283.26	289.45	295.42	301.13	306.85	312.58
Per bushel	1.92	1.57	1.58	1.64	1.66	1.67	1.68	1.70	1.71	1.73	1.74	1.75
Returns over variable costs (dollars per acre):												
Net returns	328.94	323.07	372.05	343.40	336.12	337.95	339.82	341.03	342.46	344.15	337.01	338.58

Source:
USDA Long-Term Agricultural, Projection Tables to 2019 , February 2010, Table 18 - 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 six fold from 2001 to 2009.

Section: FEEDSTOCKS
Corn Used for Ethanol Production, 1985-2009

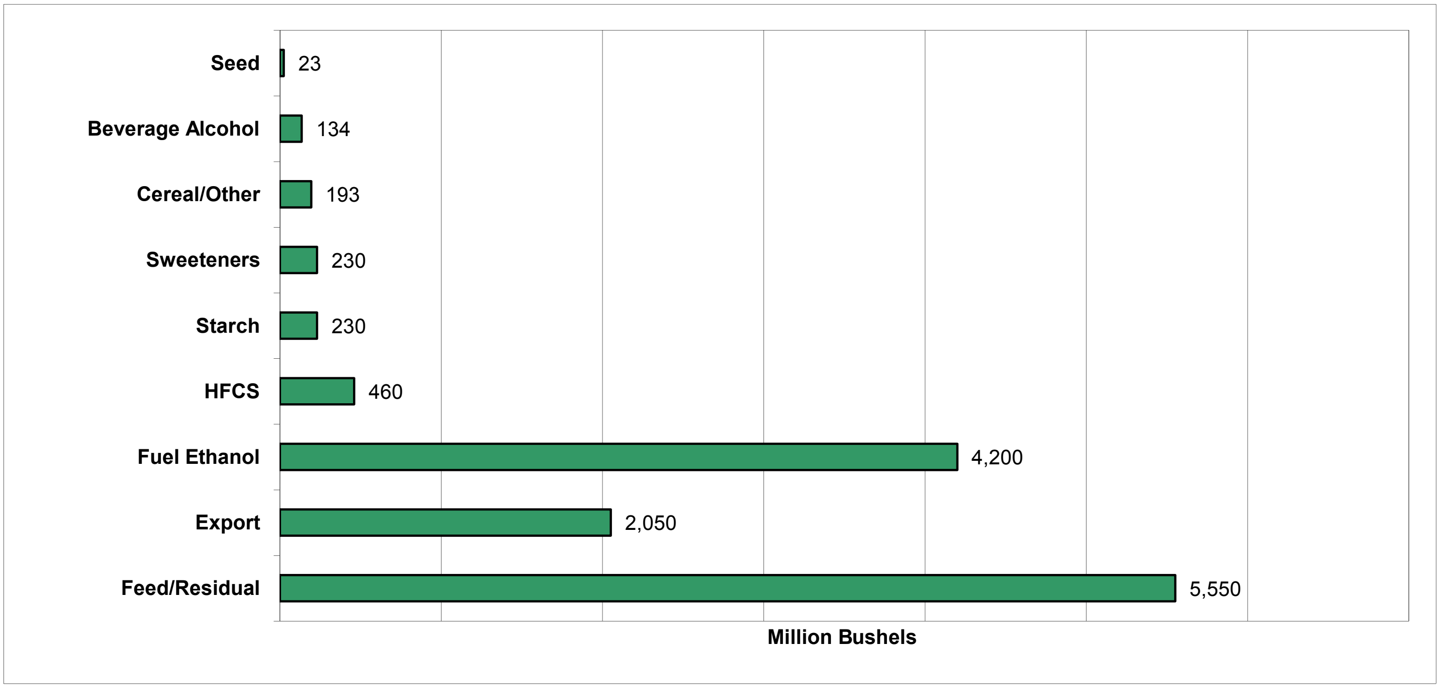


Source: National Corn Growers Association, *The World of Corn,* 2010 and previous annual editions, http://www.ncga.com

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

In 2009, ethanol production accounted for about 32 percent of the overall corn consumption and more than double the amount used for export.

Section: FEEDSTOCKS
Corn Usage by Segment, 2009

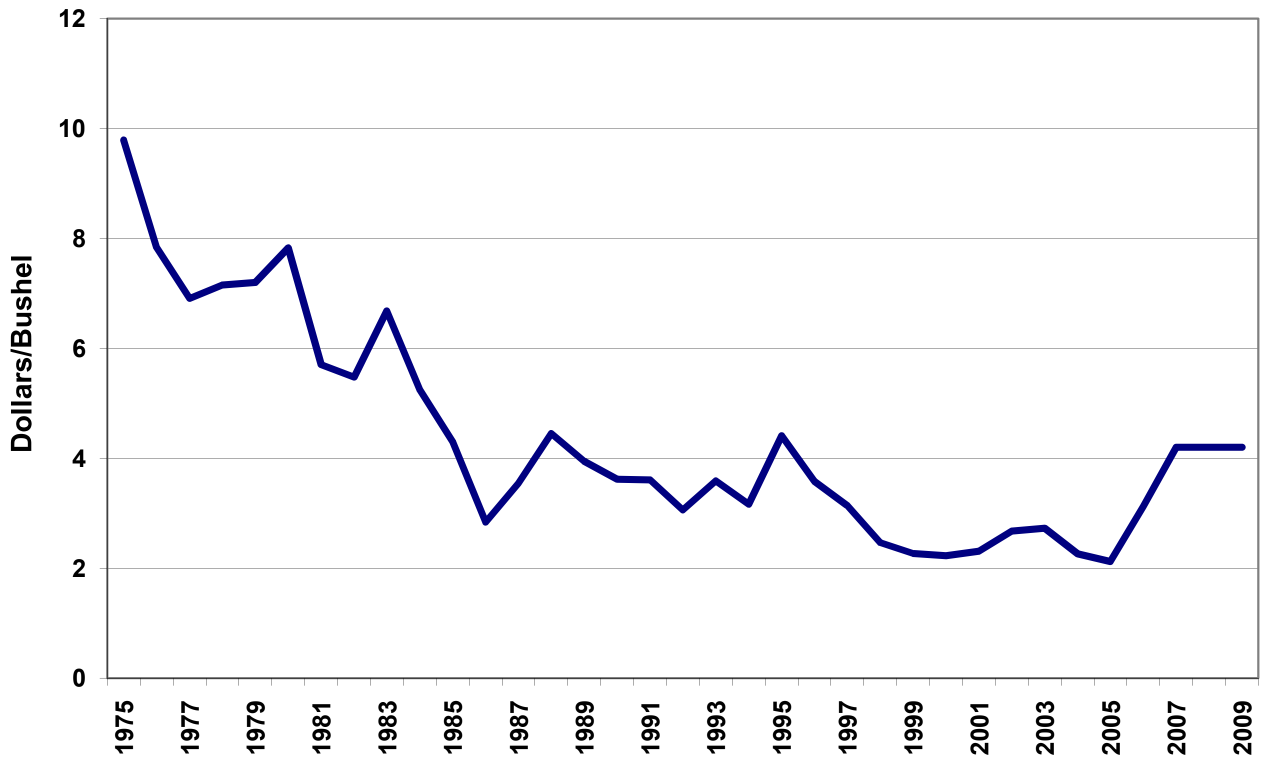


Source: National Corn Growers Association, *The World of Corn,* 2010
http://www.ncga.com/

Note: Marketing year ending August 31, 2010.

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, 1975-2009
(constant 2009 dollars)



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 2007 it rose to about 25%. Largely due to this increased demand for ethanol, the acres of corn planted rose sharply in 2007 to 93 million acres over an average of about 80 million acres in previous 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. The year 2004 provided an unusually favorable climate for high corn yields over much of the corn belt.

Section: FEEDSTOCKS
Corn: Area, Yield, Production, and Value, 1996-2008

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	78,640	153.9	12,101,238	3.90	47,377,576	5,965	18.7	111,619

Source: U.S. Department of Agriculture, *2009 Agricultural Statistics*, Table 1-35 and previous annual editions.
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

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, 2005-2008

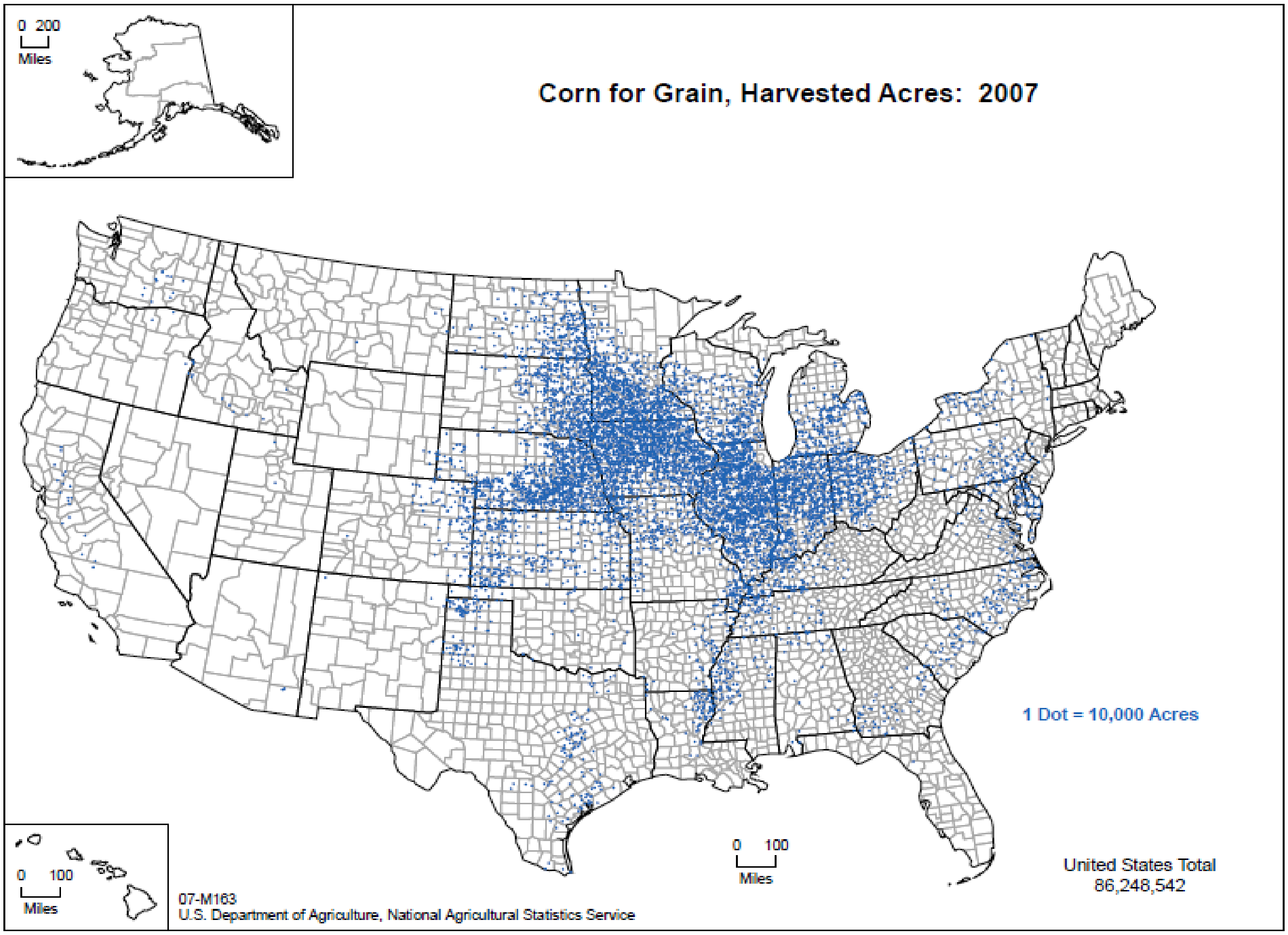
State	Area planted for all purposes			Corn for grain								
				Area harvested			Yield per harvested acre			Production		
	2006	2007	2008[a]	2006	2007	2008[a]	2006	2007	2008[a]	2006	2007	2008[a]
	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	Bushels	Bushels	Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels
Alabama	200	340	260	165	280	235	72	78	104	11,880	21,840	24,440
Arizona	50	55	50	18	22	15	170	185	165	3,060	4,070	2,475
Arkansas	190	610	440	180	590	430	146	169	155	26,280	99,710	66,650
California	520	650	670	110	190	170	165	182	195	18,150	34,580	33,150
Colorado 1,000		1,200	1,250	860	1,060	1,080	156	140	137	134,160	148,400	147,960
Connecticut	27	26	27	b	b	b	b	b	b	b	b	b
Delaware	170	195	160	161	185	152	145	99	125	23,345	18,315	19,000
Florida	60	70	70	30	35	35	82	90	105	2,460	3,150	3,675
Georgia	280	510	370	225	450	310	110	127	140	24,750	57,150	43,400
Idaho	270	320	300	65	105	80	170	170	170	11,050	17,850	13,600
Illinois	11,300	13,200	12,100	11,150	13,050	11,900	163	175	179	1,817,450	2,283,750	2,130,100
Indiana	5,500	6,500	5,700	5,380	6,370	5,460	157	154	160	844,660	980,980	873,600
Iowa	12,600	14,200	13,300	12,350	13,900	12,800	166	171	171	2,050,100	2,376,900	2,188,800
Kansas	3,350	3,900	3,850	3,000	3,680	3,630	115	138	134	345,000	507,840	486,420
Kentucky	1,120	1,440	1,210	1,040	1,340	1,120	146	128	136	151,840	171,520	152,320
Louisiana	300	740	520	290	730	510	140	163	144	40,600	118,990	73,440
Maine	26	28	29	b	b	b	b	b	b	b	b	b
Maryland	490	540	460	425	465	400	140	101	121	59,500	46,965	48,400
Massachusetts	18	18	19	b	b	b	b	b	b	b	b	b
Michigan	2,200	2,650	2,400	1,950	2,340	2,140	147	123	138	286,650	287,820	295,320
Minnesota	7,300	8,400	7,700	6,850	7,850	7,200	161	146	164	1,102,850	1,146,100	1,180,800
Mississippi	340	930	720	325	910	700	107	148	140	34,775	134,680	98,000
Missouri	2,700	3,450	2,800	2,630	3,270	2,650	138	140	144	362,940	457,800	381,600
Montana	65	84	78	18	38	35	146	140	136	2,628	5,320	4,760
Nebraska	8,100	9,400	8,800	7,750	9,200	8,550	152	160	163	1,178,000	1,472,000	1,393,650
Nevada	4	5	5	b	b	b	b	b	b	b	b	b
New Hampshire	14	14	15	b	b	b	b	b	b	b	b	b
New Jersey	80	95	85	64	82	74	129	124	116	8,256	10,168	8,584
New Mexico	130	135	140	45	54	55	185	180	180	8,325	9,720	9,900
New York	950	1060	1,090	480	550	640	129	128	144	61,920	70,400	92,160
North Carolina	790	1090	900	740	1,010	830	132	100	78	97,680	101,000	64,740
North Dakota	1,690	2,560	2,550	1,400	2,350	2,300	111	116	124	155,400	272,600	285,200
Ohio	3,150	3,850	3,300	2,960	3,610	3,120	159	150	135	470,640	541,500	421,200
Oklahoma	270	320	370	220	270	320	105	145	115	23,100	39,150	36,800
Oregon	51	60	60	29	35	33	180	200	200	5,220	7,000	6,600
Pennsylvania	1,350	1,430	1,350	960	980	880	122	124	133	117,120	121,520	117,040
Rhode Island	2	2	2	b	b	b	b	b	b	b	b	b
South Carolina	310	400	355	290	370	315	110	97	65	31,900	35,890	20,475
South Dakota	4,500	4,950	4,750	3,220	4,480	4,400	97	121	133	312,340	542,080	585,200
Tennessee	550	860	690	500	790	630	125	106	118	62,500	83,740	74,340
Texas	1,760	2,150	2,300	1,450	1,970	2,030	121	148	125	175,450	291,560	253,750
Utah	65	70	70	17	22	23	157	150	157	2,669	3,300	3,611
Vermont	85	92	94	b	b	b	b	b	b	b	b	b
Virginia	480	540	470	345	405	340	120	86	108	41,400	34,830	36,720
Washington	140	195	165	75	115	90	210	210	205	15,750	24,150	18,450
West Virginia	45	48	43	26	27	26	120	111	130	3,120	2,997	3,380
Wisconsin	3,650	4,050	3,800	2,800	3,280	2,880	143	135	137	400,400	442,800	394,560
Wyoming	85	95	95	45	60	52	129	129	134	5,805	7,740	6,968
US	**78,327**	**93,527**	**85,982**	**70,638**	**86,520**	**78,640**	**149.1**	**150.7**	**153.9**	**10,531,123**	**13,037,875**	**12,101,238**

Source:
U.S. Department of Agriculture, *2009 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.

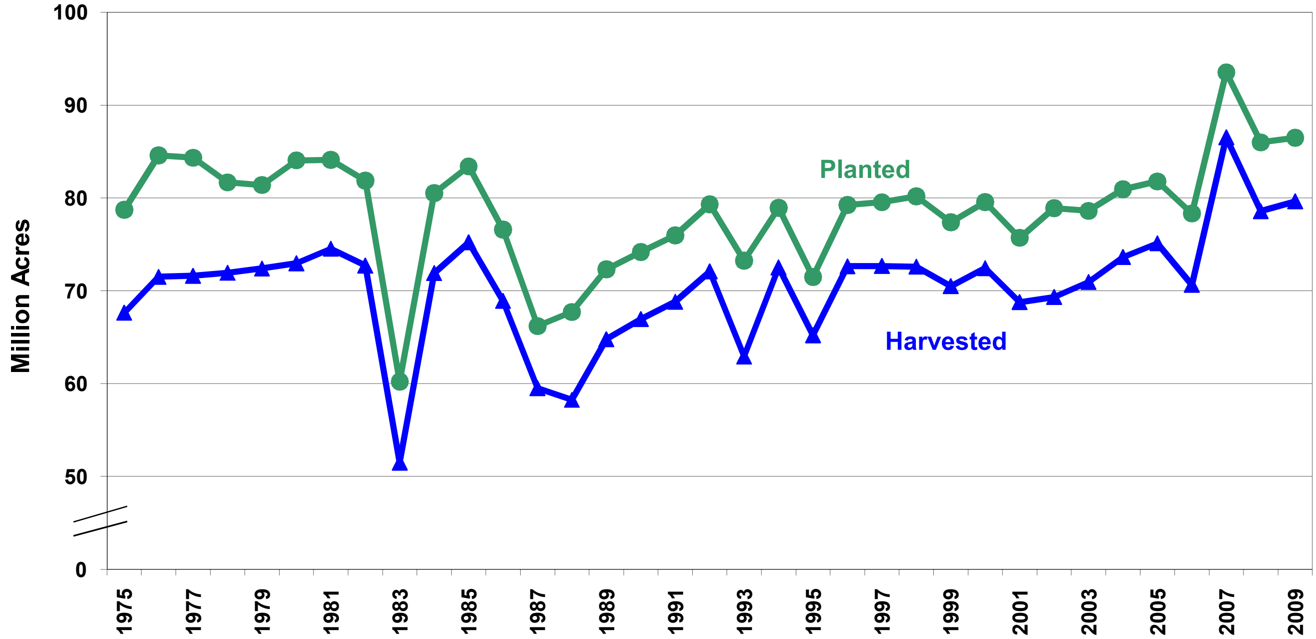
Section: FEEDSTOCKS
Corn for Grain, Harvested Acres, 2007



