BIOFUELS

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

Biodiesel		
Biodiesel Overview	**Text**	09/27/2011
Biodiesel Production		
World Biodiesel Production by Region and Selected Countries, 2005-2009	Table	09/27/2011
Biodiesel Production Capacity by State	Table	09/27/2011
Biodiesel Production, Imports and Exports, 2001 - 2010	Table	09/27/2011
Biodiesel Production Capacity by Feedstock	Table	09/27/2011
Composition of Various Oils and Fats used for Biodiesel	Table	09/27/2011
Typical Proportions of Chemicals Used to Make Biodiesel	*Figure*	09/27/2011
Specification for Biodiesel (B100)	Table	09/27/2011
Specification for Biodiesel Blends B6 to B20	Table	09/27/2011
Commercial Biodiesel Production Methods	*Figure*	09/27/2011
Sustainability		
Average Biodiesel (B100 and B20) Emissions Compared to Conventional Diesel	Table	09/27/2011
Bio-oil		
Bio-oil Overview	**Text**	09/27/2011
Output Products by Method of Pyrolysis	Table	09/27/2011
A Fast Pyrolysis Process for Making Bio-oil	*Figure*	09/27/2011
Bio-oil Characteristics	Table	09/27/2011
Bio-oil Fuel Comparisons	Table	09/27/2011
Taxes and Incentives		
Annotated Summary of Biofuel and Biomass Electric Incentives: Online Information Resources	Table	09/27/2011
Federal and State Alternative Fuel Incentives, 2011	Table	04/18/2011

Biofuels Overview

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

Fuels

Ethanol

Ethanol is most commonly made by converting the starch from corn into sugar, which is then converted into ethanol in a fermentation process similar to brewing beer. Ethanol is the most widely used biofuel today with 2010 production and consumption at over 13 billion gallons based primarily on corn. Ethanol produced from cellulosic biomass is currently the subject of extensive research, development and demonstration efforts.

Biodiesel

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

Bio-oil

A totally different process than that used for biodiesel production can be used to convert biomass into a type of fuel similar to diesel which is known as bio-oil. The process, called fast or flash pyrolysis, occurs when heating compact solid fuels at temperatures between 350 and 500 degrees Celsius for a very short period of time (less than 2 seconds). While there are several fast pyrolysis technologies under development, there are only two commercial fast pyrolysis technologies as of 2009. The bio-oils currently produced are suitable for use in boilers for electricity generation. There is currently ongoing research and development to produce bioOil of sufficient quality for transportation applications.

Other Hydrocarbon Biofuels

Biomass can be gasified to produce a synthesis gas composed primarily of hydrogen and carbon monoxide, also called syngas or biosyngas. Syngas produced today is used directly to generate heat and power but several types of biofuels may be derived from syngas. Hydrogen can be recovered from this syngas, or it can be catalytically converted to methanol or ethanol. The gas can also be run through a biological reactor to produce ethanol or can also be converted using Fischer-Tropsch catalyst into a liquid stream with properties similar to diesel fuel, called Fischer-Tropsch diesel. However, all of these fuels can also be produced from natural gas using a similar process.

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

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

Green Hydrocarbon Biofuels

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

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

The production of hydrocarbon biofuels from biomass has many advantages:

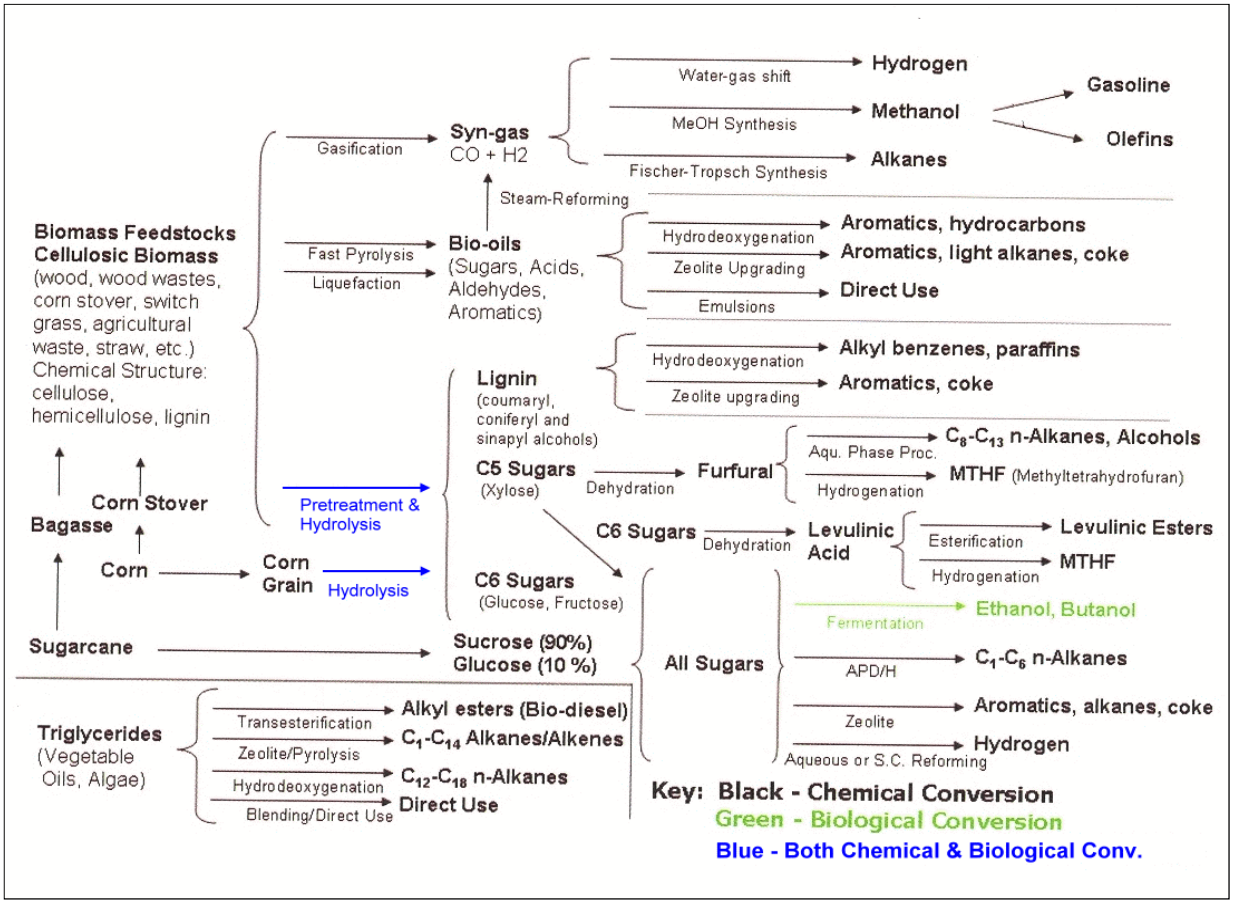
- "Green" hydrocarbon fuels are chemically essentially the same as petroleum-based fuels. Thus modifications to existing engines and fuel distribution infrastructure are not required.
- "Green" hydrocarbon fuels are energy equivalent to petroleum-based fuels, thus no mileage penalty is encountered from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

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

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

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

Section: BIOFUELS
Diagram of Routes to Make Biofuels



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

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

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

Source:

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

Ethanol Overview

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

Ethanol is the most widely used biofuel today. In 2009, more than 7.3 billion gasoline-equivalent gallons were added to gasoline in the United States to meet biofuel requirements and reduce air pollution. Ethanol is currently produced using a process similar to brewing beer where starch crops are converted into sugars, the sugars are fermented into ethanol, and the ethanol is then distilled into its final form.

Ethanol is used to increase octane and improve the emissions quality of gasoline. In many areas of the United States today, ethanol is blended with gasoline to form an E10 blend (10% ethanol and 90% gasoline), but it can be used in higher concentrations, such as E85, or in its pure form E100. All automobile manufacturers that do business in the United States approve the use of E10 in gasoline engines; however, only flex fuel vehicles (FFVs) are designed to use E85. October 2010, the Environmental Protection Agency granted a partial waiver to allow E15 to be sold in the U.S., subject to several conditions. Pure ethanol or E100 is used in Brazil but is not currently compatible with vehicles manufactured for the U.S. market. Manufacturer approval of ethanol blends is found in vehicle owners' manuals under references to refueling or gasoline.

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

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

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

Section: BIOFUELS

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

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

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

Note: ASTM = American Society for Testing and Materials

Section: BIOFUELS
Fuel Property Comparison for Ethanol, Gasoline and No. 2 Diesel

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

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

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

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

Section: BIOFUELS
World Fuel Ethanol Production by Country or Region, 2010
(Millions of gallons, all grades)

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

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

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

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

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

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

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

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

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

Between 1999 and 2011, the number of ethanol plants in the U.S. quadrupled, accompanied by a rapid rise in production capacity. Additional information on specific plant locations and up-to-date statistics can be obtained at the Renewable Fuels Association, http://www.ethanolrfa.org/pages/statistics.