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, 1975-2009



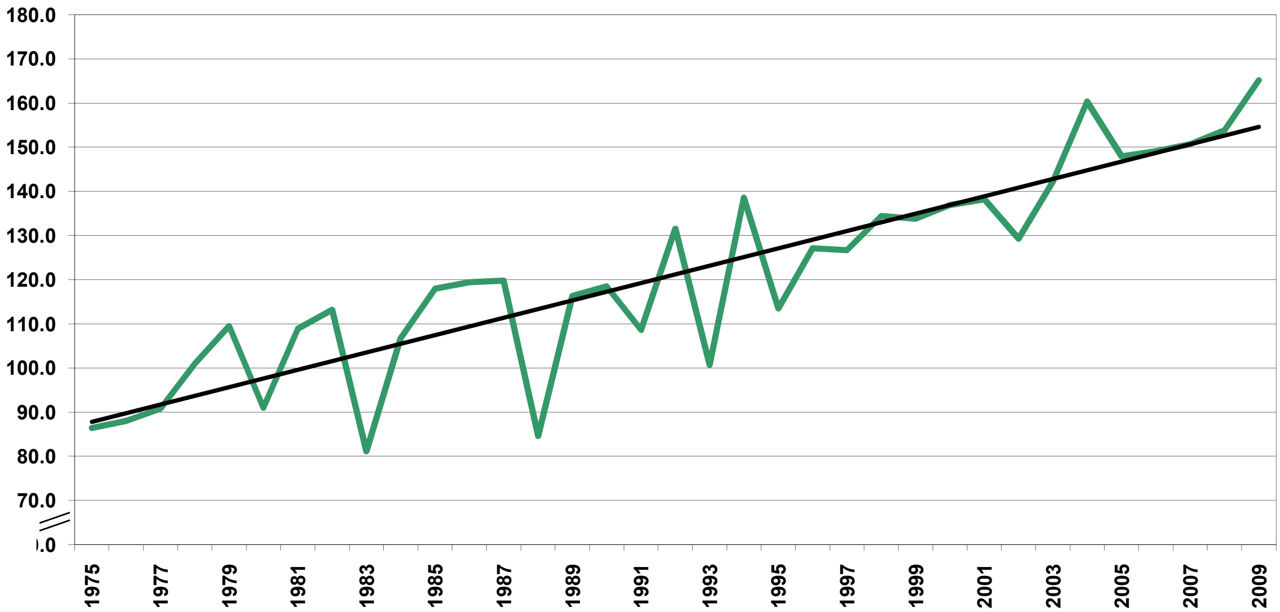
Source:
U.S. Department of Agriculture, National Agricultural Statistics Service
http://www.nass.usda.gov/

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, 1975-2009



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, 1996-2008
(million bushels)

Year (beginning September 1)	Supply				Disappearance					Ending stocks August 31		
					Domestic use							
	Beginning stocks	Production	Imports	Total	Feed and residual	Food, seed, and industrial	Total	Exports	Total disappear-ance	Privately held [a]	Govern - ment	Total
1996	426	9,233	13	9,672	5,277	1,714	6,991	1,797	8,789	881	2	883
1997	883	9,207	9	10,099	5,482	1,805	7,287	1,504	8,791	1,304	4	1,308
1998	1,308	9,759	19	11,085	5,471	1,846	7,317	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 [b]	1,304	13,038	20	14,362	5,938	4,363	10,302	2,436	12,737	1,624	0	1,624
2008 [c]	1,624	12,101	15	13,740	5,250	4,920	10,170	1,800	11,970	1,770	0	1,770

Source:
U.S. Department of Agriculture, *2009 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, 2009, 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 2006, 2007, and 2008

State[a]	Marketing year average price per bushel			Value of production		
	2006	**2007**	**2008**	**2006**	**2007**	**2008**
	Dollars	Dollars	Dollars	1,000 Dollars	1,000 Dollars	1,000 Dollars
Alabama	2.91	4.54	5.30	34,571	99,154	129,532
Arizona	4.37	5.03	5.65	13,372	20,472	13,984
Arkansas	2.73	3.80	4.35	71,744	378,898	289,928
California	3.35	4.28	4.70	60,803	148,002	155,805
Colorado 3.02		3.96	3.95	405,163	587,664	584,442
Delaware	3.61	4.76	4.45	84,275	87,179	84,550
Florida	2.80	4.00	4.50	6,888	12,600	16,538
Georgia	3.00	4.50	4.60	74,250	257,175	199,640
Idaho	3.89	4.96	4.30	42,985	88,536	58,480
Illinois	3.07	4.09	3.80	5,579,572	9,340,538	8,094,380
Indiana	3.17	4.39	3.75	2,677,572	4,306,502	3,276,000
Iowa	3.03	4.29	3.95	6,211,803	10,196,901	8,645,760
Kansas	3.08	4.13	4.25	1,062,600	2,097,379	2,067,285
Kentucky	3.18	4.14	4.05	482,851	710,093	616,896
Louisiana	2.80	3.80	4.45	113,680	452,162	326,808
Maryland	3.41	4.64	4.30	202,895	217,918	208,120
Michigan	3.10	4.37	3.60	888,615	1,257,773	1,063,152
Minnesota	2.89	4.13	3.80	3,187,237	4,733,393	4,487,040
Mississippi	2.84	3.68	4.60	98,761	495,622	450,800
Missouri	3.06	4.17	4.00	1,110,596	1,909,026	1,526,400
Montana	3.93	4.76	4.05	10,328	25,323	19,278
Nebraska	3.00	4.14	3.90	3,534,000	6,094,080	5,435,235
New Jersey	3.37	4.65	4.15	27,823	47,281	35,624
New Mexico	3.70	5.20	5.65	30,803	50,544	55,935
New York	3.42	5.05	4.30	211,766	355,520	396,288
North Carolina	3.03	4.00	4.80	295,970	404,000	310,752
North Dakota	2.77	4.06	3.85	430,458	1,106,756	1,098,020
Ohio	3.08	4.29	3.95	1,449,571	2,323,035	1,663,740
Oklahoma	3.17	4.07	4.50	73,227	159,341	165,600
Oregon	3.24	4.36	3.90	16,913	30,520	25,740
Pennsylvania	3.54	4.56	3.75	414,605	554,131	438,900
South Carolina	2.98	3.88	4.80	95,062	139,253	98,280
South Dakota	2.88	4.17	3.60	899,539	2,260,474	2,106,720
Tennessee	2.93	3.80	4.50	183,125	318,212	334,530
Texas	3.20	4.35	4.80	561,440	1,268,286	1,218,000
Utah	3.29	4.18	4.10	8,781	13,794	14,805
Virginia	3.07	4.39	4.50	127,098	152,904	165,240
Washington	3.72	4.50	4.10	58,590	108,675	75,645
West Virginia	3.57	4.60	4.40	11,138	13,786	14,872
Wisconsin	3.04	4.11	3.50	1,217,216	1,819,908	1,380,960
Wyoming	2.64	3.12	4.00	15,325	24,149	27,872
US	**3.04**	**4.20**	**3.90**	**32,083,011**	**54,666,959**	**47,377,576**

Source: U.S. Department of Agriculture, *2009 Agricultural Statistics,* Table 1-40, http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] States with no data are not listed.

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.

Corn Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2008-2009[a]
(dollars per planted acre)

	United States		Heartland		Northern Crescent		Northern Great Planes		Prairie Gateway		Eastern Uplands		Southern Seaboard	
Item	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**
Gross value of production														
Primary product: Corn grain	627.84	560.04	685.72	610.09	473.8	444.78	559.36	476.1	624.44	532.14	569.52	560.04	430.1	433.92
Secondary product: Corn silage	1.52	1.18	0.78	0.70	3.12	3.02	6.17	4.58	3.09	2.47	7.56	5.73	0.00	0.00
Total, gross value of production	**629.36**	**561.22**	**686.50**	**610.79**	**476.92**	**447.80**	**565.53**	**480.68**	**627.53**	**534.61**	**577.08**	**565.77**	**430.10**	**433.92**
Operating costs:														
Seed	60.02	78.92	61.29	80.61	61.29	80.61	58.48	76.91	54.02	71.04	55.90	73.52	54.31	71.43
Fertilizer [b]	139.18	132.53	146.62	139.37	158.09	150.28	93.31	88.70	96.64	91.86	177.46	168.69	148.39	141.06
Chemicals	25.19	28.23	27.68	30.96	22.34	24.99	17.71	19.81	20.87	23.34	24.94	27.90	24.06	26.91
Custom operations[c]	10.98	11.98	9.80	10.67	13.59	14.80	9.99	10.88	14.74	16.05	9.67	10.53	7.05	7.68
Fuel, lube, and electricity	42.64	29.12	32.73	22.14	41.11	27.98	41.67	28.24	98.36	66.97	27.95	19.68	33.64	24.20
Repairs	15.37	15.69	13.46	13.72	15.50	15.80	16.77	17.10	23.44	23.90	13.04	13.29	22.29	22.72
Purchased irrigation water	0.14	0.14	0.00	0.00	0.02	0.02	1.64	1.79	0.19	0.21	0.00	0.00	0.00	0.00
Interest on operating capital	2.17	0.43	2.16	0.43	2.31	0.46	1.77	0.35	2.28	0.43	2.29	0.45	2.14	0.43
Total, operating costs	**295.69**	**297.04**	**293.74**	**297.90**	**314.25**	**314.94**	**241.34**	**243.78**	**310.54**	**293.80**	**311.25**	**314.06**	**291.88**	**294.43**
Allocated overhead:														
Hired labor	2.37	2.41	1.56	1.59	3.36	3.43	3.66	3.74	3.92	4.01	1.29	1.32	6.77	6.92
Opportunity cost of unpaid labor	25.12	25.67	21.96	22.44	35.26	36.03	23.60	24.12	25.97	26.54	41.86	42.77	27.39	27.99
Capital recovery of machinery and equipmen	76.36	81.48	73.02	77.91	73.13	78.03	83.44	89.03	94.36	100.68	68.64	73.24	76.86	82.01
Opportunity cost of land (rental rate)	107.37	116.10	123.66	133.40	90.98	98.15	70.51	76.07	77.98	84.12	74.02	79.85	64.50	69.58
Taxes and insurance	8.29	9.48	7.64	8.70	11.35	12.92	5.12	5.83	9.35	10.65	6.47	7.37	9.93	11.31
General farm overhead	14.18	14.49	13.35	13.61	19.43	19.81	10.12	10.32	13.44	13.70	11.60	11.83	18.53	18.89
Total, allocated overhead	**233.69**	**249.63**	**241.19**	**257.65**	**233.51**	**248.37**	**196.45**	**209.11**	**225.02**	**239.70**	**203.88**	**216.38**	**203.98**	**216.70**
Total, costs listed	**529.38**	**546.67**	**534.93**	**555.55**	**547.76**	**563.31**	**437.79**	**452.89**	**535.56**	**533.50**	**515.13**	**530.44**	**495.86**	**511.13**
Value of production less total costs listed	99.98	14.55	151.57	55.24	-70.84	-115.51	127.74	27.79	91.97	1.11	61.95	35.33	-65.76	-77.21
Value of production less operating costs	333.67	264.18	392.76	312.89	162.67	132.86	324.19	236.90	316.99	240.81	265.83	251.71	138.22	139.49
Supporting information:														
Yield (bushels per planted acre)	144	156	158	169	115	126	128	138	134	147	126	156	85	113
Price (dollars per bushel at harvest)	4.36	3.59	4.34	3.61	4.12	3.53	4.37	3.45	4.66	3.62	4.52	3.59	5.06	3.84
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.

Section: FEEDSTOCKS
Oats: Area, Yield, Production, and Value, 1996-2008

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 [b]	3,217	1,395	63.5	88,635	3.10	262,240

Source: U.S. Department of Agriculture, *2009 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, 2006-2008

	Area planted[a]			Area harvested			Yield per harvested acre			Production		
	2006	**2007**	**2008**	**2006**	**2007**	**2008**	**2006**	**2007**	**2008**	**2006**	**2007**	**2008**
	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	50	45	50	10	16	15	40	58	50	400	928	750
California	270	215	230	20	25	20	90	99	75	1,800	2,475	1,500
Colorado 85		75	45	10	10	7	70	55	70	700	550	490
Georgia	70	70	65	30	30	25	53	56	69	1,590	1,680	1,725
Idaho	90	70	70	20	20	20	72	61	69	1,440	1,220	1,380
Illinois	60	35	45	40	24	30	77	62	70	3,080	1,488	2,100
Indiana	25	25	15	14	8	5	80	53	75	1,120	424	375
Iowa	210	145	150	110	67	75	76	71	65	8,360	4,757	4,875
Kansas	100	90	60	40	35	25	46	45	53	1,840	1,575	1,325
Maine	29	29	32	28	28	31	55	70	65	1,540	1,960	2,015
Michigan	80	70	75	65	55	60	62	56	66	4,030	3,080	3,960
Minnesota	290	270	250	200	180	175	56	60	68	11,200	10,800	11,900
Missouri	40	25	15	28	8	6	65	50	55	1,820	400	330
Montana	70	75	60	24	35	30	46	50	51	1,104	1,750	1,530
Nebraska	160	120	95	45	35	35	45	61	70	2,025	2,135	2,450
New York	85	100	80	67	60	64	74	58	66	4,958	3,480	4,224
North Carolina	60	50	60	26	15	30	65	55	80	1,690	825	2,400
North Dakota	420	460	320	120	260	130	41	59	51	4,920	15,340	6,630
Ohio	70	75	75	55	50	50	75	62	70	4,125	3,100	3,500
Oklahoma	35	80	50	8	15	10	30	31	40	240	465	400
Oregon	50	60	45	20	18	18	95	78	100	1,900	1,404	1,800
Pennsylvania	135	115	105	110	80	80	64	56	58	7,040	4,480	4,640
South Carolina	33	33	33	18	14	19	50	42	64	900	588	1,216
South Dakota	380	330	220	95	130	120	57	72	73	5,415	9,360	8,760
Texas	760	710	600	100	100	100	37	40	50	3,700	4,000	5,000
Utah	45	35	40	7	4	4	77	80	75	539	320	300
Virginia	16	16	12	4	5	4	50	60	70	200	300	280
Washington	30	30	20	8	9	5	84	50	80	672	450	400
Wisconsin	370	270	270	230	160	190	63	67	62	14,490	10,720	11,780
Wyoming	48	40	30	12	8	12	57	47	50	684	376	600
US	**4,166**	**3,763**	**3,217**	**1,564**	**1,504**	**1,395**	**59.8**	**60.1**	**63.5**	**93,522**	**90,430**	**88,635**

Source:
U.S. Department of Agriculture, *2009 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.

Section: FEEDSTOCKS

Oats Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2008-2009[a]
(dollars per planted acre)

Item	United States		Northern Great Plains		Prarie Gateway		Northern Crescent		Heartland	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Gross value of production										
Primary product: Oats	225.09	155.35	187.55	132.30	123.42	91.41	226.78	154.38	192.92	127.73
Secondary product: Straw	62.97	59.35	29.83	29.50	7.70	6.53	82.38	77.41	86.91	76.81
Secondary product: Hay, silage, grazing	37.81	21.05	35.54	19.10	95.98	64.03	30.43	16.88	25.76	14.92
Total, gross value of production	**325.87**	**235.75**	**252.92**	**180.90**	**227.10**	**161.97**	**339.59**	**248.67**	**305.59**	**219.46**
Operating costs:										
Seed	12.49	12.54	9.11	9.11	10.16	10.16	14.41	14.41	13.70	13.70
Fertilizer [b]	49.78	46.63	24.01	22.89	72.57	69.19	65.42	62.37	41.62	39.68
Chemicals	2.38	2.52	3.45	3.79	0.89	0.98	2.25	2.47	1.84	2.01
Custom operations	8.97	9.18	2.78	2.80	3.03	3.06	11.94	12.02	12.52	12.61
Fuel, lube, and electricity	23.27	15.53	18.39	12.19	16.28	10.79	28.56	18.93	23.30	15.44
Repairs	12.62	12.94	13.92	14.19	10.24	10.44	13.08	13.33	11.97	12.20
Purchased irrigation water	2.70	2.84	0.83	0.84	0.26	0.27	1.97	2.01	6.08	6.20
Interest on operating inputs	0.93	0.15	0.60	0.10	0.94	0.15	1.14	0.18	0.92	0.15
Total, operating costs	**113.14**	**102.33**	**73.09**	**65.91**	**114.37**	**105.04**	**138.77**	**125.72**	**111.95**	**101.99**
Allocated overhead:										
Hired labor	0.77	0.79	0.37	0.37	0.39	0.40	1.60	1.63	0.21	0.22
Opportunity cost of unpaid labor	34.46	35.29	22.57	23.06	28.13	28.74	44.71	45.68	33.58	34.32
Capital recovery of machinery and equipment	63.55	68.25	70.64	75.37	50.14	53.49	62.39	66.56	64.68	69.01
Opportunity cost of land (rental rate)	73.74	84.89	53.91	61.30	42.72	48.58	73.05	83.06	102.64	116.71
Taxes and insurance	5.79	6.48	4.64	5.21	6.37	7.16	6.00	6.74	6.20	6.96
General farm overhead	8.67	8.93	7.59	7.74	5.57	5.67	9.47	9.66	9.75	9.94
Total, allocated overhead	**186.98**	**204.63**	**159.72**	**173.05**	**133.32**	**144.04**	**197.22**	**213.33**	**217.06**	**237.16**
Total, costs listed	**300.12**	**306.96**	**232.81**	**238.96**	**247.69**	**249.08**	**335.99**	**339.05**	**329.01**	**339.15**
Value of production less total costs listed	25.75	-71.21	20.11	-58.06	-20.59	-87.11	3.60	-90.38	-23.42	-119.69
Value of production less operating costs	212.73	133.42	179.83	114.99	112.73	56.93	200.82	122.95	193.64	117.47
Supporting information:										
Yield (bushels per planted acre)	61	65	55	63	34	33	58	62	53	53
Price (dollars per bushel at harvest)	3.69	2.39	3.41	2.10	3.63	2.77	3.91	2.49	3.64	2.41
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, 1996-2008

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	16.50	3,390,666

Source: U.S. Department of Agriculture, *2009 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, 2006-2008

State[a]	Area Planted			Area harvested			Yield per harvested acre			Production		
	2006	**2007**	**2008[b]**	**2006**	**2007**	**2008[b]**	**2006**	**2007**	**2008[b]**	**2006**	**2007**	**2008[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	1,406.0	1,331.0	1,401.0	1,400.0	1,325.0	1,395.0	6,900	7,230	6,660	96,565	95,814	92,938
California	526.0	534.0	519.0	523.0	533.0	517.0	7,660	8,200	8,320	40,040	43,684	43,030
Louisiana	350.0	380.0	470.0	345.0	378.0	464.0	5,880	6,140	5,830	20,294	23,222	27,037
Mississippi	190.0	190.0	230.0	189.0	189.0	229.0	7,000	7,350	6,850	13,230	13,892	15,687
Missouri	216.0	180.0	200.0	214.0	178.0	199.0	6,400	6,900	6,620	13,696	12,279	13,173
Texas	150.0	146.0	175.0	150.0	145.0	172.0	7,170	6,550	6,900	10,760	9,497	11,868
US	**2,838.0**	**2,761.0**	**2,995.0**	**2,821.0**	**2,748.0**	**2,976.0**	**6,898**	**7,219**	**6,846**	**194,585**	**198,388**	**203,733**

Source: U.S. Department of Agriculture, *2009 Agricultural Statistics,* Table 1-27,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

Notes:

[a] States with no data are not listed.