Section: BIOFUELS
Ethanol Plant Statistics, 1999-2011

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

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

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

[a] Operating plants

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

Section: BIOFUELS
Ethanol Production Capacity by Feedstock, 2011

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

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

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

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

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

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

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

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

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

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

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

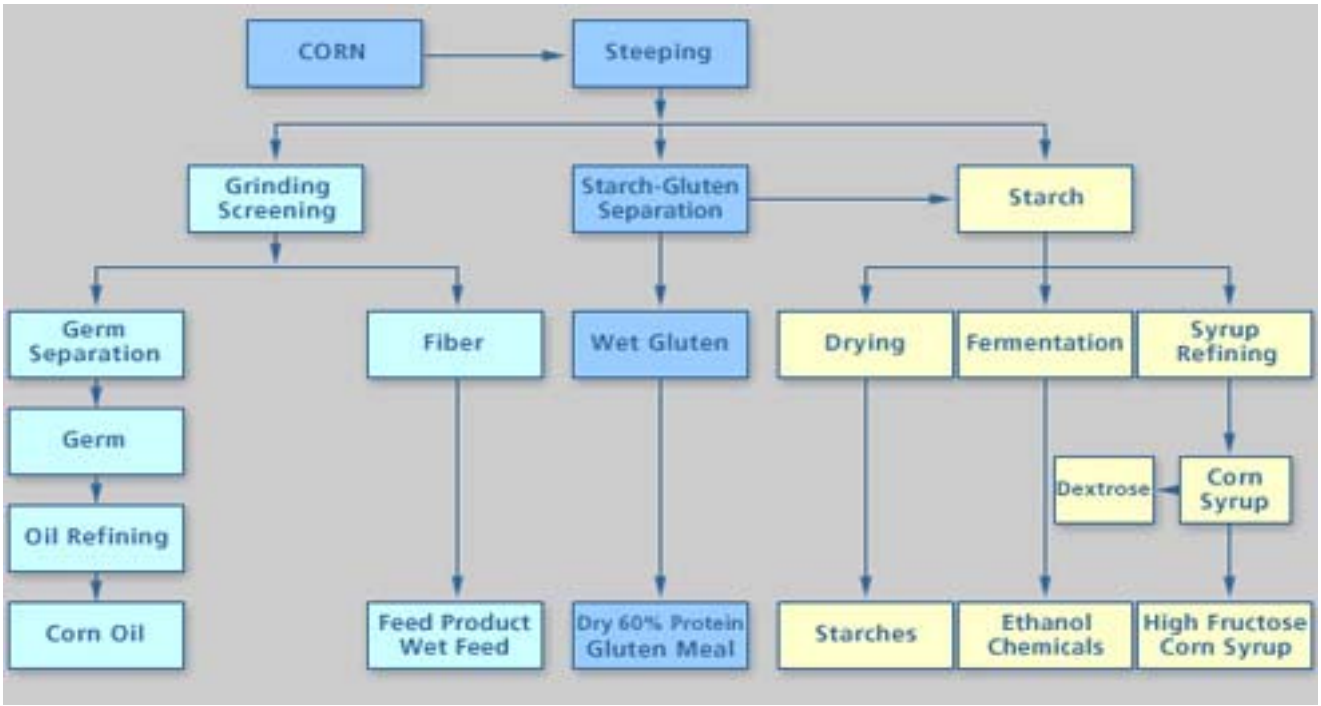
Source:
Renewable Fuels Association:
http://www.ethanolrfa.org/bio-refinery-locations/

Note:
mgy = million gallons per year

Totals were estimated when individual plant data were not available.

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

Section: BIOFUELS
The Ethanol Production Process - Wet Milling



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

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

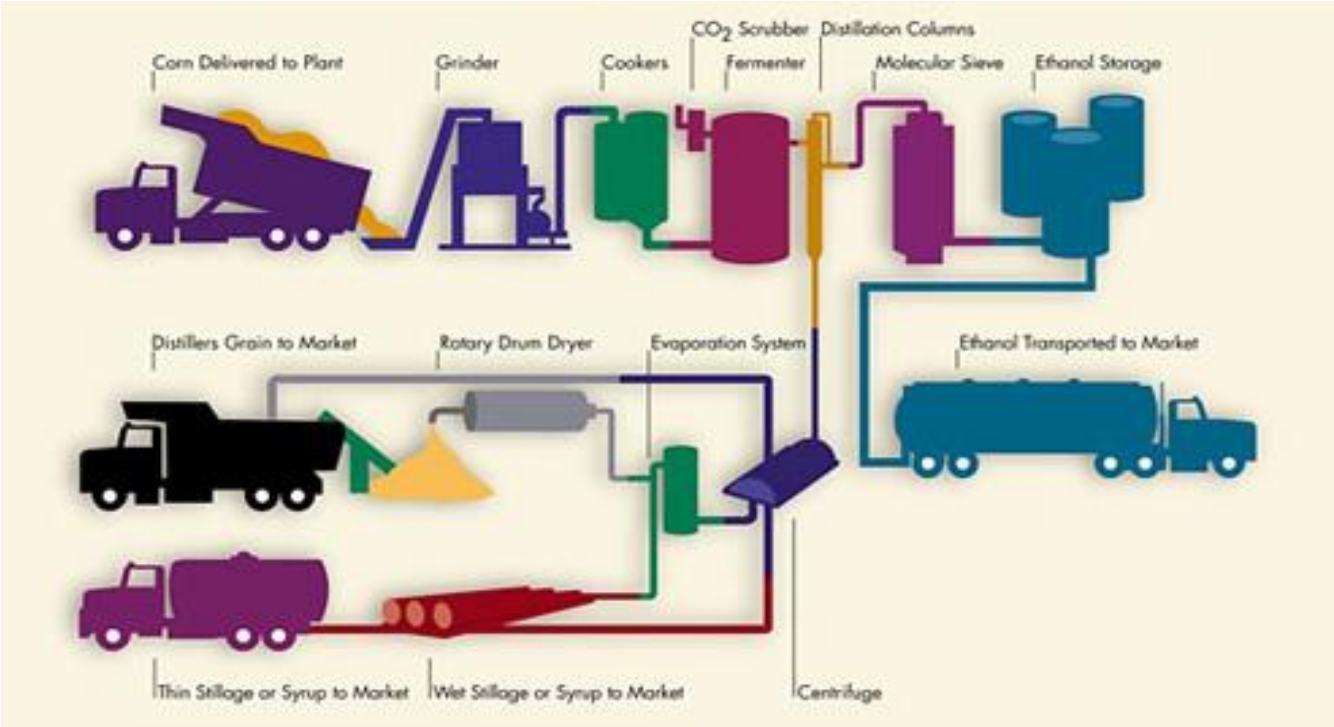
The steeping liquor is concentrated in an evaporator. This concentrated product, heavy steep water, is co-dried with the fiber component and is then sold as corn gluten feed to the livestock industry. Heavy steep water is also sold by itself as a feed ingredient and is used as a component in Ice Ban,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