[b] Preliminary

Section: FEEDSTOCKS

Rice Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2008-2009[a]

(dollars per planted acre)

	United States		Ark Non-Delta		California		Mississippi River Delta		Gulf Coast	
Item	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**
Gross value of production										
Primary product: Rice	1287.36	1072.26	1190.70	940.75	1731.38	1594.44	1238.08	987.69	937.44	794.14
Total, gross value of production	**1287.36**	**1072.26**	**1190.70**	**940.75**	**1731.38**	**1594.44**	**1238.08**	**987.69**	**937.44**	**794.14**
Operating costs:										
Seed	45.09	65.48	42.19	61.20	50.81	73.72	48.29	70.05	43.05	62.45
Fertilizer [b]	110.80	108.59	94.09	92.40	125.92	123.66	107.39	105.46	136.01	133.55
Chemicals	68.68	76.92	60.25	67.39	96.48	107.91	59.56	66.61	71.53	80.01
Custom operations	44.91	49.03	29.34	31.95	86.13	93.80	35.76	38.95	51.18	55.74
Fuel, lube, and electricity	138.96	91.80	147.76	97.94	91.71	60.79	139.95	92.75	160.01	106.05
Repairs	27.96	28.50	29.38	29.95	27.03	27.56	26.49	27.00	27.25	27.78
Purchased irrigation water	11.32	12.42	0.19	0.21	45.17	49.19	0.00	0.00	16.78	18.28
Commercial drying	27.60	19.03	18.33	12.33	50.66	34.79	14.80	9.81	39.89	28.88
Interest on operating inputs	3.31	0.63	2.98	0.55	3.87	0.78	3.09	0.58	3.74	0.70
Total, operating costs	**478.63**	**452.40**	**424.51**	**393.92**	**577.78**	**572.20**	**435.33**	**411.21**	**549.44**	**513.44**
Allocated overhead:										
Hired labor	19.52	20.08	20.99	21.44	25.38	25.94	21.16	21.62	9.82	10.04
Opportunity cost of unpaid labor	44.40	45.42	37.80	38.62	69.75	71.28	30.97	31.65	49.82	50.91
Capital recovery of machinery and equipment	110.87	118.33	113.17	120.75	116.24	124.02	103.06	109.97	109.24	116.56
Opportunity cost of land (rental rate)	139.71	159.66	106.17	120.72	278.00	316.10	100.26	114.00	130.52	148.41
Taxes and insurance	19.26	21.66	19.84	22.27	16.66	18.70	24.09	27.04	15.47	17.37
General farm overhead	25.28	25.86	20.32	20.71	36.60	37.31	28.56	29.12	22.71	23.15
Total, allocated overhead	**359.04**	**391.01**	**318.29**	**344.51**	**542.63**	**593.35**	**308.10**	**333.40**	**337.58**	**366.44**
Total, costs listed	**837.67**	**843.41**	**742.80**	**738.43**	**1,120.41**	**1,165.55**	**743.43**	**744.61**	**887.02**	**879.88**
Value of production less total costs listed	449.69	228.85	447.90	202.32	610.97	428.89	494.65	243.08	50.42	-85.74
Value of production less operating costs	808.73	619.86	766.19	546.83	1153.60	1022.24	802.75	576.48	388.00	280.70
Supporting information:										
Price (dollars per cwt at harvest)	17.88	14.49	17	13	21	19	17	14	17	13
Yield (cwt per planted acre)	72.00	74.00	70.00	71.00	83.00	86.00	73.00	73.00	54.00	59.00
Enterprise size (planted acres) [a]	511	511	521	521	431	431	634	634	469	469

Source:

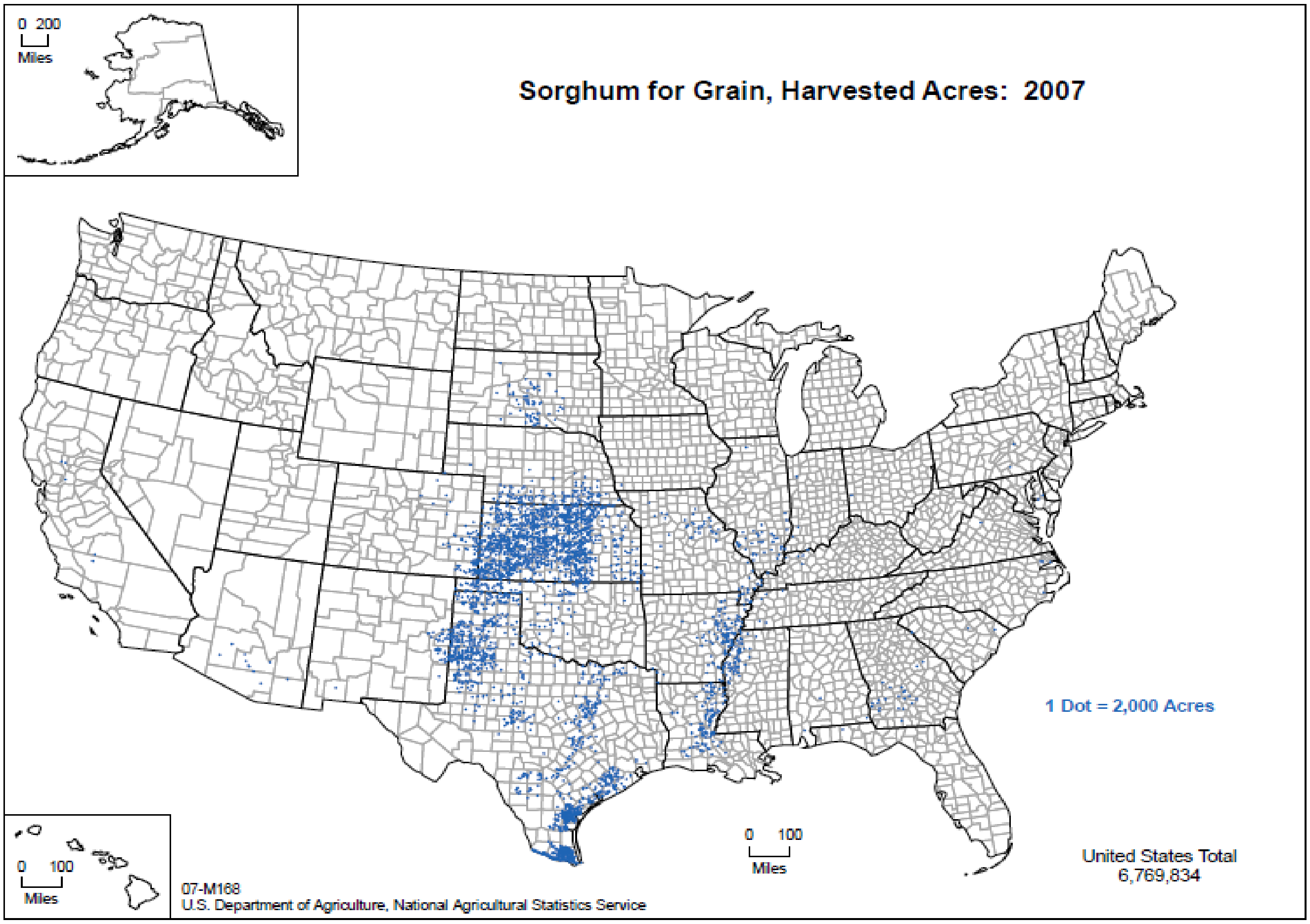
Economic Research Service, US Department of Agriculture,
http://www.ers.usda.gov/data/costsandreturns/testpick.htm

[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.

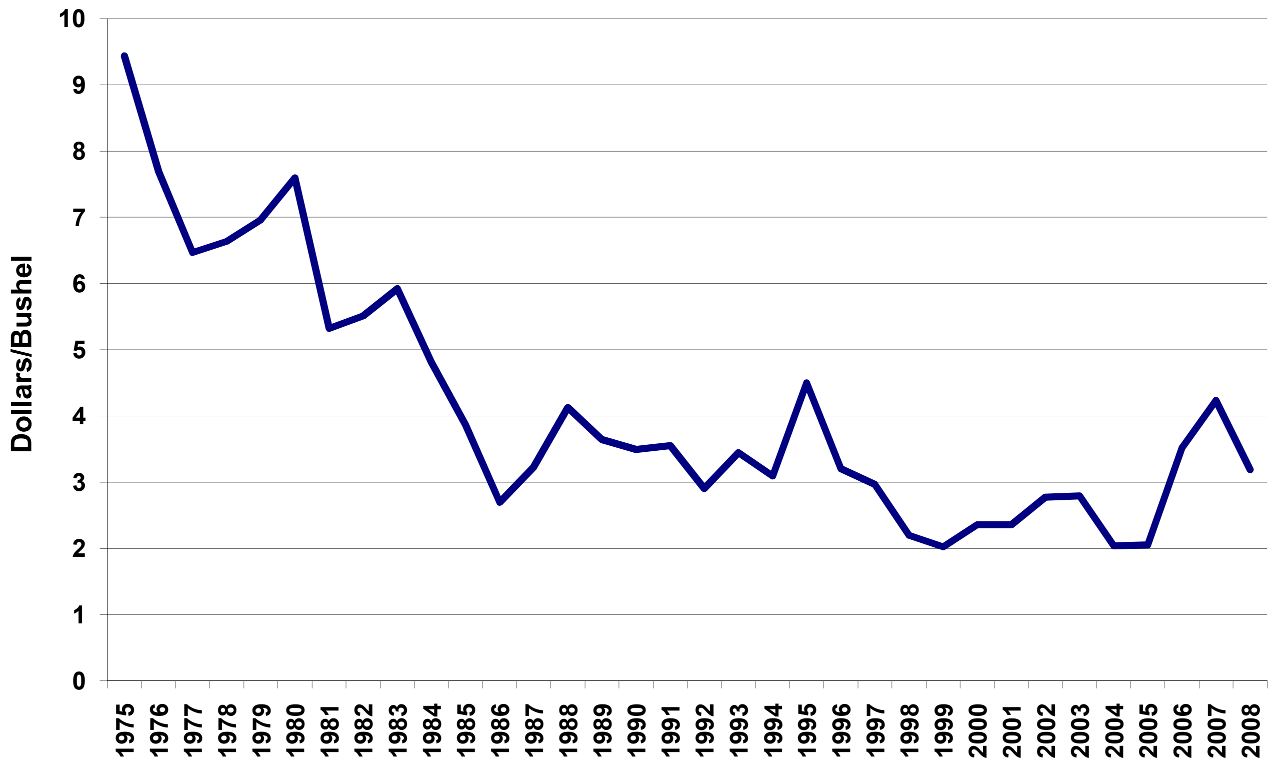
Section: FEEDSTOCKS
Sorghum for Grain, Harvested Acres, 2007



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, 1975-2008
(Constant 2008 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, 1996-2008

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,d]	Value of production[c,d]	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[d]	8,284	7,271	65.0	472,342	5.70	1,681,558	408	13.8	5,646

Source:
USDA, *2009, 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, 2006-2008

State	Area planted for all purposes			Sorghum for grain								
				Area harvested			Yield per harvested acre			Production		
	2006	2007	2008[a]	2006	2007	2008[a]	2006	2007	2008[a]	2006	2007	2008[a]
	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	Bushels	Bushels	Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels
Alabama	10	12	12	5	6	6	38	40	53	190	240	318
Arizona	24	42	57	7	20	27	90	90	90	630	1,800	2,430
Arkansas	63	225	125	60	215	115	85	96	88	5,100	20,640	10,120
California	32	39	47	10	10	9	105	85	95	1,050	850	855
Colorado 280		220	230	130	150	150	26	37	30	3,380	5,550	4,500
Georgia	40	65	60	26	45	44	45	46	45	1,170	2,070	1,980
Illinois	75	80	80	72	77	76	89	81	103	6,408	6,237	7,828
Kansas	2,750	2,800	2,900	2,500	2,650	2,750	58	79	78	145,000	209,350	214,500
Kentucky	18	15	13	16	12	11	85	90	90	1,360	1,080	990
Louisiana	90	250	120	87	245	110	94	95	87	8,178	23,275	9,570
Mississippi	15	145	85	13	115	82	80	85	71	1,040	9,775	5,822
Missouri	100	110	90	95	100	80	85	96	97	8,075	9,600	7,760
Nebraska	370	350	300	240	240	210	78	94	91	18,720	22,560	19,110
New Mexico	110	105	130	60	75	80	35	40	43	2,100	3,000	3,440
North Carolina	17	12	16	13	8	13	47	55	56	611	440	728
Oklahoma	270	240	350	200	220	310	34	56	45	6,800	12,320	13,950
Pennsylvania	13	15	11	5	3	3	66	56	37	330	168	111
South Carolina	11	9	12	7	6	8	51	35	46	357	210	368
South Dakota	220	210	170	80	130	115	36	60	64	2,880	7,800	7,360
Tennessee	14	18	26	11	15	22	95	82	91	1,045	1,230	2,002
Texas	2,000	2,750	3,450	1,300	2,450	3,050	48	65	52	62,400	159,250	158,600
US	**6,522**	**7,712**	**8,284**	**4,937**	**6,792**	**7,271**	**56**	**73**	**65**	**276,824**	**497,445**	**472,342**

Source:
USDA, *2009 Agricultural Statistics*, Table 1-65,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Preliminary.

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, 2008-2009[a]

(dollars per planted acre)

Item	United States		Heartland		Prairie Gateway		Fruitful Rim		Northern Great Plains	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Gross value of production:										
Primary product: Sorghum	240.13	183.60	356.40	248.80	246.14	202.34	207.46	125.02	270.40	151.90
Secondary product: Sorgum silage	11.57	9.32	0.00	0.00	15.59	12.30	0.00	0.00	9.92	5.46
Total, gross value of production	**251.7**	**192.92**	**356.40**	**248.80**	**261.73**	**214.64**	**207.46**	**125.02**	**280.32**	**157.36**
Operating costs:										
Seed	6.63	7.47	10.86	12.31	6.07	6.88	7.90	8.96	8.48	9.61
Fertilizer[b]	45.92	43.41	90.28	85.94	44.59	42.45	48.76	46.42	38.88	37.01
Chemicals	18.68	21.18	21.89	24.48	22.20	24.83	8.10	9.06	15.61	17.46
Custom operations	10.46	11.37	6.18	6.73	10.38	11.30	11.25	12.25	8.11	8.83
Fuel, lube, and electricity	54.50	36.76	23.53	15.16	63.00	42.60	35.76	22.67	11.54	7.18
Repairs	18.91	19.27	16.95	17.28	20.01	20.40	16.97	17.30	8.89	9.06
Purchased irrigation water	0.15	0.15	0.00	0.00	0.00	0.00	0.63	0.69	0.17	0.19
Interest on operating inputs	1.15	0.21	1.26	0.23	1.23	0.22	0.96	0.17	0.68	0.13
Total, operating costs	**156.40**	**139.82**	**170.95**	**162.13**	**167.48**	**148.68**	**130.33**	**117.52**	**92.36**	**89.47**
Allocated overhead:										
Hired labor	6.23	6.11	2.55	2.61	3.72	3.80	14.93	15.26	0.64	0.65
Opportunity cost of unpaid labor	29.19	29.87	27.44	28.04	31.02	31.7	25.29	25.84	17.07	17.44
Capital recovery of machinery and equipment	73.98	78.96	65.30	69.67	76.84	81.99	68.97	73.59	49.42	52.73
Opportunity cost of land	41.09	44.70	79.21	86.55	40.04	43.75	42.02	45.91	43.900	47.97
Taxes and insurance	4.88	5.42	26.22	29.44	4.92	5.52	3.400	3.82	6.88	7.720
General farm overhead	8.56	8.58	28.71	29.27	7.25	7.39	11.11	11.33	11.89	12.12
Total, allocated overhead	163.93	173.64	229.43	245.58	163.79	174.15	165.72	175.75	129.8	138.63
Total costs listed	**320.33**	**313.46**	**400.38**	**407.71**	**331.27**	**322.83**	**296.05**	**293.27**	**222.16**	**228.10**
Value of production less total costs listed	-68.63	-120.54	-43.98	-158.91	-69.54	-108.19	-88.59	-168.25	58.16	-70.74
Value of production less operating costs	95.30	53.10	185.45	86.67	94.25	65.96	77.13	7.500	187.96	67.89
Supporting information:										
Sorghum Yield: bushels per planted acre	59	60	90	80	62	67	46	38	65	49
Price: dollars per bushel	4.07	3.06	3.96	3.11	3.97	3.02	4.51	3.29	4.16	3.10
Enterprise size (planted acres)[a]	297	297	125	125	269	269	785	785	272	272
Production practices:[a]										
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.

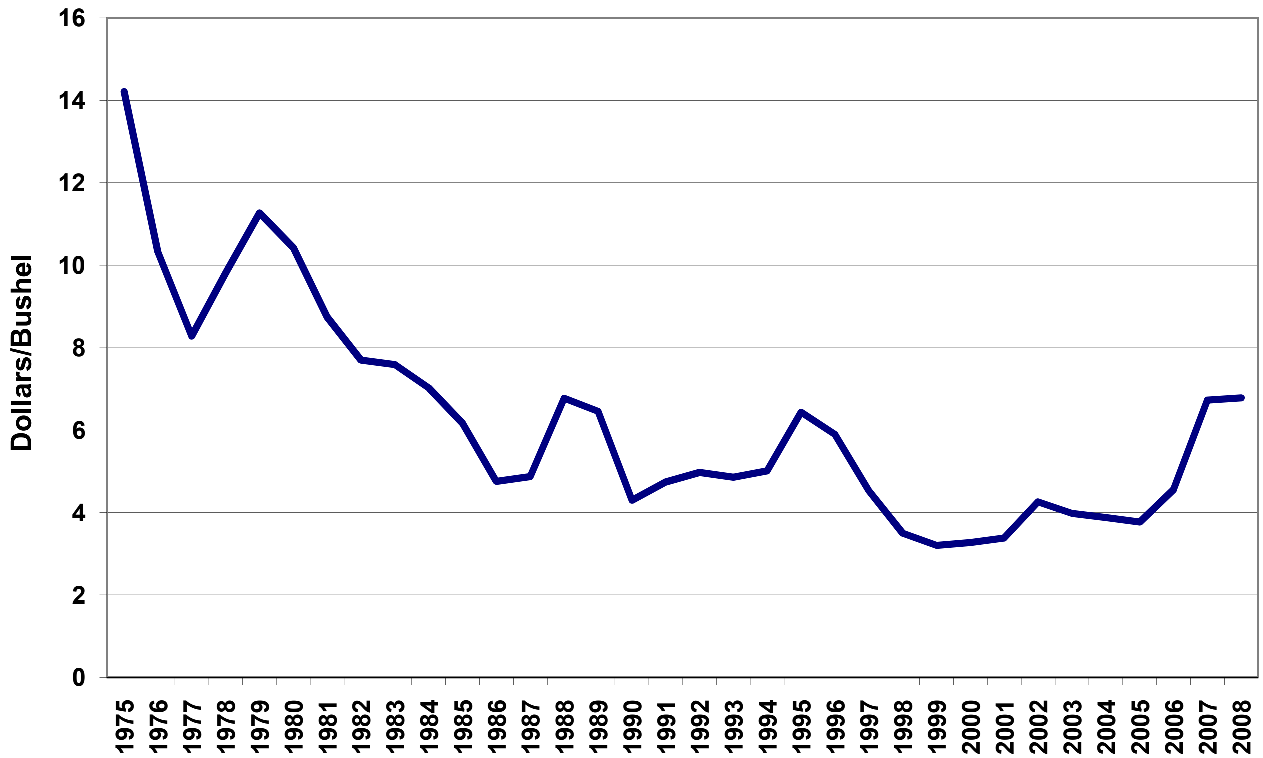
Section: FEEDSTOCKS
Wheat Baseline Projections, 2008 - 2019

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
Area (million acres):												
Planted acres	63.2	59.1	55.0	56.0	55.0	53.5	54.0	54.0	54.0	54.0	54.0	53.5
Harvested acres	55.7	49.9	46.8	47.6	46.8	45.5	45.9	45.9	45.9	45.9	45.9	45.5
Yields (bushels per acre):												
Yield/harvested acre	44.9	44.4	42.7	43.9	44.2	44.6	44.9	45.3	45.6	46.0	46.3	46.7
Supply and use (million bushels):												
Beginning stocks	306	657	885	874	895	873	811	775	750	736	728	727
Production	2,499	2,216	2,000	2,090	2,070	2,030	2,060	2,080	2,095	2,110	2,125	2,125
Imports	127	110	110	110	110	110	115	115	120	120	125	125
Supply	2,932	2,983	2,995	3,074	3,075	3,013	2,986	2,970	2,965	2,966	2,978	2,977
Food	925	955	960	980	990	999	1,008	1,017	1,026	1,035	1,044	1,053
Seed	75	78	76	74	72	73	73	73	73	73	72	72
Feed and Residual	260	190	210	225	240	230	230	230	230	230	235	235
Domestic Use	1,260	1,223	1,246	1,279	1,302	1,302	1,311	1,320	1,329	1,338	1,351	1,360
Exports	1,015	875	875	900	900	900	900	900	900	900	900	900
Total use	2,275	2,098	2,121	2,179	2,202	2,202	2,211	2,220	2,229	2,238	2,251	2,260
Ending stocks	657	885	874	895	873	811	775	750	736	728	727	717
Stocks/use ratio, percent	28.9	42.2	41.2	41.1	39.6	36.8	35.1	33.8	33.0	32.5	32.3	31.7
Prices (dollars per bushel):												
Farm price	6.78	4.85	5.00	4.90	4.65	4.70	4.70	4.75	4.75	4.75	4.75	4.75
Loan rate	2.75	2.75	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94
Variable costs of production (dollars):												
Per acre	127.30	107.93	108.32	113.55	116.45	118.84	121.22	123.91	126.52	129.05	131.58	134.13
Per bushel	2.97	3.18	2.54	2.59	2.63	2.66	2.70	2.74	2.77	2.81	2.84	2.87
Returns over variable costs (dollars per acre):												
Net returns	177	107	105	102	89	91	90	91	90	89	88	88

Source:
USDA Long-Term Agricultural, Projection Tables to 2019, February 2010, Table 22 - 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, 1975-2008
(constant 2008 dollars)



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

Section: FEEDSTOCKS
Wheat: Area, Yield, Production, and Value, 1996-2008

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	63,147	55,685	44.9	2,499,524	6.80	16,568,211

Source: U.S. Department of Agriculture, *2009 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, 2006-2008

State	Area planted[a]			Area harvested			Yield per harvested acre			Production		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
	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	100	120	240	45	76	200	57.0	42.0	71.0	2,565	3,192	14,200
Arizona	79	89	163	76	86	161	99.7	101.4	97.8	7,580	8,724	15,742
Arkansas	365	820	1,070	305	700	980	61.0	41.0	57.0	18,605	28,700	55,860
California	520	640	820	315	345	555	66.5	85.4	90.6	20,935	29,465	50,275
Colorado 2,170		2,520	2,190	1,919	2,369	1,936	21.6	39.2	30.8	41,515	92,980	59,700
Delaware	48	57	80	45	55	79	67.0	68.0	77.0	3,015	3,740	6,083
Florida	8	13	25	5	9	23	42.0	55.0	55.0	210	495	1,265
Georgia	230	360	480	120	230	400	49.0	40.0	56.0	5,880	9,200	22,400
Idaho	1,255	1,235	1,400	1,195	1,175	1,330	75.6	71.2	73.8	90,315	83,645	98,170
Illinois	930	1,000	1,200	910	890	1,150	67.0	55.0	64.0	60,970	48,950	73,600
Indiana	470	420	580	460	370	560	68.0	56.0	69.0	31,280	20,720	38,640
Iowa	25	35	40	18	28	35	66.0	48.0	48.0	1,188	1,344	1,680
Kansas	9,800	10,400	9,600	9,100	8,600	8,900	32.0	33.0	40.0	291,200	283,800	356,000
Kentucky	430	440	580	320	250	460	71.0	48.0	71.0	22,720	12,000	32,660
Louisiana	115	235	400	105	220	385	53.0	54.0	57.0	5,565	11,880	21,945
Maryland	210	220	255	125	160	180	67.0	66.0	73.0	8,375	10,560	13,140
Michigan	660	550	730	650	530	710	73.0	65.0	69.0	47,450	34,450	48,990
Minnesota	1,750	1,765	1,925	1,695	1,710	1,870	47.4	47.9	55.9	80,340	81,900	104,440
Mississippi	85	370	520	73	330	485	59.0	56.0	62.0	4,307	18,480	30,070
Missouri	1,000	1,050	1,250	910	880	1,160	54.0	43.0	48.0	49,140	37,840	55,680
Montana	5,300	5,170	5,740	5,215	5,065	5,470	29.4	29.6	30.1	153,075	149,820	164,730
Nebraska	1,800	2,050	1,750	1,700	1,960	1,670	36.0	43.0	44.0	61,200	84,280	73,480
Nevada	23	23	21	10	13	11	105.6	99.2	100.1	1,056	1,290	1,101
New Jersey	25	31	35	22	28	33	60.0	51.0	61.0	1,320	1,428	2,013
New Mexico	440	490	430	120	300	140	34.0	28.0	30.0	4,080	8,400	4,200
New York	105	100	130	95	85	122	61.0	53.0	63.0	5,795	4,505	7,686
North Carolina	560	630	820	420	500	720	59.0	40.0	60.0	24,780	20,000	43,200
North Dakota	8,800	8,595	9,230	8,290	8,405	8,640	30.3	35.6	36.0	251,590	298,875	311,200
Ohio	990	820	1,120	960	730	1,090	68.0	61.0	68.0	65,280	44,530	74,120
Oklahoma	5,700	5,900	5,600	3,400	3,500	4,500	24.0	28.0	37.0	81,600	98,000	166,500
Oregon	870	855	960	835	835	945	51.7	52.3	55.7	43,190	43,680	52,600
Pennsylvania	160	170	195	150	155	185	59.0	58.0	64.0	8,850	8,990	11,840
South Carolina	130	160	220	123	135	205	50.0	30.0	54.0	6,150	4,050	11,070
South Dakota	3,310	3,508	3,661	2,576	3,327	3,420	32.6	43.1	50.5	84,090	143,515	172,540
Tennessee	280	420	620	190	260	520	64.0	41.0	63.0	12,160	10,660	32,760
Texas	5,550	6,200	5,800	1,400	3,800	3,300	24.0	37.0	30.0	33,600	140,600	99,000
Utah	144	146	150	136	132	139	45.0	42.8	41.4	6,120	5,656	5,756
Virginia	190	230	310	155	205	280	68.0	64.0	71.0	10,540	13,120	19,880
Washington	2,280	2,170	2,260	2,225	2,137	2,225	62.1	58.7	52.8	138,250	125,342	117,530
West Virginia	8	8	11	6	6	8	61.0	57.0	60.0	366	342	480
Wisconsin	261	299	373	240	278	357	76.2	67.1	64.5	18,290	18,640	23,012
Wyoming	158	146	163	141	130	146	27.5	25.4	29.4	3,879	3,300	4,286
US	**57,344**	**60,460**	**63,147**	**46,800**	**50,999**	**55,685**	**38.6**	**40.2**	**44.9**	**1,808,416**	**2,051,088**	**2,499,524**

Source:
U.S. Department of Agriculture, *2009 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, 1996-2008
(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 disappea rance	
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 [c]	306	2,500	125	2,930	922	79	247	1,248	1,015	2,263	667

Source:
U.S. Department of Agriculture, *2009 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.

Like corn and soybeans, the price per bushel of wheat rose considerably between 2006 and 2007.

Section: FEEDSTOCKS
Wheat: Marketing Year Average Price and Value, by State, Crop of 2006, 2007, and 2008

State[a]	Marketing year average price per bushel 2006	2007	2008[b]	Value of production 2006	2007	2008[b]
	Dollars	Dollars	Dollars	1,000 Dollars	1,000 Dollars	1,000 Dollars
Alabama	3.95	5.30	6.00	10,132	16,918	85,200
Arizona	4.85	7.03	8.25	36,774	61,329	129,633
Arkansas	3.52	4.72	5.85	65,490	135,464	326,781
California	4.14	5.41	6.90	86,686	159,583	350,080
Colorado 4.54		6.01	6.50	189,027	561,326	388,980
Delaware	3.27	5.56	6.00	9,859	20,794	36,498
Florida	3.15	4.00	5.50	662	1,980	6,958
Georgia	3.70	6.50	6.00	21,756	59,800	134,400
Idaho	4.16	6.56	6.60	375,608	549,000	646,431
Illinois	3.40	5.37	5.45	207,298	262,862	401,120
Indiana	3.41	5.20	5.95	106,665	107,744	229,908
Iowa	3.35	5.25	5.90	3,980	7,056	9,912
Kansas	4.56	5.93	7.15	1,327,872	1,682,934	2,545,400
Kentucky	3.45	5.28	5.70	78,384	63,360	186,162
Louisiana	3.60	5.20	5.50	20,034	61,776	120,698
Maryland	3.43	5.97	6.50	28,726	63,043	85,410
Michigan	3.41	5.01	5.65	161,805	172,595	276,794
Minnesota	4.55	7.28	6.80	364,404	595,467	713,958
Mississippi	3.52	4.30	5.55	15,161	79,464	166,889
Missouri	3.52	5.17	5.55	172,973	195,633	309,024
Montana	4.54	7.14	6.55	693,854	1,075,754	1,091,189
Nebraska	4.57	5.82	6.70	279,684	490,510	492,316
Nevada	4.15	6.50	7.20	4,356	8,363	7,916
New Jersey	3.80	5.80	6.30	5,016	8,282	12,682
New Mexico	4.55	5.50	6.75	18,564	46,200	28,350
New York	4.03	6.92	6.50	23,354	31,175	49,959
North Carolina	3.26	4.90	5.80	80,783	98,000	250,560
North Dakota	4.50	7.74	7.20	1,129,611	2,339,614	2,298,658
Ohio	3.35	5.37	5.80	218,688	239,126	429,896
Oklahoma	4.70	6.22	6.50	383,520	609,560	1,082,250
Oregon	4.48	8.23	6.50	192,911	358,968	340,178
Pennsylvania	3.52	6.60	6.05	31,152	59,334	71,632
South Carolina	3.05	4.55	6.00	18,758	18,428	66,420
South Dakota	4.44	6.42	6.80	374,316	899,263	1,175,158
Tennessee	3.53	5.05	6.05	42,925	53,833	198,198
Texas	4.47	6.40	7.45	150,192	899,840	737,550
Utah	4.85	8.30	7.30	29,385	46,822	41,940
Virginia	3.24	5.78	6.10	34,150	75,834	121,268
Washington	4.49	7.58	6.40	617,865	949,132	754,712
West Virginia	3.50	6.17	6.00	1,281	2,110	2,880
Wisconsin	3.47	5.30	5.80	63,490	99,002	133,402
Wyoming	4.53	6.68	7.20	17,583	22,048	30,861
US	**4.26**	**6.48**	**6.80**	**7,694,734**	**13,289,326**	**16,568,211**

Source: U.S. Department of Agriculture, *2009 Agricultural Statistics,* Table 1-10, http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

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

Section: FEEDSTOCKS

Wheat Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2008-2009[a]

(dollars per planted acre)

Item	United States		Northern Great Plains		Prarie Gateway		Basin and Range		Fruitful Rim		Northern Crescent		Heartland	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Gross value of production														
Primary product: Wheat grain	324.618	218.968	337.016	239.259	265.776	167.042	395.640	282.490	422.368	300.780	392.430	321.177	419.840	274.392
Secondary product: Silage, straw, grazing	9.21	7.98	3.86	3.34	10.90	9.44	4.20	3.64	12.89	11.17	31.06	26.91	18.62	16.13
Total, gross value of production	**333.828**	**226.948**	**340.876**	**242.599**	**276.676**	**176.482**	**399.840**	**286.130**	**435.258**	**311.950**	**423.490**	**348.087**	**438.460**	**290.522**
Operating costs:														
Seed	16.02	15.82	16.19	16.47	10.89	11.08	21.74	22.11	18.56	18.88	40.34	41.03	32.00	32.55
Fertilizer[b]	52.51	61.14	44.21	52.56	45.19	53.73	71.38	84.87	58.33	69.35	106.77	126.95	102.67	122.08
Chemicals	9.32	10.11	15.72	17.32	4.13	4.56	15.40	16.97	9.69	10.68	5.93	6.54	5.30	5.84
Custom operations	7.86	7.90	8.16	8.22	7.49	7.54	7.51	7.56	8.17	8.23	12.82	12.91	7.06	7.11
Fuel, lube, and electricity	25.25	17.13	13.09	8.68	31.81	21.08	19.56	12.96	79.81	52.90	15.74	10.43	12.50	8.28
Repairs	13.34	13.72	11.37	11.59	14.56	14.84	14.45	14.73	20.70	21.10	12.25	12.49	10.22	10.42
Purchased irrigation water and straw baling	0.35	0.38	0.11	0.12	0.08	0.09	0.85	0.94	3.06	3.37	0.85	0.94	0.59	0.65
Interest on operating inputs	1.03	0.18	0.90	0.17	0.95	0.16	1.25	0.23	1.65	0.27	1.62	0.31	1.41	0.27
Total, operating costs	**125.68**	**126.38**	**109.75**	**115.13**	**115.10**	**113.08**	**152.14**	**160.37**	**199.97**	**184.78**	**196.32**	**211.60**	**171.75**	**187.20**
Allocated overhead:														
Hired labor	2.65	2.74	2.06	2.10	2.60	2.65	4.51	4.60	8.06	8.24	1.33	1.36	1.17	1.19
Opportunity cost of unpaid labor	23.04	23.82	15.94	16.29	26.99	27.58	30.25	30.91	37.65	38.48	27.84	28.45	18.73	19.14
Capital recovery of machinery and equipmen	58.95	62.92	54.77	58.43	56.70	60.50	71.32	76.10	93.75	100.03	65.56	69.96	57.40	61.24
Opportunity cost of land (rental rate)	48.90	54.42	45.71	51.97	36.12	41.07	61.60	70.04	92.17	104.80	79.65	90.57	88.13	100.21
Taxes and insurance	9.05	10.05	11.40	12.79	6.46	7.25	11.43	12.83	11.40	12.79	12.89	14.47	8.26	9.28
General farm overhead	9.13	9.21	10.34	10.54	7.14	7.28	9.67	9.85	12.84	13.09	16.18	16.50	9.52	9.70
Total, allocated overhead	**151.72**	**163.16**	**140.22**	**152.12**	**136.01**	**146.33**	**188.78**	**204.33**	**255.87**	**277.43**	**203.45**	**221.31**	**183.21**	**200.76**
Total, costs listed	**277.40**	**289.54**	**249.97**	**267.25**	**251.11**	**259.41**	**340.92**	**364.70**	**455.84**	**462.21**	**399.77**	**432.91**	**354.96**	**387.96**
Value of production less total costs listed	56.43	-62.59	90.91	-24.65	25.57	-82.93	58.92	-78.57	-20.58	-150.26	23.72	-84.82	83.50	-97.44
Value of production less operating costs	208.15	100.57	231.13	127.47	161.58	63.40	247.70	125.76	235.29	127.17	227.17	136.49	266.71	103.32
Supporting information:														
Yield (bushels per planted acre)	41.3	40.4	41.2	46.1	33.6	28.9	50.4	53.3	53.6	55.7	63.5	70.9	64.0	61.8
Price (dollars per bushel at harvest)	7.86	5.42	8.18	5.19	7.91	5.78	7.85	5.30	7.88	5.40	6.18	4.53	6.56	4.44
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	*	*	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.

Section: FEEDSTOCKS
Cotton: Area, Yield, Production, and Value, 1996-2008

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	14,653	12,888	705	18,942.0	70.50	6,408,144
1997	13,898	13,406	673	18,793.0	66.20	5,975,585
1998	13,393	10,684	625	13,918.2	61.70	4,119,911
1999	14,874	13,425	607	16,968.0	46.80	3,809,560
2000	15,517	13,053	632	17,188.3	51.60	4,260,417
2001	15,769	13,828	705	20,302.8	32.00	3,121,848
2002	13,958	12,417	665	17,208.6	45.70	3,777,132
2003	13,480	12,003	730	18,255.2	63.00	5,516,761
2004	13,659	13,057	855	23,250.7	44.70	4,993,565
2005	14,245	13,803	831	23,890.2	49.70	5,695,217
2006	15,274	12,732	814	21,587.8	48.40	5,013,238
2007	10,827	10,489	879	19,206.9	61.30	5,652,907
2008[b]	9,470	7,728	810	13,035.6	56.60	3,538,573

Source: U.S. Department of Agriculture, *2009 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 2006, 2007, and 2008

State and cotton classification	Area Planted			Area Harvested			Yield per Harvested Acre			Production[a]		
	2006	2007	2008[b]	2006	2007	2008[b]	2006	2007	2008[b]	2006	2007	2008[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	575.0	400.0	290.0	560.0	385.0	287.0	579	519	836	675.0	416.0	500.0
Arizona	190.0	170.0	135.0	188.0	168.0	133.0	1,420	1,469	1,444	556.0	514.0	400.0
Arkansas	1,170.0	860.0	620.0	1,160.0	850.0	615.0	1,045	1,071	1,022	2,525.0	1,896.0	1,310.0
California	285.0	195.0	120.0	283.0	194.0	117.0	1,321	1,608	1,518	779.0	650.0	370.0
Florida	103.0	85.0	67.0	101.0	81.0	65.0	789	687	901	166.0	116.0	122.0
Georgia	1,400.0	1,030.0	940.0	1,370.0	995.0	920.0	818	801	840	2,334.0	1,660.0	1,610.0
Kansas	115.0	47.0	35.0	110.0	43.0	28.0	511	639	686	117.0	57.2	40.0
Louisiana	635.0	335.0	300.0	630.0	330.0	240.0	946	1,017	560	1,241.0	699.0	280.0
Mississippi	1,230.0	660.0	365.0	1,220.0	655.0	360.0	829	966	920	2,107.0	1,318.0	690.0
Missouri	500.0	380.0	306.0	496.0	379.0	303.0	953	968	1,061	985.0	764.0	670.0
New Mexico	50.0	43.0	37.0	48.0	39.0	34.0	930	1,095	988	93.0	89.0	70.0
North Carolina	870.0	500.0	430.0	865.0	490.0	428.0	713	767	864	1,285.0	783.0	770.0
Oklahoma	320.0	175.0	170.0	180.0	165.0	155.0	541	817	805	203.0	281.0	260.0
South Carolina	300.0	180.0	135.0	298.0	158.0	134.0	697	486	896	433.0	160.0	250.0
Tennessee	700.0	515.0	285.0	695.0	510.0	280.0	945	565	917	1,368.0	600.0	535.0
Texas	6,400.0	4,900.0	5,000.0	4,100.0	4,700.0	3,400.0	679	843	649	5,800.0	8,250.0	4,600.0
Virginia	105.0	60.0	61.0	104.0	59.0	60.0	717	829	896	155.4	101.9	112.0
Total	**14,948.0**	**10,535.0**	**9,296.0**	**12,408.0**	**10,201.0**	**7,559.0**	**806**	**864**	**799**	**20,822.4**	**18,355.1**	**12,589.0**
American-Pima:												
Arizona	7.0	2.5	0.8	7.0	2.5	0.8	919	883	960	13.4	4.6	1.6
California	275.0	260.0	155.0	274.0	257.0	151.0	1,204	1,481	1,319	687.0	793.0	415.0
New Mexico	13.0	4.7	2.7	12.5	4.6	2.6	768	856	1,108	20.0	8.2	6.0
Texas	31.0	25.0	15.5	30.0	24.0	15.0	720	920	768	45.0	46.0	24.0
Total	326.0	292.2	174.0	323.5	288.1	169.4	1,136	1,419	1,265	765.4	851.8	446.6
U.S. Total	**15,274.0**	**10,827.2**	**9,470.0**	**12,731.5**	**10,489.1**	**7,728.4**	**814**	**879**	**810**	**21,587.8**	**19,206.9**	**13,035.6**

Source: U.S. Department of Agriculture, *2009 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.