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

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

Source:
Renewable Fuels Association,
http://www.ethanolrfa.org/pages/how-ethanol-is-made

Section: BIOFUELS
The Ethanol Production Process - Dry Milling



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

The mash is processed in a high-temperature cooker to reduce bacteria levels ahead of fermentation. The mash is cooled and transferred to fermenters where yeast is added and the conversion of sugar to ethanol and carbon dioxide (CO^2) begins.

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

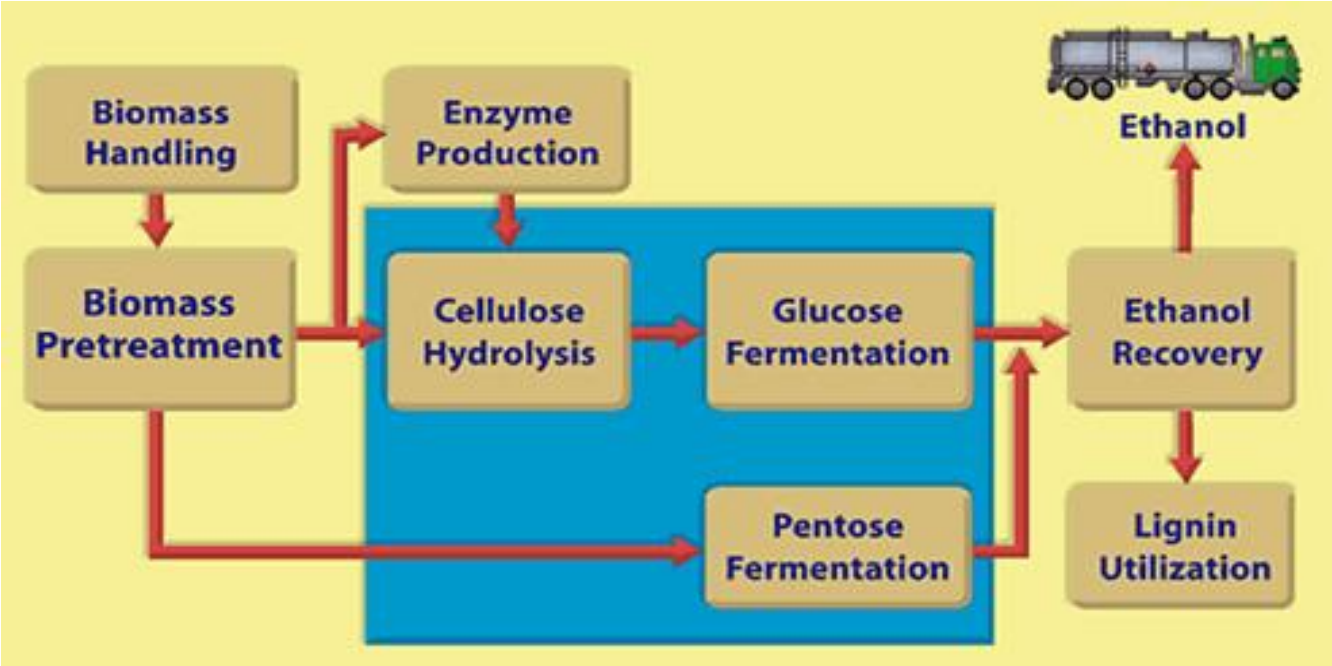
The anhydrous ethanol is blended with about 5% denaturant (such as natural gasoline) to render it undrinkable and thus not subject to beverage alcohol tax. It is then ready for shipment to gasoline terminals or retailers.

The stillage is sent through a centrifuge that separates the coarse grain from the solubles. The solubles are then concentrated to about 30% solids by evaporation, resulting in Condensed Distillers Solubles (CDS) or "syrup." The coarse grain and the syrup are dried together to produce dried distillers grains with solubles (DDGS), a high quality, nutritious livestock feed. The CO^2 released during fermentation is captured and sold for use in carbonating soft drinks and the manufacture of dry ice.

Source:
Renewable Fuels Association,
http://www.ethanolrfa.org/pages/how-ethanol-is-made

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

Section: BIOFUELS
The Production of Ethanol from Cellulosic Biomass



Hydrolysis is the chemical reaction that converts the complex polysaccharides in the raw feedstock to simple sugars. In the biomass-to-bioethanol process, acids and enzymes are used to catalyze this reaction.
Fermentation is a series of chemical reactions that convert sugars to ethanol. The fermentation reaction is caused by yeast or bacteria, which feed on the sugars. Ethanol and carbon dioxide are produced as the sugar is consumed.

Process Description. The basic processes for converting sugar and starch crops are well-known and used commercially today. While these types of plants generally have a greater value as food sources than as fuel sources there are some exceptions to this. For example, Brazil uses its huge crops of sugar cane to produce fuel for its transportation needs. The current U.S. fuel ethanol industry is based primarily on the starch in the kernels of feed corn, America's largest agricultural crop.