Section: FEEDSTOCKS

Cotton Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2008-2009[a]

(dollars per planted acre)

Item	United States		Heartland		Prarie Gateway		Southern Seaboard		Fruitful Rim		Mississippi Portal	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**
Gross value of production												
Primary product: Cotton	366.56	349.98	613.20	495.72	261.08	264.32	462.00	490.20	436.74	425.04	477.68	408.10
Secondary product: Cottonseed	114.95	79.44	194.81	118.80	83.16	61.04	120.06	79.32	158.21	122.70	151.80	96.08
Total, gross value of production	**481.51**	**429.42**	**808.01**	**614.52**	**344.24**	**325.36**	**582.06**	**569.52**	**594.95**	**547.74**	**629.48**	**504.18**
Operating costs:												
Seed	64.78	73.52	106.04	121.43	49.70	56.91	72.10	82.56	66.51	76.16	90.44	103.56
Fertilizer[b]	90.95	89.30	115.24	113.16	52.91	51.96	143.10	140.52	119.77	117.62	122.32	120.12
Chemicals	62.76	68.88	81.81	91.50	38.67	43.25	82.83	92.65	89.68	100.30	95.73	107.08
Custom operations	20.79	22.11	13.02	14.18	12.83	13.97	21.09	22.97	57.58	62.71	26.79	29.18
Fuel, lube, and electricity	61.10	40.11	63.15	40.91	61.80	41.41	51.39	34.11	112.72	74.99	46.91	30.63
Repairs	33.22	33.52	42.24	43.06	30.77	31.37	33.07	33.71	35.64	36.33	38.55	39.30
Ginning	96.24	100.72	154.86	140.43	65.44	78.06	105.09	112.57	171.96	187.44	126.30	118.83
Purchased irrigation water	2.91	2.86	0.00	0.00	0.00	0.00	0.00	0.00	33.59	36.58	0.00	0.00
Interest on operating capital	3.20	0.63	4.27	0.82	2.31	0.46	3.76	0.75	5.09	1.00	4.05	0.80
Total, operating costs	435.95	431.65	580.63	565.49	314.43	317.39	512.43	519.84	692.54	693.13	551.09	549.50
Allocated overhead:												
Hired labor	14.21	14.26	17.16	17.54	11.68	11.94	13.17	13.46	26.84	27.43	16.27	16.63
Opportunity cost of unpaid labor	25.62	26.11	26.85	27.44	28.58	29.20	20.25	20.70	32.11	32.81	19.97	20.41
Capital recovery of machinery and equipment	120.33	129.07	164.14	177.69	108.74	117.71	120.02	129.92	138.43	149.85	138.73	150.18
Opportunity cost of land (rental rate)	57.77	63.77	85.99	96.67	34.20	38.44	69.63	78.29	97.36	109.46	87.63	98.52
Taxes and insurance	8.17	8.67	7.43	7.96	6.86	7.35	8.47	9.08	11.10	11.90	10.33	11.08
General farm overhead	15.42	15.51	13.45	13.71	11.81	12.04	17.77	18.12	26.34	26.86	18.71	19.07
Total, allocated overhead	241.53	257.39	315.02	341.01	201.87	216.68	249.31	269.57	332.18	358.31	291.64	315.89
Total costs listed	**677.48**	**689.04**	**895.65**	**906.50**	**516.30**	**534.07**	**761.74**	**789.41**	**1,024.72**	**1,051.44**	**842.73**	**865.39**
Value of production less total costs listed	-195.97	-259.62	-87.64	-291.98	-172.06	-208.71	-179.68	-219.89	-429.77	-503.70	-213.25	-361.21
Value of production less operating costs	45.56	-2.23	227.38	49.03	29.81	7.97	69.63	49.68	-97.59	-145.39	78.39	-45.32
Supporting information:												
Cotton Yield (pounds per planted acre)	632	614	1095	918	428	472	825	817	753	759	853	742
Price (dollars per pound)	0.58	0.57	0.56	0.54	0.61	0.56	0.56	0.6	0.58	0.56	0.56	0.55
Cottonseed Yield (pounds per planted acre)	1,045	993	1,771	1,485	693	763	1,334	1,322	1,217	1,227	1,380	1,201
Price (dollars per pound)	0.11	0.08	0.11	0.08	0.12	0.08	0.09	0.06	0.13	0.10	0.11	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.

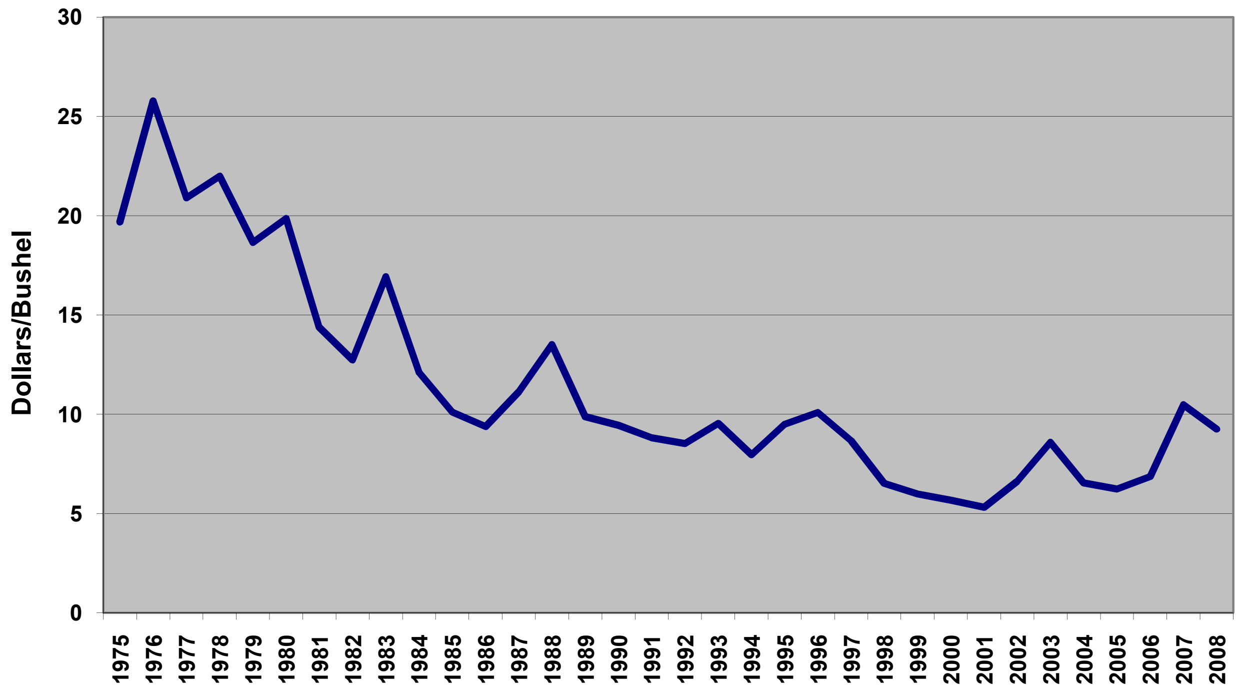
Section: FEEDSTOCKS
Soybeans and Products Baseline Projections, 2008-2019

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
Area (million acres):												
Planted	75.7	77.5	76.5	73.5	74.5	75.5	76.0	76.0	76.0	76.0	76.0	76.0
Harvested	74.7	76.6	75.5	72.5	73.5	74.5	75.0	75.0	75.0	75.0	75.0	75.0
Yield/harvested acre (bushels)	39.7	43.3	42.8	43.2	43.6	44.0	44.4	44.9	45.3	45.7	46.1	46.5
Supply (million bushels)												
Beginning stocks, Sept 1	205	138	270	354	299	271	260	258	260	261	262	262
Production	2,967	3,319	3,230	3,130	3,205	3,280	3,330	3,370	3,400	3,430	3,460	3,490
Imports	13	8	5	5	5	5	5	5	5	5	5	5
Total supply	3,185	3,465	3,505	3,489	3,509	3,556	3,595	3,633	3,665	3,696	3,727	3,757
Disposition (million bushels)												
Crush	1,662	1,695	1,680	1,695	1,710	1,735	1,755	1,775	1,800	1,820	1,840	1,860
Seed and residual	101	175	171	170	173	176	177	178	179	179	180	181
Exports	1,283	1,325	1,300	1,325	1,355	1,385	1,405	1,420	1,425	1,435	1,445	1,455
Total disposition	3,047	3,196	3,151	3,190	3,238	3,296	3,337	3,373	3,404	3,434	3,465	3,496
Carryover stocks, August 31												
Total ending stocks	138	270	354	299	271	260	258	260	261	262	262	261
Stocks/use ratio, percent	4.5	8.4	11.2	9.4	8.4	7.9	7.7	7.7	7.7	7.6	7.6	7.5
Prices (dollars per bushel)												
Loan rate	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Soybean price, farm	9.97	9.20	9.00	9.10	9.20	9.20	9.25	9.25	9.25	9.25	9.20	9.20
Variable costs of production (dollars):												
Per acre	127.06	121.36	122.99	127.42	129.71	131.73	133.71	135.88	138.02	140.07	142.12	144.18
Per bushel	3.20	2.80	2.87	2.95	2.97	2.99	3.01	3.03	3.05	3.07	3.08	3.10
Returns over variable costs (dollars per acre):												
Net returns	269	277	262	266	271	273	277	279	281	283	282	284
Soybean oil (million pounds)												
Beginning stocks, Oct. 1	2,485	2,739	2,304	2,109	2,109	2,059	2,019	1,934	1,854	1,839	1,829	1,824
Production	18,753	19,240	19,070	19,255	19,445	19,745	19,990	20,235	20,540	20,785	21,030	21,280
Imports	90	75	85	95	105	115	125	135	145	155	165	175
Total supply	21,328	22,054	21,459	21,459	21,659	21,919	22,134	22,304	22,539	22,779	23,024	23,279
Domestic disappearance	16,339	16,500	16,600	16,800	17,200	17,400	17,600	17,800	18,000	18,200	18,400	18,600
For methyl ester [a]	1,904	2,200	2,400	2,600	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900
Exports	2,250	3,250	2,750	2,550	2,400	2,500	2,600	2,650	2,700	2,750	2,800	2,850
Total demand	18,589	19,750	19,350	19,350	19,600	19,900	20,200	20,450	20,700	20,950	21,200	21,450
Ending stocks, Sept. 30	2,739	2,304	2,109	2,109	2,059	2,019	1,934	1,854	1,839	1,829	1,824	1,829
Soybean oil price ($/lb)	0.3216	0.3500	0.3700	0.3900	0.3950	0.3950	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
Soybean meal (thousand short tons)												
Beginning stocks, Oct. 1	294	239	300	300	300	300	300	300	300	300	300	300
Production	39,112	40,321	40,035	40,335	40,735	41,235	41,735	42,285	42,785	43,285	43,785	44,285
Imports	90	140	165	165	165	165	165	165	165	165	165	165
Total supply	39,496	40,700	40,500	40,800	41,200	41,700	42,200	42,750	43,250	43,750	44,250	44,750
Domestic disappearance	30,757	30,800	30,800	30,900	31,250	31,700	32,150	32,650	33,150	33,650	34,150	34,650
Exports	8,500	9,600	9,400	9,600	9,650	9,700	9,750	9,800	9,800	9,800	9,800	9,800
Total demand	39,257	40,400	40,200	40,500	40,900	41,400	41,900	42,450	42,950	43,450	43,950	44,450
Ending stocks, Sept. 30	239	300	300	300	300	300	300	300	300	300	300	300
Soybean meal price ($/ton)	331.17	280.00	255.00	250.00	255.00	255.00	255.00	255.00	255.00	255.00	253.00	253.00
Crushing yields (pounds per bushel)												
Soybean oil	11.28	11.35	11.35	11.36	11.37	11.38	11.39	11.40	11.41	11.42	11.43	11.44
Soybean meal	47.08	47.58	47.60	47.60	47.60	47.60	47.60	47.60	47.60	47.60	47.60	47.60
Crush margin ($ per bushel)	1.45	1.43	1.27	1.28	1.36	1.36	1.38	1.38	1.38	1.39	1.39	1.40

Source:
U.S.Department of Agriculture, *USDA Agricultural Projections to 2019*, February 2010, Table 23 - U.S. soybean and products, long term projections
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1192

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, 1975-2008
(constant 2008 dollars)



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

In 2001, only 5 million gallons of biodiesel fuel was produced requiring a very small amount of all soybeans harvested. By 2007, about 450 million gallons of biodiesel fuel was produced with about 90% being derived from soybeans. At a conversion rate of 1.5 gallons of biodiesel per bushel of soybeans[a], the total bushels of soybeans used in biodiesel production was approximately 675 million bushels.

Section: FEEDSTOCKS
Soybeans: Area, Yield, Production, and Value, 1996-2008

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	74,641	39.6	2,959,174	9.25	27,398,638

Source:
U.S. Department of Agriculture, *2009 Agricultural Statistics*, Table 3-31,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] National Biodiesel Board

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, 2006-2008

State	Area planted			Soybeans for beans								
				Area harvested			Yield per harvested acre			Production		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
	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	160	190	360	150	185	350	20.0	21.0	35.0	3,000	3,885	12,250
Arizona	3,110	2,850	3,300	3,070	2,820	3,250	35.0	36.0	38.0	107,450	101,520	123,500
Delaware	180	160	195	177	155	193	31.5	26.0	27.5	5,576	4,030	5,308
Florida	7	14	32	5	12	29	27.0	24.0	38.0	135	288	1,102
Georgia	155	295	430	140	285	415	25.0	30.0	30.0	3,500	8,550	12,450
Illinois	10,100	8,300	9,200	10,050	8,280	9,100	48.0	43.5	47.0	482,400	360,180	427,700
Indiana	5,700	4,800	5,450	5,680	4,790	5,430	50.0	46.0	45.0	284,000	220,340	244,350
Iowa	10,150	8,650	9,750	10,100	8,630	9,670	50.5	52.0	46.0	510,050	448,760	444,820
Kansas	3,150	2,650	3,300	3,080	2,610	3,250	32.0	33.0	37.0	98,560	86,130	120,250
Kentucky	1,380	1,120	1,390	1,370	1,100	1,380	44.0	27.5	34.0	60,280	30,250	46,920
Louisiana	870	615	1,050	840	600	950	36.0	43.0	33.0	30,240	25,800	31,350
Maryland	470	405	495	465	390	485	34.0	27.5	30.0	15,810	10,725	14,550
Michigan	2,000	1,800	1,900	1,990	1,790	1,890	46.0	40.0	37.0	91,540	71,600	69,930
Minnesota	7,350	6,350	7,050	7,250	6,290	6,950	44.5	42.5	38.0	322,625	267,325	264,100
Mississippi	1,670	1,460	2,000	1,650	1,440	1,960	26.0	40.5	40.0	42,900	58,320	78,400
Missouri	5,150	4,700	5,200	5,110	4,670	5,030	38.0	37.5	38.0	194,180	175,125	191,140
Nebraska	5,050	3,870	4,900	5,010	3,850	4,860	50.0	51.0	46.5	250,500	196,350	225,990
New Jersey	88	82	92	86	80	90	35.0	31.0	29.0	3,010	2,480	2,610
New York	200	205	230	198	203	226	46.0	39.0	46.0	9,108	7,917	10,396
North Carolina	1,370	1,440	1,690	1,360	1,380	1,670	32.0	22.0	33.0	43,520	30,360	55,110
North Dakota	3,900	3,100	3,800	3,870	3,060	3,760	31.5	35.5	28.0	121,905	108,630	105,280
Ohio	4,650	4,250	4,500	4,620	4,240	4,480	47.0	47.0	36.0	217,140	199,280	161,280
Oklahoma	310	190	400	215	180	360	17.0	26.0	25.0	3,655	4,680	9,000
Pennsylvania	430	435	435	425	430	430	40.0	41.0	40.0	17,000	17,630	17,200
South Carolina	400	460	540	390	440	530	29.0	18.5	32.0	11,310	8,140	16,960
South Dakota	3,950	3,250	4,100	3,850	3,240	4,060	34.0	42.0	34.0	130,900	136,080	138,040
Tennessee	1,160	1,080	1,490	1,130	1,010	1,460	39.0	19.0	34.0	44,070	19,190	49,640
Texas	225	95	230	155	92	205	24.0	37.5	24.0	3,720	3,450	4,920
Virginia	520	510	580	510	500	570	31.0	27.5	32.0	15,810	13,750	18,240
West Virginia	17	15	19	16	14	18	42.0	33.0	41.0	672	462	738
Wisconsin	1,650	1,400	1,610	1,640	1,380	1,590	44.0	40.5	35.0	72,160	55,890	55,650
US	**75,522**	**64,741**	**75,718**	**74,602**	**64,146**	**74,641**	**42.9**	**41.7**	**39.6**	**3,196,726**	**2,677,117**	**2,959,174**

Source:
U.S.Department of Agriculture, *2009 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 1995-2007.

Section: FEEDSTOCKS
Soybeans: Supply and Disappearance, 1995-2007
(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[b]	143,000	430,810	573,810	2,677,117	3,260,798

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[b]	1,801,324	93,445	1,166,995	3,055,764

Source:
U.S. Department of Agriculture, *2009 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 by about 77 cents from 2005 to 2006 and then rose sharply by nearly 4 dollars between 2006 and 2007.

Section: FEEDSTOCKS

Soybeans for Beans: Marketing Year Average Price and Value, by State, Crop of 2006, 2007, and 2008

State[a]	Marketing year average price per bushel 2006	2007	2008[b]	Value of production 2006	2007	2008[b]
	Dollars	Dollars	Dollars	1,000 Dollars	1,000 Dollars	1,000 Dollars
Alabama	6.85	11.40	9.50	20,550	44,289	116,375
Arkansas	6.41	9.02	8.85	688,755	915,710	1,092,975
Delaware	6.60	11.50	9.00	36,802	46,345	47,772
Florida	6.25	8.90	8.50	844	2,563	9,367
Georgia	6.85	11.90	9.20	23,975	101,745	114,540
Illinois	6.68	10.40	9.35	3,222,432	3,745,872	3,998,995
Indiana	6.53	10.20	9.30	1,854,520	2,247,468	2,272,455
Iowa	6.58	10.50	9.65	3,356,129	4,711,980	4,292,513
Kansas	6.37	10.10	8.60	627,827	869,913	1,034,150
Kentucky	6.68	10.10	8.85	402,670	305,525	415,242
Louisiana	5.94	8.43	9.30	179,626	217,494	291,555
Maryland	6.40	11.20	8.75	101,184	120,120	127,313
Michigan	6.27	9.69	9.20	573,956	693,804	643,356
Minnesota	6.26	10.20	9.60	2,019,633	2,726,715	2,535,360
Mississippi	6.23	8.36	8.75	267,267	487,555	686,000
Missouri	6.47	10.10	9.00	1,256,345	1,768,763	1,720,260
Nebraska	6.05	9.92	9.40	1,515,525	1,947,792	2,124,306
New Jersey	6.25	10.10	8.75	18,813	25,048	22,838
New York	6.19	11.20	8.25	56,379	88,670	85,767
North Carolina	6.35	10.10	8.65	276,352	306,636	476,702
North Dakota	5.98	9.63	9.10	728,992	1,046,107	958,048
Ohio	6.46	9.93	9.60	1,402,724	1,978,850	1,548,288
Oklahoma	6.35	10.00	9.00	23,209	46,800	81,000
Pennsylvania	6.25	10.70	8.75	106,250	188,641	150,500
South Carolina	6.80	10.90	8.70	76,908	88,726	147,552
South Dakota	6.03	9.60	9.05	789,327	1,306,368	1,249,262
Tennessee	6.30	10.30	8.75	277,641	197,657	434,350
Texas	5.40	10.40	9.25	20,088	35,880	45,510
Virginia	6.54	11.40	8.65	103,397	156,750	157,776
West Virginia	6.40	11.30	8.85	4,301	5,221	6,531
Wisconsin	6.04	9.83	9.20	435,846	549,399	511,980
US	**6.43**	**10.10**	**9.25**	**20,468,267**	**26,974,406**	**27,398,638**

Source: U.S. Department of Agriculture, *2009 Agricultural Statistics,* Table 3-38, http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

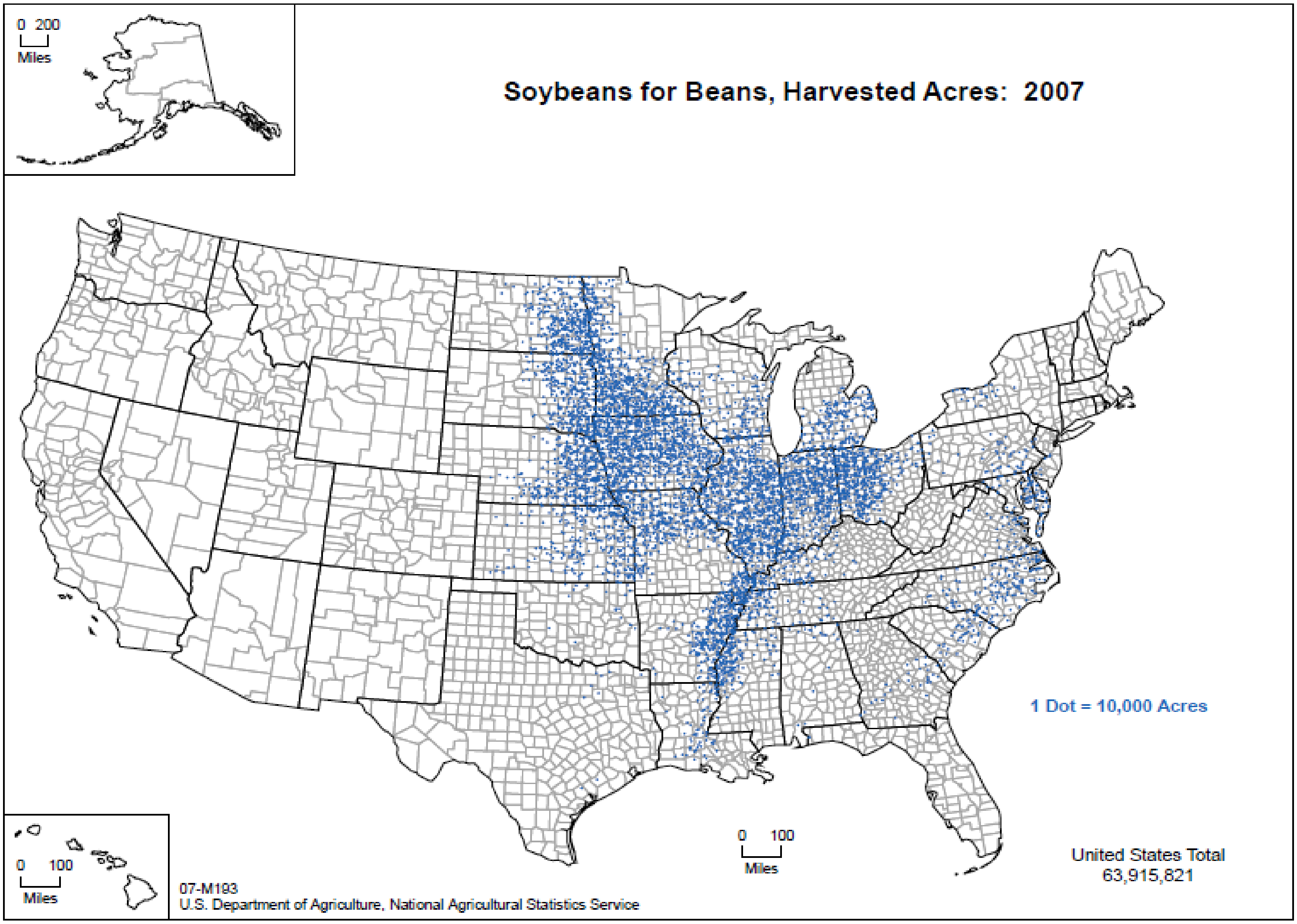
Notes:

[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, 2008-2009[a]

(dollars per planted acre)

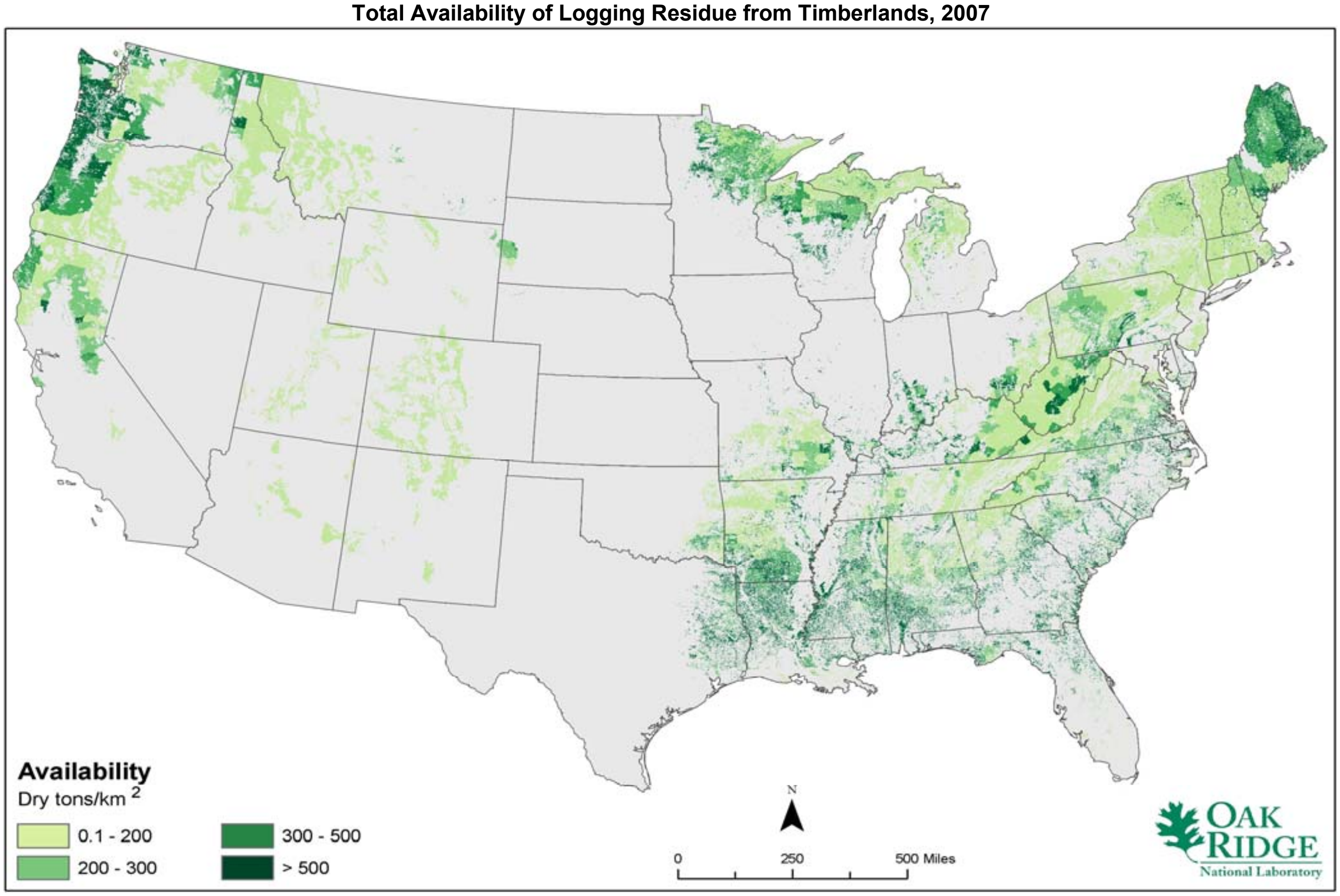
	United States		Heartland		Northern Crescent		Northern Great Plains		Prarie Gateway		Eastern Uplands		Southern Seaboard		Mississippi Portal	
Item	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**
Gross value of production																
Primary product: Soybeans	446.45	438.96	502.58	498.74	393.80	418.26	338.02	325.15	478.12	484.88	389.55	388.72	384.68	375.39	352.47	340.27
Total, gross value of production	**446.45**	**438.96**	**502.58**	**498.74**	**393.80**	**418.26**	**338.02**	**325.15**	**478.12**	**484.88**	**389.55**	**388.72**	**384.68**	**375.39**	**352.47**	**340.27**
Operating costs:																
Seed	44.35	55.26	42.98	53.50	46.55	57.94	46.13	57.43	41.20	51.29	42.21	52.55	40.59	50.52	43.75	54.47
Fertilizer [b]	25.12	23.96	23.42	22.30	36.10	34.36	11.31	10.77	14.04	13.36	38.84	36.97	63.95	60.88	23.92	22.77
Chemicals	15.73	17.26	15.29	16.76	14.80	16.22	13.26	14.53	13.76	15.08	12.21	13.39	16.74	18.35	19.74	21.64
Custom operations	6.56	7.17	5.54	6.03	8.58	9.35	5.30	5.78	8.08	8.80	7.60	8.28	5.61	6.11	9.61	10.47
Fuel, lube, and electricity	20.20	13.48	15.82	10.48	17.92	11.88	14.57	9.65	37.91	25.13	16.78	11.12	14.36	9.52	38.37	25.43
Repairs	12.91	13.22	11.25	11.47	11.18	11.40	13.03	13.29	17.90	18.24	11.15	11.37	10.22	10.42	19.00	19.37
Purchased irrigation water	0.12	0.14	0.00	0.00	0.00	0.00	0.00	0.00	1.62	1.76	0.00	0.00	0.00	0.00	0.00	0.00
Interest on operating capital	2.80	0.19	2.56	0.17	3.03	0.20	2.32	0.16	3.01	0.19	2.88	0.19	3.39	0.23	3.46	0.22
Total, operating costs	**127.79**	**130.67**	**116.86**	**120.71**	**138.16**	**141.35**	**105.92**	**111.61**	**137.52**	**133.85**	**131.67**	**133.87**	**154.86**	**156.03**	**157.85**	**154.37**
Allocated overhead:																
Hired labor	2.07	2.09	1.23	1.23	1.25	1.25	1.61	1.61	2.03	2.03	2.89	2.89	2.84	2.84	7.15	7.15
Opportunity cost of unpaid labor	16.77	16.82	15.34	15.34	17.88	17.88	14.14	14.14	20.37	20.37	17.80	17.80	18.65	18.65	19.40	19.40
Capital recovery of machinery and equipment	70.98	75.88	67.16	71.65	60.84	64.92	75.58	80.65	83.39	88.98	62.90	67.11	58.85	62.80	79.18	84.48
Opportunity cost of land (rental rate)	94.58	108.98	110.67	127.92	77.54	89.62	50.95	58.89	66.23	76.55	61.83	71.47	42.79	49.46	70.27	81.22
Taxes and insurance	9.64	10.84	9.51	10.68	11.97	13.43	8.25	9.26	9.59	10.77	7.38	8.28	8.18	9.18	8.98	10.08
General farm overhead	14.29	14.57	14.34	14.62	18.44	18.80	11.42	11.64	15.63	15.94	13.96	14.23	10.66	10.87	10.31	10.51
Total, allocated overhead	208.35	229.19	218.25	241.44	187.92	205.90	161.95	176.19	197.24	214.64	166.76	181.78	141.97	153.80	195.29	212.84
Total costs listed	**336.13**	**359.86**	**335.11**	**362.15**	**326.08**	**347.25**	**267.87**	**287.80**	**334.76**	**348.49**	**298.43**	**315.65**	**296.83**	**309.83**	**353.14**	**367.21**
Value of production less total costs listed	110.32	79.10	167.47	136.58	67.72	71.01	70.15	37.35	143.36	136.39	91.12	73.06	87.85	65.56	-0.67	-26.95
Value of production less operating costs	318.66	308.29	385.72	378.02	255.64	276.91	232.10	213.54	340.60	351.03	257.88	254.84	229.82	219.36	194.62	185.89
Supporting information:																
Yield (bushels per planted acre)	43	47	46	51	38	42	31	35	44	51	36	40	36	38	34	35
Price (dollars per bushel at harvest)	10.48	9.30	11.04	9.86	10.46	9.90	10.74	9.24	10.96	9.46	10.79	9.84	10.76	9.84	10.40	9.76
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.

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
Total Availability of Logging Residue from Timberlands, 2007



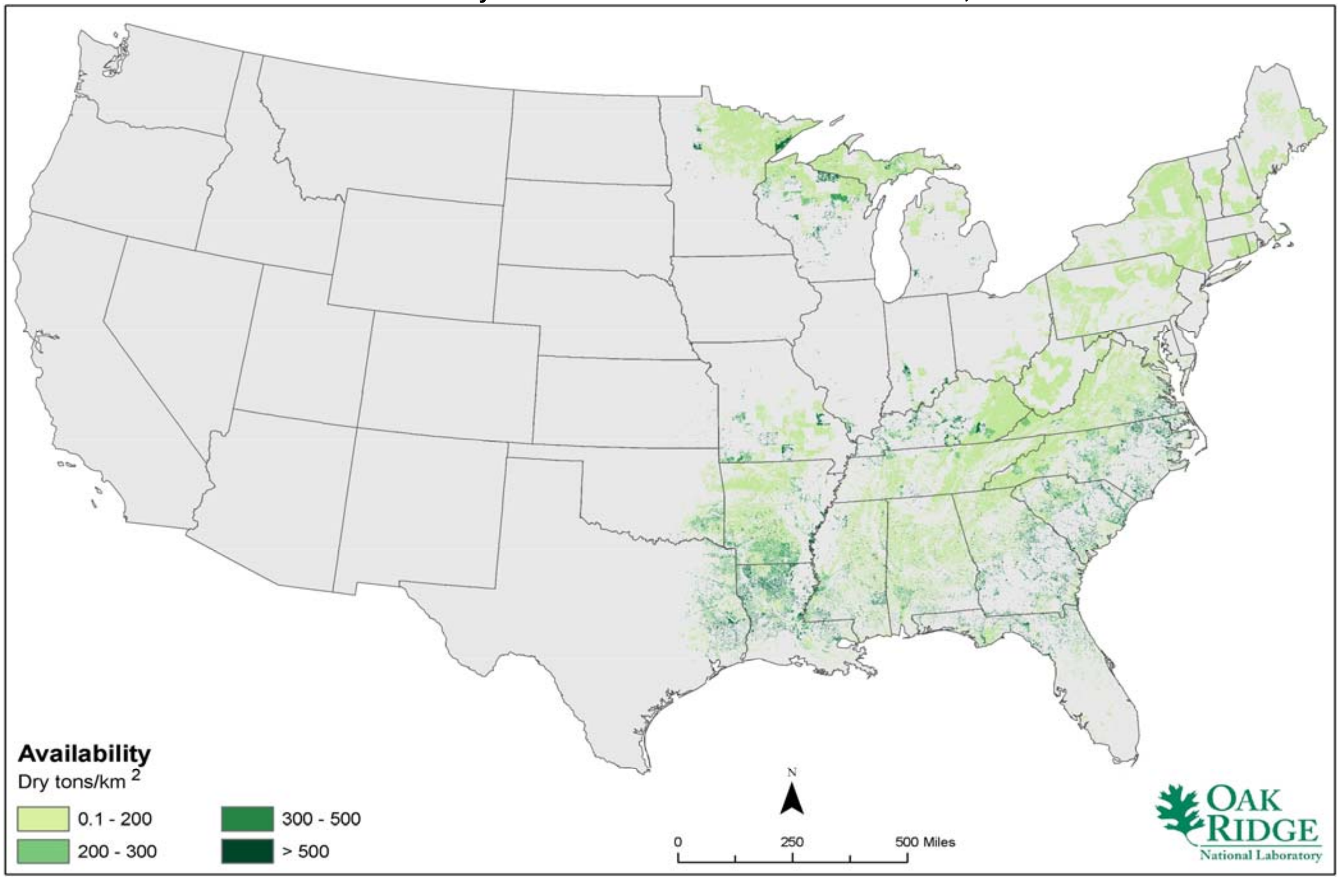
Source:

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.

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
Total Availability of Other Removal Residue from Timberlands, 2007

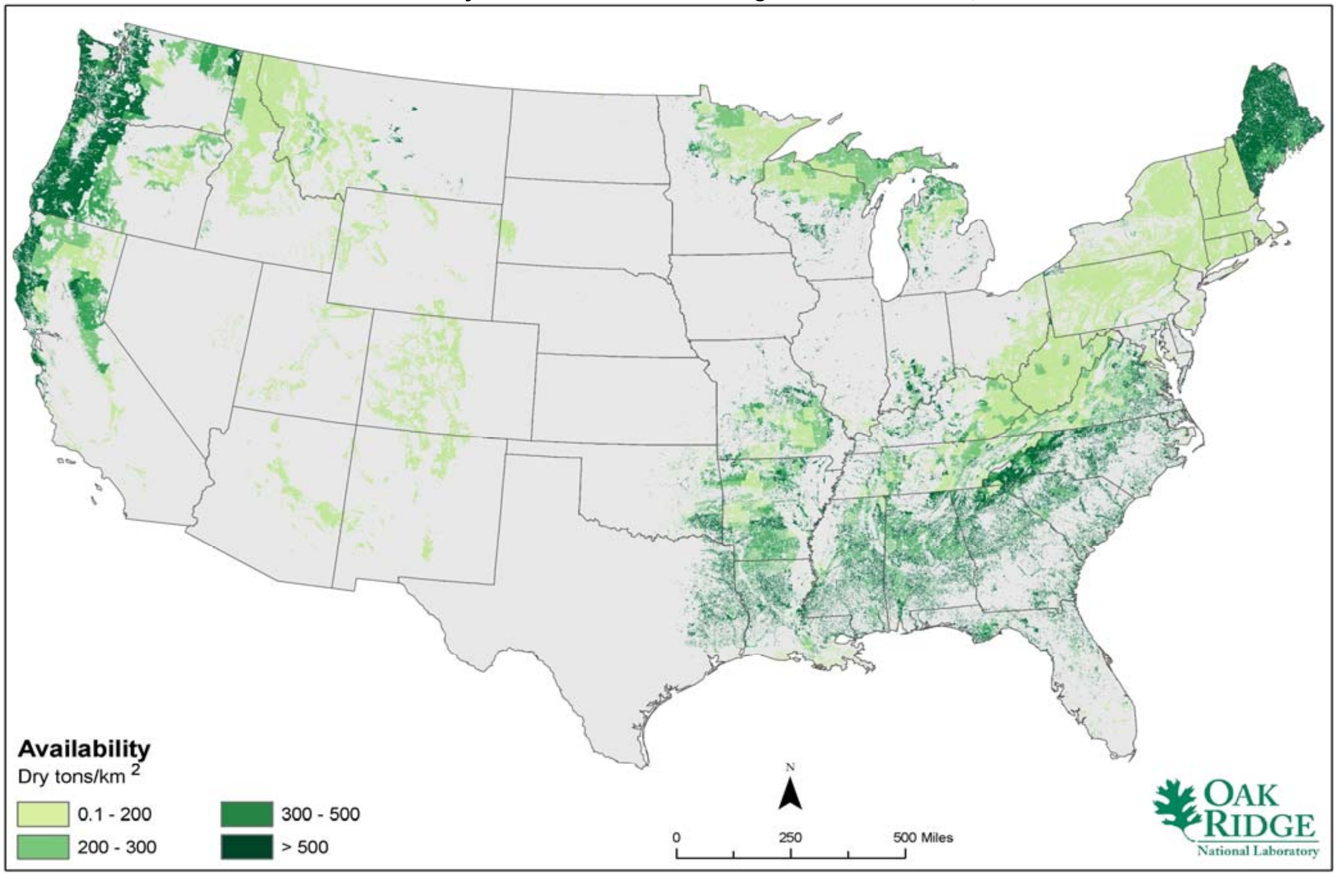


Source:
USDA-FS (U.S. Department of Agriculture - Forest Service). 2007. “Timber Products Output Mapmaker Version 1.0.”

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

Fuel treatment thinnings are the material generated from fuel treatment operations and 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.

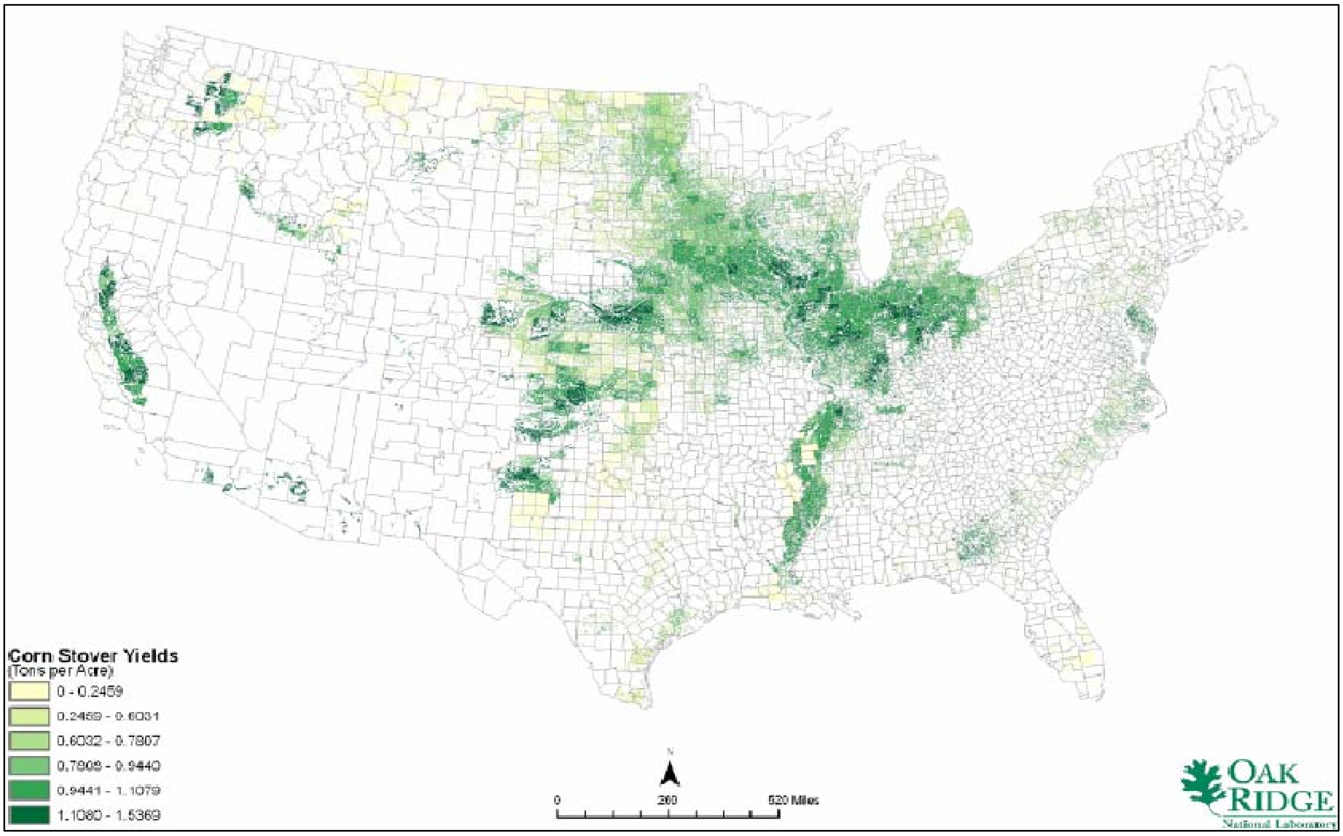
Section: FEEDSTOCKS
Total Availability of Fuel Treatment Thinnings from Timberlands, 2007



Source:

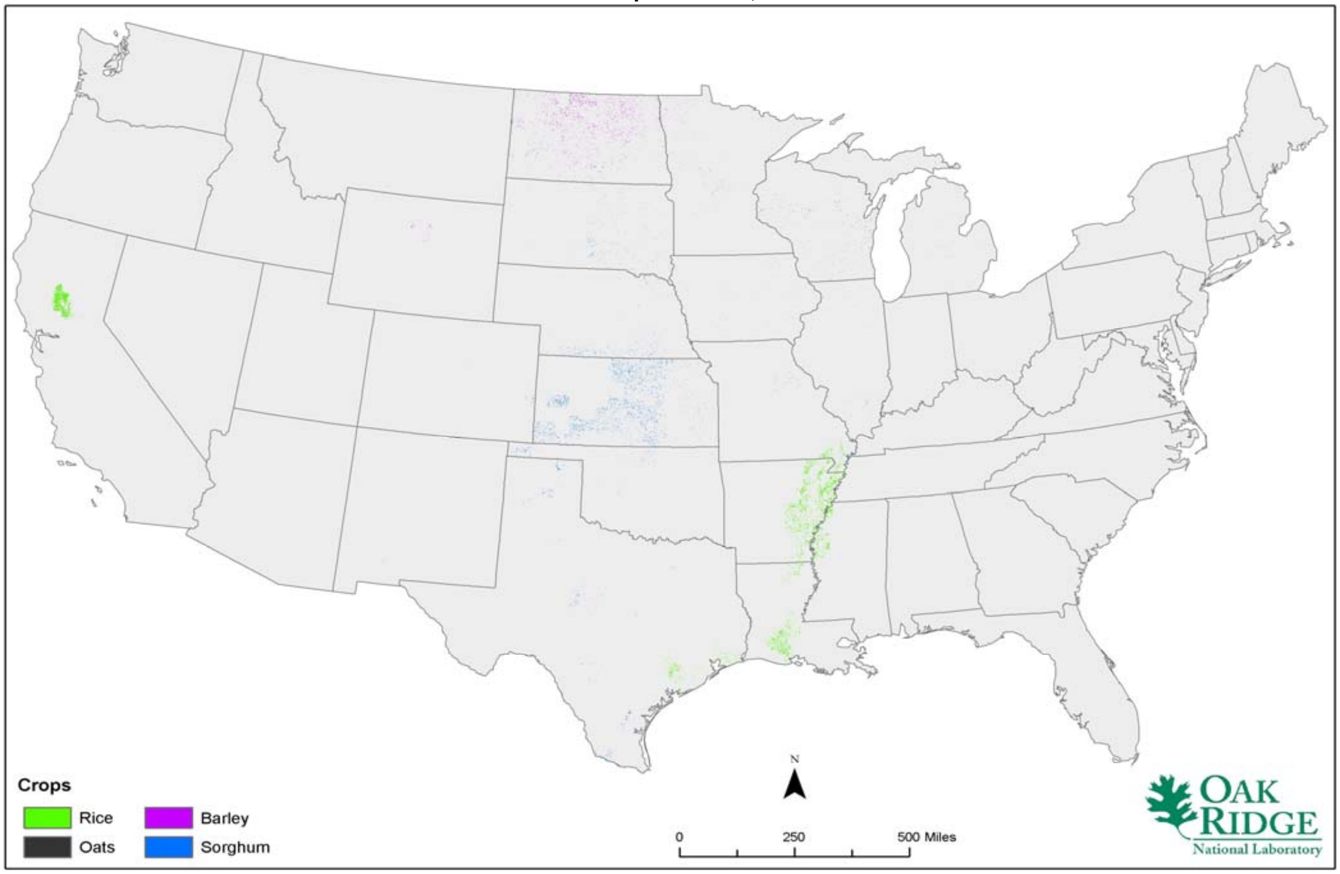
Bioenergy Resource and Engineering Systems Program, Oak Ridge National Laboratory.

Total Availability of Corn Stover Residue, 2007



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

Section: FEEDSTOCKS
Other Crop Residues, 2008



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

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. 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, at the agency 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

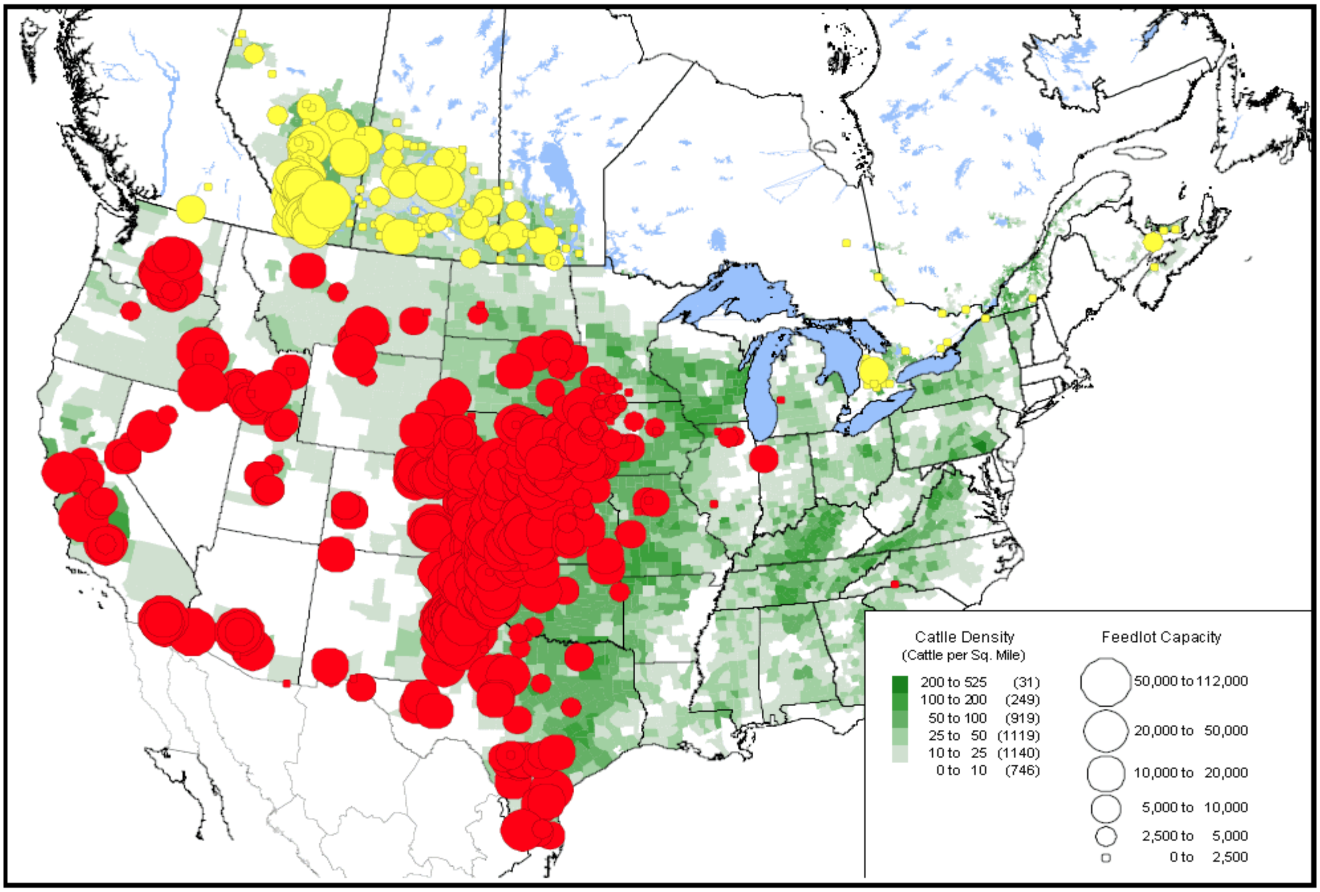
U.S. Forest Service - Woody Biomass Utilization Grantees 2009 & 2010

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

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.

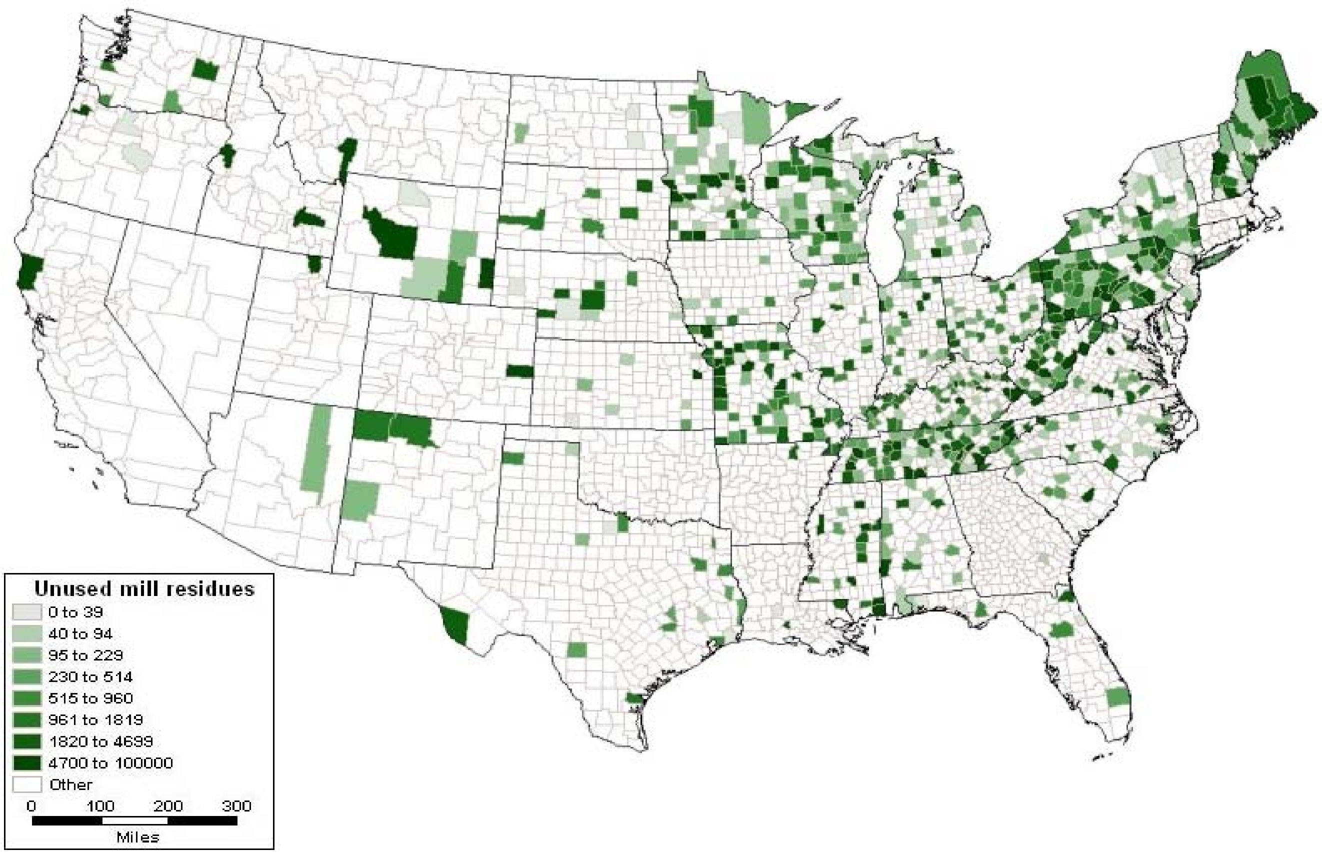
Section: FEEDSTOCKS
Primary Mill Residue Production and Use by State, 2007
(Dry tons)

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

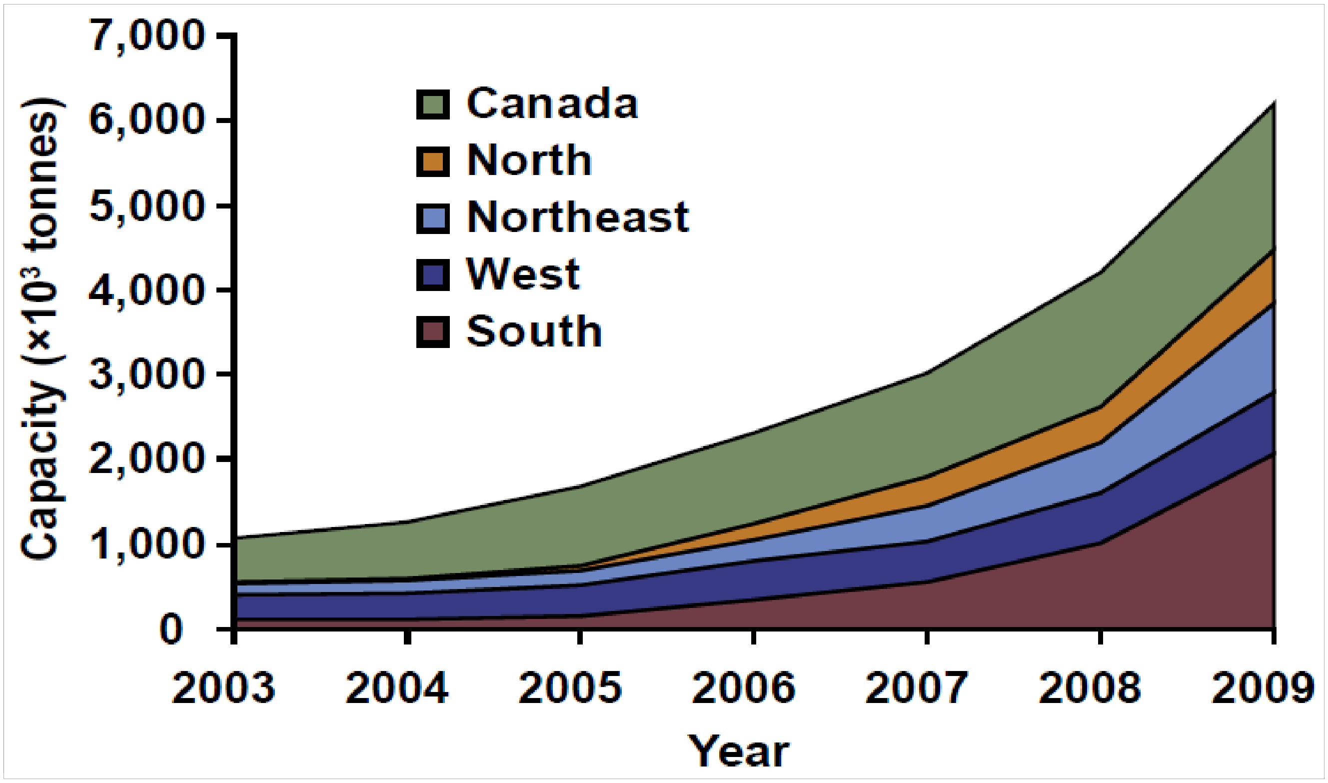


Source:
USDA-FS (U.S. Department of Agriculture - Forest Service). 2007. "Timber Products Output Mapmaker Version 1.0"

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 pellet appliances nearly quadrupled between 1998 and 2006 while cordwood appliance shipments have remained relatively level although, by volume, cordwood appliances are by far the largest share of wood burning appliances.

Section: FEEDSTOCKS
Pellet and Cordwood Appliance Shipments from Manufacturers, 1998-2009

	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	46,124	-67%	235,647	-32%

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.

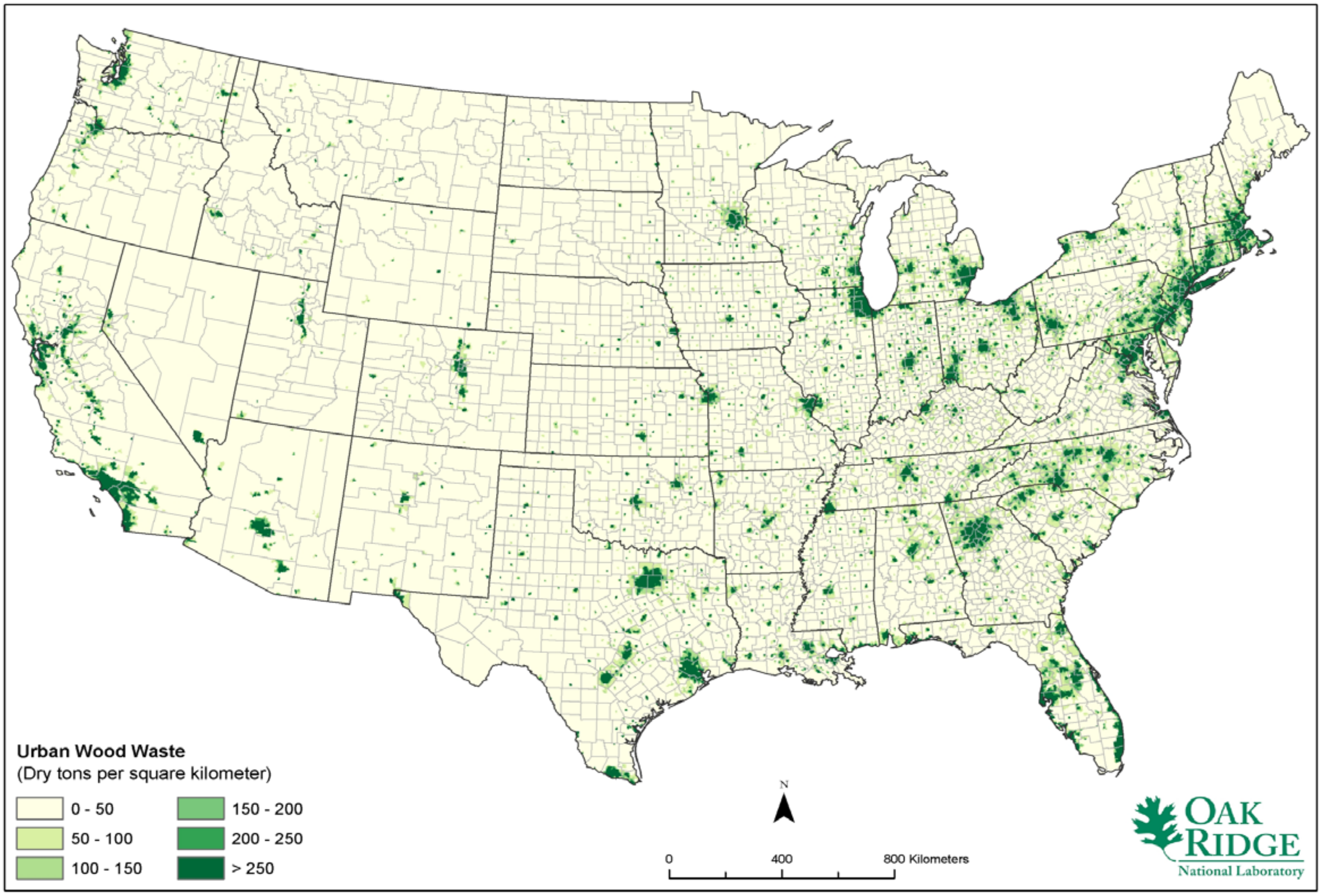
The category "other wood waste from the urban environment" could include trimmings from urban trees, which technically fits the definition of primary biomass. However, because this material is normally handled as a waste stream along with other post-consumer wastes from urban environments (and included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