1. Biomass Handling. Biomass goes through a size-reduction step to make it easier to handle and to make the ethanol production process more efficient. For example, agricultural residues go through a grinding process and wood goes through a chipping process to achieve a uniform particle size.

2. Biomass Pretreatment. In this step, the hemicellulose fraction of the biomass is broken down into simple sugars. A chemical reaction called hydrolysis occurs when dilute sulfuric acid is mixed with the biomass feedstock. In this hydrolysis reaction, the complex chains of sugars that make up the hemicellulose are broken, releasing simple sugars. The complex hemicellulose sugars are converted to a mix of soluble five-carbon sugars, xylose and arabinose, and soluble six-carbon sugars, mannose and galactose. A small portion of the cellulose is also converted to glucose in this step.

3. Enzyme Production. The cellulase enzymes that are used to hydrolyze the cellulose fraction of the biomass are grown in this step. Alternatively the enzymes might be purchased from commercial enzyme companies.

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

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

• **Cellulose hydrolysis.** The crystalline structure of cellulose makes it difficult to hydrolyze to simple sugars, ready for fermentation. Researchers are developing enzymes that work together to efficiently break down cellulose.

• **Pentose fermentation.** While there are a variety of yeast and bacteria that will ferment six-carbon sugars, most cannot easily ferment five-carbon sugars, which limits ethanol production from cellulosic biomass. Researchers are using genetic engineering to design microorganisms that can efficiently ferment both five- and six-carbon sugars to ethanol at the same time.

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

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

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

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

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

Source:

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

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

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

[c]Including thremal recovery, upgrading and refining.

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

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

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

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

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

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

Section: BIOFUELS
Economic Contribution of the Ethanol Industry, 2009

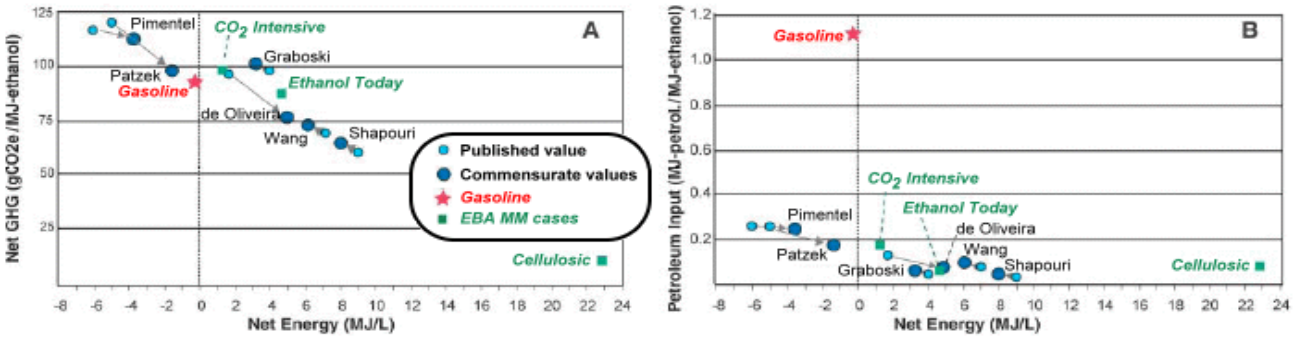
		Impact		
	Expenditures (Mil 2009$)	**GDP (Mil 2009$)**	**Earnings (Mil 2009$)**	**Employment (Jobs)**
Annual Operations				
Feedstock (Corn)	$10,041.0	$13,507.0	$5,353.0	180,111
Enzymes and chemicals	$1,052.0	$1,477.0	$755.0	14,564
Denaturants	$443.0	$450.0	$241.0	4,220
Electricity	$398.0	$571.0	$239.0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

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

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

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

Section: BIOFUELS
Ethanol Net Energy Balances and Greenhouse Gas Emissions



Source:

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

Additional references:

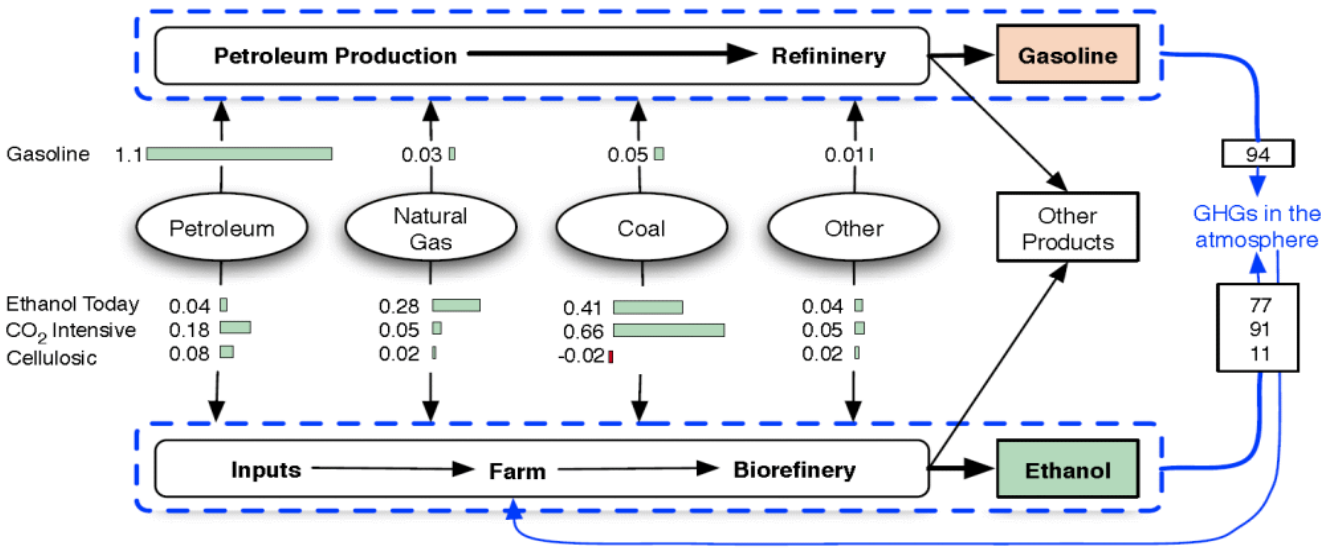
T. Patzek. *Crit. Rev. Plant Sci*. **23**, 519 (2004).
D. Pimentel, T. Patzek, *Nat. Resourc. Res.* **14**, 65(2005).
M.E.D. de Oliveira, B.E. Vaughn, E.J. Rykiel, *Bioscience*, **55**, 593(2005).
H. Shapouri, A. McAloon, "The 2001 net energy balance of corn ethanol" (U.S. Department of Agriculture, Washington, D.C. 2004).
M. Graboski, "Fossil energy use in the manufacture of corn ethanol" (National Corn Growers Association, Washington, DC. 2002). http://www.ncga.com/
M. Wang, "Development and use of GREET 1.6 fuel-cycle model for transportation fuels and vehicle technologies" (Tech. Rep. ANL/ESD/TM-163, Argonne National Laboratory, Argonne, IL, 2001). http://www.transportation.anl.gov/pdfs/TA/153.pdf

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

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

Section: BIOFUELS

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



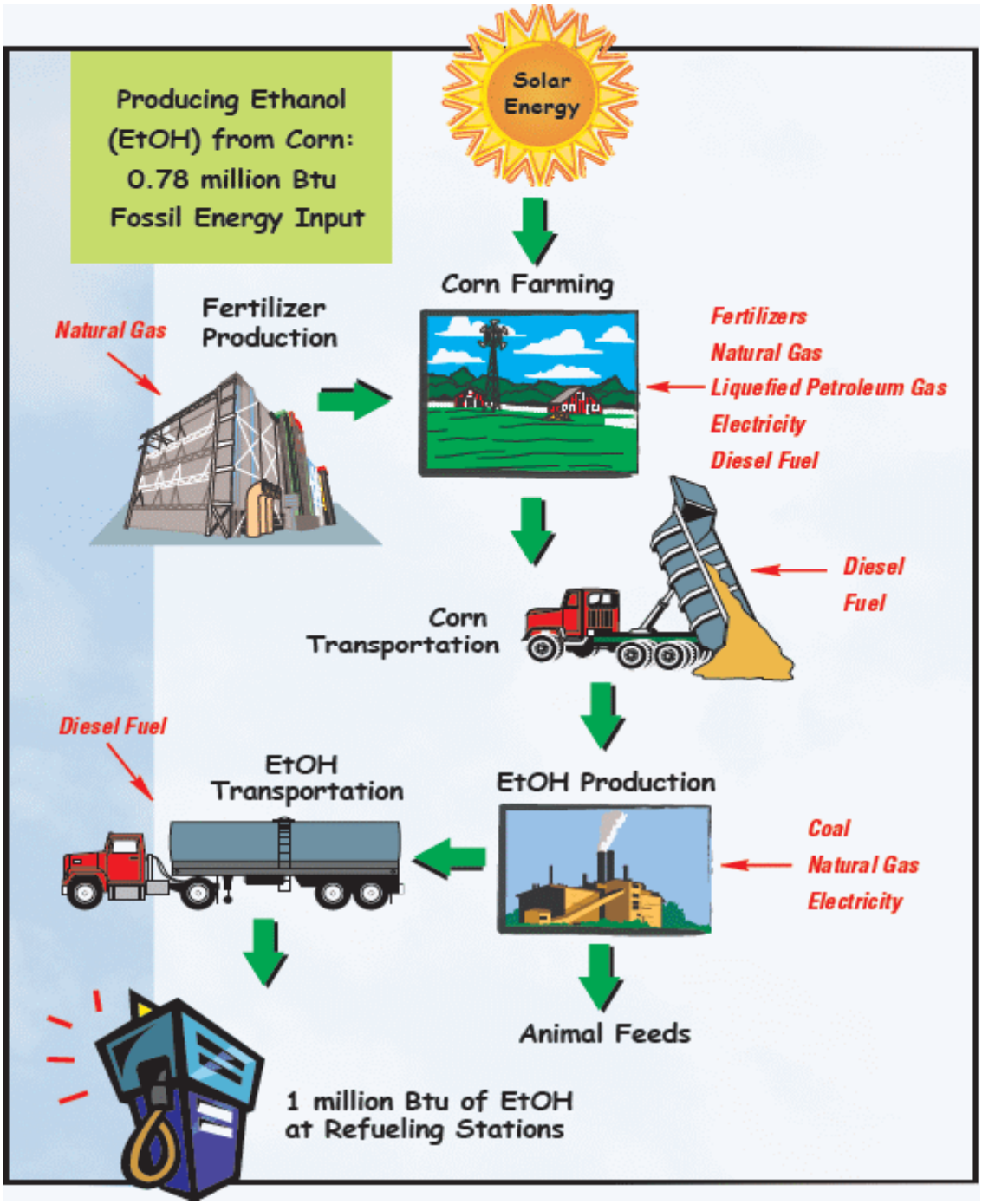
Source:

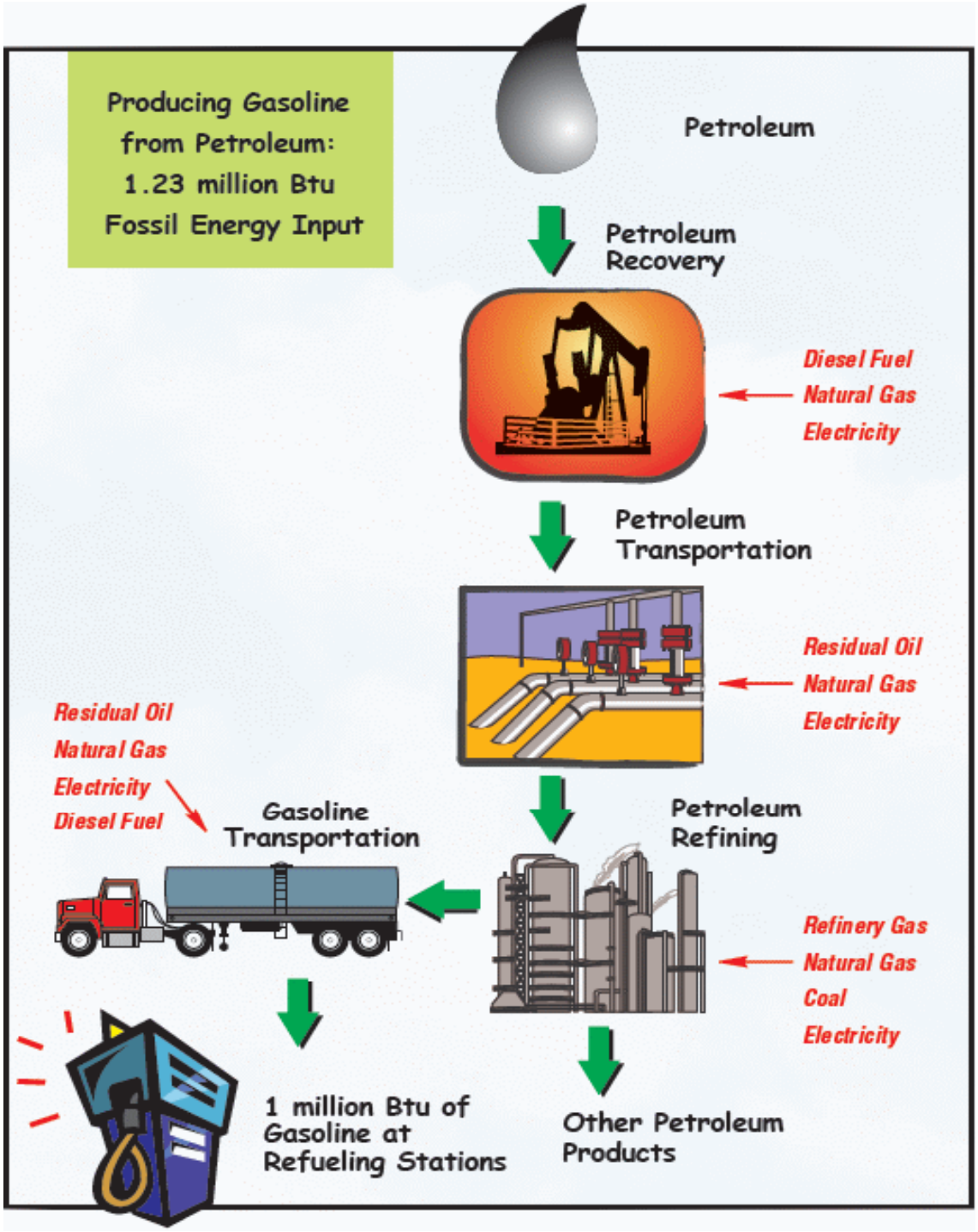
A.E. Farrell, R.J. Plevin, B.T. Turner, A.D. Jones, M. O'Hare, and D.M. Kammen. Ethanol Can Contribute To Energy and Environmental Goals. Science, Vol 311, January 27, 2006.
http://www.sciencemag.org/content/311/5760/506.full

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

Section: BIOFUELS

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




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

The GREET model was developed by Argonne National Laboratory under the sponsorship of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy in order to fully evaluate energy and emission impacts of advanced vehicle technologies and new transportation fuels. The first version of this public domain model was released in 1996. Since then, Argonne has continued to update and expand the model with GREET 1.8d.1 version now available. The model allows researchers and analysts to evaluate various vehicle and fuel combinations on a full fuel-cycle basis that includes wells to wheels and the vehicle cycle through material recovery and vehicle disposal.