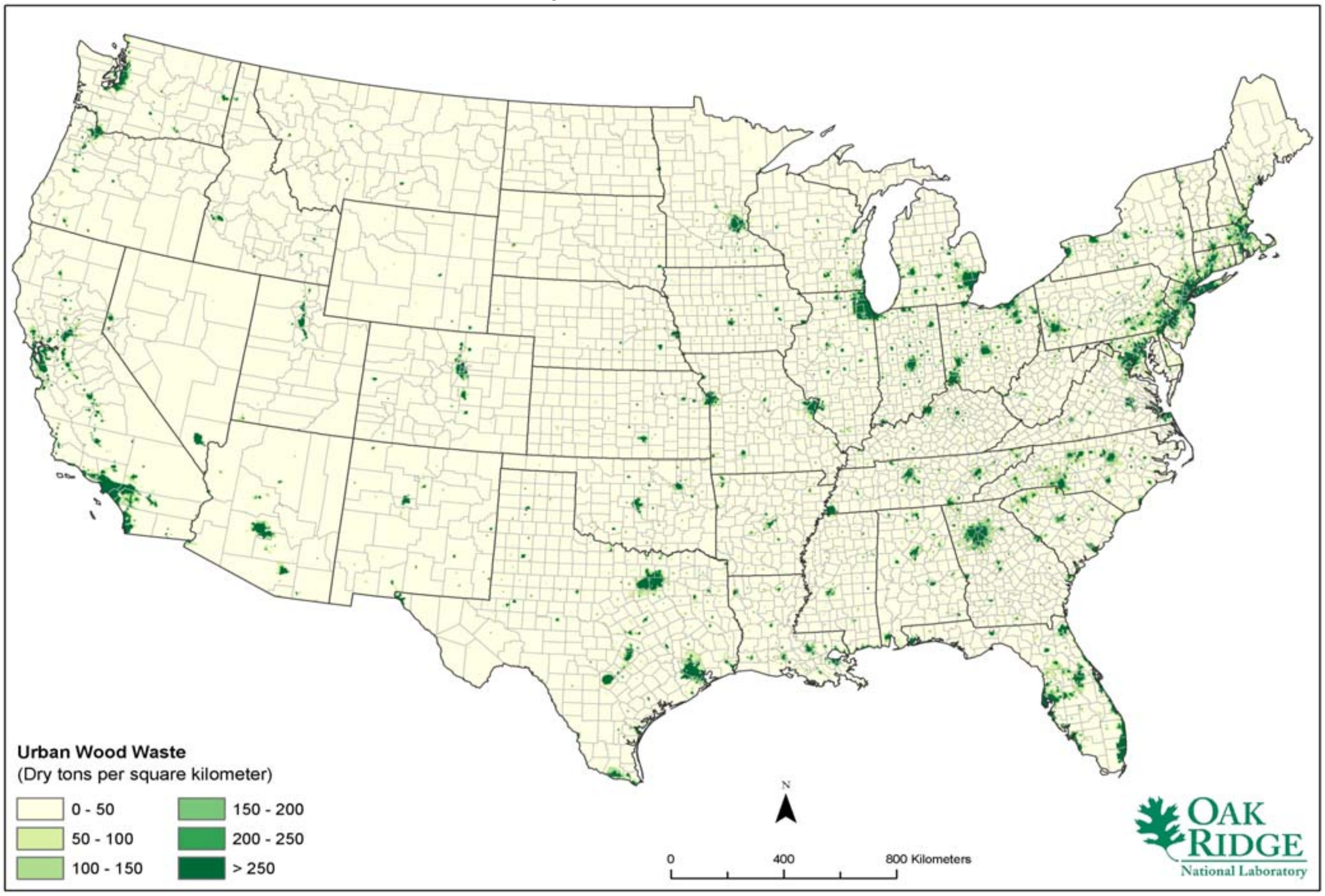
Sources:

Map created by Bioenergy Resources and Engineering Systems Program, 2010, Oak Ridge National Laboratory. http://www.esd.ornl.gov/eess/bioenergy/

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

Urban wood wastes include wood (discarded furniture, pallets, containers, packaging materials and lumber scraps), yard and tree trimmings, and construction and demolition wood. This can be a significant source of bioenergy feedstock depending on location and concentration; type of material; and acquisition, transport, and processing costs.

Section: FEEDSTOCKS
Total Municipal Solid Waste Wood Residues



Sources:

Map created by Bioenergy Resources and Engineering Systems Program, 2010, Oak Ridge National Laboratory. http://www.esd.ornl.gov/eess/bioenergy/

EPA (Environmental Protection Agency). 2007. Municipal Solid Waste in the United States: 2007: Facts And Figures, Office

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

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, October 2010

State	Operational Projects	Candidate Landfills
Alabama	3	22
Alaska	0	1
Arizona	3	14
Arkansas	3	7
California	74	37
Colorado	1	10
Connecticut	3	3
Delaware	3	a
Florida	15	16
Georgia	12	24
Hawaii	0	8
Idaho	2	3
Illinois	32	25
Indiana	20	13
Iowa	4	12
Kansas	6	8
Kentucky	7	18
Louisiana	6	7
Maine	2	2
Maryland	10	11
Massachusetts	19	4
Michigan	34	4
Minnesota	7	6
Mississippi	2	13
Missouri	10	12
Montana	1	3
Nebraska	2	5
Nevada	0	3
New Hampshire	7	3
New Jersey	19	3
New Mexico	2	1
New York	26	8
North Carolina	15	34
North Dakota	2	1
Ohio	18	21
Oklahoma	3	12
Oregon	6	3
Pennsylvania	37	12
Puerto Rico	0	11
Rhode Island	2	a
South Carolina	11	7
South Dakota	1	1
Tennessee	6	12
Texas	27	53
Utah	4	5
Vermont	4	a
Virginia	23	11
Virgin Islands	0	2
Washington	6	9
West Virginia	1	8
Wisconsin	25	7
Wyoming	0	2
U.S. Total	**526**	**~515**

Source:
EPA's Landfill Methane Outreach Program, October 13, 2010,
http://www.epa.gov/lmop/

[a] No data available.

Appendix A

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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 Transportation Fuel Cycle Analysis Model, GREET 1.8b, developed by Argonne National Laboratory, Argonne, IL, released May 8, 2008.
http://www.transportation.anl.gov/software/GREET/index.html

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 fuel density values. The heating values for liquid fuels in units of Btu/lb are calculated based on heating values in units of Btu/gal and the corresponding fuel density values.

[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.

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[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.

http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends.html

[a] Higher heating value

MSW = Municipal Solid Waste

The heating value of any fuel, is the heat release per unit mass when the fuel initially at 25°C (77°F) reacts completely with oxygen, and the products are returned to 25°C (77°F). The heating value is reported as the higher heating value (HHV) when the water is condensed or as the lower heating value (LHV) when the water is not condensed. The LHV is obtained from the HHV by subtracting the heat of vaporization of water in the products. Thus: LHV = HHV – ((mH20/ mfuel)*hfg) where m = mass and hfg is the latent heat of vaporization of water at 25°C (77°F) which equals 2,440 kJ/kg water (1,050 Btu/lbm). The water includes moisture in the fuel as well as water formed from hydrogen in the fuel.

The HHV and LHV provided in Tables 1 and 2 of the Biomass Energy Data Book, Appendix A assume that the fuels contain 0% water. Since recently harvested wood fuels usually contain 30 to 55% water it is useful to understand the effect of moisture content on the heating value of wood fuels. The table below shows the effect of percent moisture content (MC) on the higher heating value as-fired (HHV-AF) of a wood sample starting at 8,500 Btu/lb (oven-dry).

Section: Appendix A
The Effect of Fuel Moisture on Wood Heat Content[a]

Moisture Content (MC) wet basis (%)	0	15	20	25	30	35	40	45	50	55	60
Higher Heating Value as fired (HHV-AF) Btus/lb	8,500	7,275	6,800	6,375	5,950	5,525	5,100	4,575	4,250	3,825	3,400

Sources:

1. Borman, G.L. and K.W. Ragland. Combustion Engineering. McGraw-Hill. 1998. 613 pp.

2. Maker, T.M. Wood-Chip Heating Systems: A Guide for Institutional and Commercial Biomass Installations. 1994 (revised 2004 by Biomass Energy Resource Center).

3. American Pulpwood Association, Southern Division Office. The Forester's Wood Energy Handbook. 1980.

Notes:

Moisture contents (MC) wet and dry weight basis are calculated as follows:

MC (dry basis) = 100 (wet weight-dry weight)/dry weight;
MC (wet basis) = 100 (wet weight – dry weight)/wet weight
To convert MC wet basis to MC dry basis: MC(dry) = 100xMC(wet) /100-MC(wet)
To convert MC dry basis to MC wet basis : MC(wet)= 100 x MC(dry)/100 +MC(dry)

Some sources report heat contents of fuels "as-delivered" rather than at 0% moisture for practical reasons. Because most wood fuels have bone dry (oven-dry) heat contents in the range of 7,600 to 9,600 Btu/lb (15,200,000 to 19,200,000 Btu/ton or 18 to 22 GJ/Mg), lower values will always mean that some moisture is included in the delivered fuel. Grass fuels are usually delivered at < 20% MC.

[a] If the oven-dry HHV (Btu /lb)is known (e.g. 8,500) then the HHV-AF can be calculated as follows:
oven-dry HHV x (1-MC wet basis/100).

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.

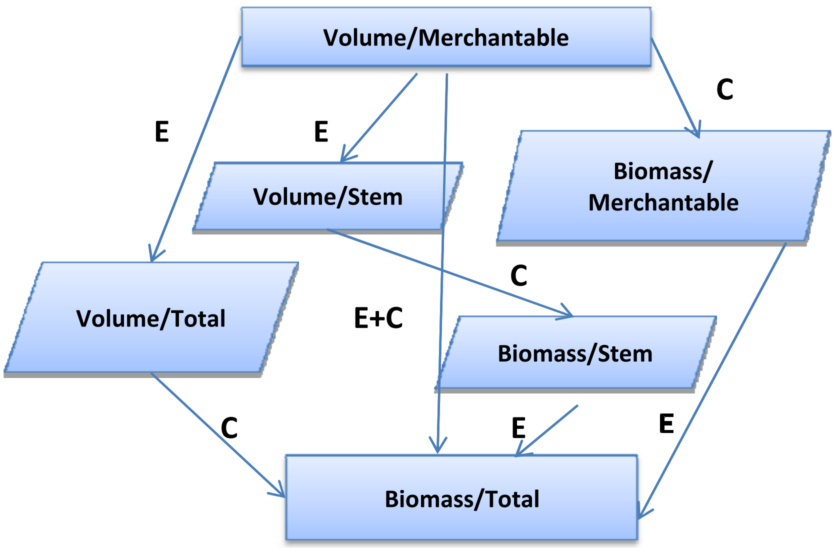

Figure 1 Source: Somogyi Z. et al. Indirect methods of large-scale biomass estimation. Eur J Forest Res (2006) DOI 10.1007/s10342-006-0125-7

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 on the diagram) 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 stump may or may not be appropriate to include 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) .

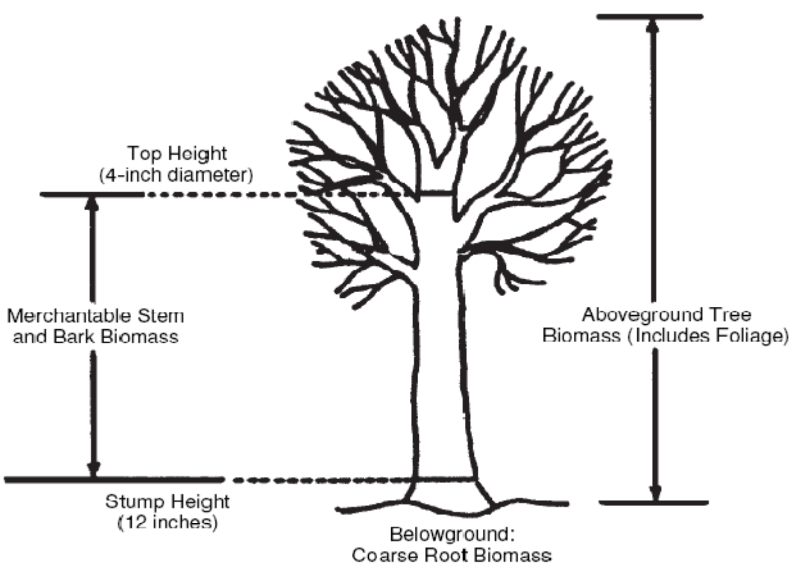

Figure 2 Source: Jenkins, JC, Chojnacky DC, Heath LS, Birdsey RA. Comprehensive Database of Diameter-based Biomass Regressions for North American Tree Species. United States Department of Agriculture, Forest Service General Technical Report NE-319, pp 1-45 (2004)

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.

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[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

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

FROM	TO: 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:
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

Notes

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.

[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 in section 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
	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
A, B, C, H, and I	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
	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
D and E	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
	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
G	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	Softwood[a]							
	Bark	% MC	Chipable[b]	% MC	Shavings	% MC	Fine[c]	%MC
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

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: websites www.gordonengland.co.uk/conversion and www.convert-me.com/en/convert and the Family Farm Series Publication "Vegetable Crop Production" at website "www.sfc.ucdavis.edu/pubs/Family_Farm_Series/Veg/Fertilizing/appendix.html#tables

[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 barrell (dry)	=	13.1248	US pk	1 barrell (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.

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 Energy Units and Energy per Unit Weight Conversions

Energy Units

FROM	TO: 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

FROM	TO: $J\ kg^{-1}$	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
$calorie_{th}$ per gram ($cal_{IT}\ g^{-1}$)	4186.8	4.1868	1	1.8
Btu_{IT} per pound ($Btu_{IT}\ lb^{-1}$)	2326	2.326	0.5555	1

Other commonly used energy unit conversions in biomass literature

1 Quadrillion Btu's (Quad) = 1×10^{15} Btu = 1.055 Exajoules (EJ) = 1.055×10^{18} J
1 Million Btu's (MMbtu) = 1×10^{6} Btu = 1.055 Gigajoules (GJ) = 1.055×10^{9} J
1000 Btu per pound x 2000 lbs per ton = 2 MMbtu per ton = 2.326 GJ per Mg
e.g. 8500 Btu per pound (average HHV of wood) = 17 MMbtu per ton = 19.8 GJ per Mg

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

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.

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	$2.52 \text{ X } 10^{-8}$	1	2.931×10^{-4}
Gigawatthours	3.6	860	8.6×10^{-5}	3412	1

Source:
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.

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.

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 b	y	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

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.

Appendix C - Sustainability

Sustainability and Biomass Energy Systems

In the late 1970's when oil supply disruptions caused the U.S. Government to begin to support research on biomass feedstocks for fuels and chemicals, the renewability of the bioenergy resources was the most important criteria. All of the projects initiated as a result of the U.S. Department of Energy's (DOE's) first biomass solicitation in 1977 were directed toward evaluating the potential for wood production and harvest scenarios that would supply renewable bioenergy resources. Much debate at the time centered around the environmental soundness of various feedstock technology choices and the energy input versus output ratios (e.g. Braunstein et al., 1981) but sustainability was not yet a term in poplar usage. It was with a high level of environmental and social sensitivity that the herbaceous crops program solicitation in 1984 sought crops that would "increase the production of biomass for energy without significantly reducing food production" (ORNL, 1984). This goal lead to a decision to solicit research on crops suitable for marginal cropland. However, because marginal croplands are often sloping or have poor quality (low nutrient) soils, crops that could minimize erosion, be productive with minimal fertilizer inputs and increase soil carbon were also given higher priority.

Although many crop and soil management techniques now considered essential elements of sustainable agriculture were researched and published during the 1945 to 1979 time period (Gold and Gates , 2007) the term sustainability did not come into popular usage until after a definition of sustainable development was published in the 1987 Bruntland Commission Report. It defined sustainable developments as those that "meet the present needs without compromising the ability of future generations to meet their needs" (United Nations,1987). In the US the first legislation to specifically promote "sustainable" agriculture was the 1985 Farm Bill, but it was not officially defined until the 1990 Farm Bill. The 1990 Farm Bill definition of sustainable agriculture was: "An integrated system of plant and animal production practices having a site-specific application that over the long term will: (1) satisfy human food and fiber needs, (2) enhance environmental quality and the natural resource base upon which the agricultural economy depends, (3) make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls, (4) sustain the economic viability of farm operations, and (5) enhance the quality of life for farmers and society as a whole."

Most sustainability definitions, however, seem to stimulate debate, rather than provide guidance regarding the types of crop management systems that should be used for biomass production. A 1995 Doane's Agricultural Report on the 1995 Farm Bill debate (Vol. 58, No.7-5), noted there were two contrasting viewpoints on what constituted sustainable agriculture. One view argued that sustainable agricultural policy should encourage the use of fewer and lower levels of pesticides and fertilizers in producing crops. The other view argued that the goal should be to produce more food (or biomass) on fewer acres using high-yield techniques, including pesticide and fertilizer use (and genetically modified crops). A similar debate still rages today for biomass production systems with some researchers proposing low-input, high-diversity grasslands as the most environmentally desirable approach (Tilman et al, 2006) while others show that at the low yields obtained, the land area required is prohibitive and moderate input, low-diversity, high-yield biomass crops are environmentally sound and more likely to be economically viable (Mitchell and Vogel, in press 2009). Some convergence is occurring as several researchers are evaluating the possibility of attaining high yield in polyculture systems including mixed grasses, mixed trees, and even mixtures of grasses or forbs and trees.

The first attempt at developing a set of principals and guidelines for environmentally sound bioenergy systems began in 1992. The Electric Power Research Institute and the National Audubon Society (with help from DOE) collaborated to conduct several roundtable discussions across the nation and to produce a report entitled "Principles and Guidelines for the Development of Biomass Energy Systems (National Biofuels Roundtable, 1994). The principles developed included the concepts of environmental soundness, economic viability, and social fairness, very similar to many definitions of sustainability though the word sustainability was purposely omitted from the report. A large range of environmental impacts were addressed in developing guidelines, but of particular interest at that time was the potential impacts (positive and negative) of biomass energy systems on greenhouse gas emissions on a full life cycle basis, and on the impacts of scale of technology implementation.

In 2008 a Roundtable on Sustainable Biofuels was initiated by an international group with many industry leaders and representatives from developing as well as developed countries on the steering board. Stakeholder meetings have been held around the world, including two in the US in spring 2009. A draft statement of global principals and criteria for sustainable biofuels production called "Version Zero" is currently circulating and available for comment through the website www.bioenergywiki.net. The draft contains 12 principals including more in the area of social fairness than any previous statement of sustainability principals. The issue of effects of bioenergy energy system implementation on direct and indirect land use change (recently highlighted by Searchinger et al. 2008) are incorporated within the principal pertaining to greenhouse gas emissions.

The Ecological Society of America (ESA), held a workshop on Biofuels in March 2008 to address sustainability issues. Reports generated by working groups at that workshop will be published in the near future. Meanwhile, the ESA policy statement on biofuel sustainability can be found at http://www.esa.org/pao/policyStatements/Statements/biofuel.php. As expected it focuses on ecological principals, with the three key principals being "systems thinking, conservation of ecological services, and scale alignment".

The Department of Energy's Biomass Program continues to be committed to developing the technologies, processes and systems needed to sustainably convert a broad range of cellulosic feedstocks into clean, abundant biofuels. Program literature states that the DOE Biomass Program aims to develop processes and products that reduce carbon emissions, protects human health and the environment, and add value to the biofuel life cycle.

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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 (K_2O + NaO_2) 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).

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 (CO_2) - 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 m^3); 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 (O_2) 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 CH_3OCH_3. 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.

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 CH_30H. 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 (H_2), 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 (10^{15} 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 SO_2 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 (SO_2) - Formed by combustion of fuels containing sulfur, primarily coal and oil. Major health effects associated with SO_2 include asthma, respiratory illness, and aggravation of existing cardiovascular disease. SO_2 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.

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.