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

- Consumption of total energy (energy in non-renewable and renewable sources) and fossil fuels petroleum, natural gas, and coal).
- Emissions of CO2-equivalent greenhouse gases – primarily carbon dioxide, methane, and nitrous oxide.
- Emissions of six criteria pollutants: volatile organic compounds, carbon monoxide, nitrogen oxide, particulate matter with size smaller than 10 micron (PM10), particulate matter with size smaller than 2.5 micron, and sulfur oxides.

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

GREET includes more than 80 vehicle/fuel systems:

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

Source:

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

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

Section: BIOFUELS

Comparison of Ethanol Energy Balance With and Without Inclusion of Coproduct Energy Credits

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

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

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

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

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

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

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

Source:

H. Shappouri, A. McAloon, *The 2001 Net Energy Balance of Corn Ethanol,* U.S. Department of Agriculture, Washington, D.C. 2004.
http://www.usda.gov/oce/reports/energy/net_energy_balance.pdf

Biodiesel Overview

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

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

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

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

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

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

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

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

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

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

SECTION: BIOFUELS
Biodiesel Production Capacity by State

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

Source:
National Biodiesel Board.

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

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

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

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

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

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

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

SECTION: BIOFUELS
Biodiesel Production Capacity by Feedstock

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

Source:
National Biodiesel Board.

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

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

Section: BIOFUELS

Composition of Various Oils and Fats Used for Biodiesel

(percentage of each type of fatty acid common to each type of feedstock)

Oil or fat	14:0	16:0	18:0	18:1	18:2	18:3	20:0	22:1
Soybean		6-10	2-5	20-30	50-60	5-11		
Corn	1-2	8-12	2-5	19-49	34-52	trace		
Peanut		8-9	2-3	50-60	20-30			
Olive		9-10	2-3	73-84	10-12	trace		
Cottonseed	0-2	20-25	1-2	23-35	40-50	trace		
Hi Linoleic Safflower		5.9	1.5	8.8	83.8			
Hi Oleic Safflower		4.8	1.4	74.1	19.7			
Hi Oleic Rapeseed		4.3	1.3	59.9	21.1	13.2		
Hi Erucic Rapeseed		3.0	0.8	13.1	14.1	9.7	7.4	50.7
Butter	7-10	24-26	10-13	28-31	1-2.5	.2-.5		
Lard	1-2	28-30	12-18	40-50	7-13	0-1		
Tallow	3-6	24-32	20-25	37-43	2-3			
Linseed Oil		4-7	2-4	25-40	35-40	25-60		
Yellow grease (typical)	2.43	23.24	12.96	44.32	6.97	0.67		
		16:1=3.97						

Source:

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

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

Section: BIOFUELS
Typical Proportions of Chemicals Used to Make Biodiesel

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

Triglyceride	+	**methanol**	→	**mixture of fatty esters**	+	**glycerol**
$CH_2-O-\overset{\overset{\displaystyle O}{\|}}{C}-R_1$				$CH_3-O-\overset{\overset{\displaystyle O}{\|}}{C}-R_1$		
$CH_2-O-\overset{\overset{\displaystyle O}{\|}}{C}-R_2$	$+\ 3CH_3OH$		$\xrightarrow[\text{(Catalyst)}]{}$	$CH_3-O-\overset{\overset{\displaystyle O}{\|}}{C}-R_2$	+	CH_2-OH
						$CH-OH$
$CH_2-O-\overset{\overset{\displaystyle O}{\|}}{C}-R_3$				$CH_3-O-\overset{\overset{\displaystyle O}{\|}}{C}-R_3$		CH_2-OH

R_1, R_2, and R_3 in the above equation are long chains of carbons and hydrogen atoms, sometimes called fatty acid chains. There are five types of chains that are common in soybean oil and animal fats shown below (others are present in small amounts).

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

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

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

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

Section: BIOFUELS
Specification for Biodiesel (B100)

Property	ASTM Method	Limits	Units
Calcium and Magnesium, combined	EN 14538	5 max.	ppm
Flash Point	D93	93.0	Degrees C
Alcohol Control (one of the following must be met)			
1. Methanol Content	EN 14110	0.2 max	% mass
2. Flash Point	D93	130 min	Degrees C
Water & Sediment	D2709	0.050 max	% vol
Kinematic Viscosity, 40°C	D445	1.9 - 6.0	mm^2/sec
Sulfated Ash	D874	0.020 max	% mass
Sulfur S15 Grade	D5453	0.0015 max	% mass (ppm)
Sulfur S500 Grade	D5453	0.05 max	% mass (ppm)
Copper Strip Corrosion	D130	No. 3 max	
Cetane Number	D613	47 min	
Cloud Point	D2500	Report to customer	Degrees C
Carbon Residue 100% sample[a]	D4530	0.050 max	% mass
Acid Number	D664	0.50 max	mg KOH/gm
Free Glycerin	D6584	0.020 max	% mass
Total Glycerin	D6584	0.240 max	% mass
Phosphorus Content	D 4951	0.001 max	% mass
Distillation, T90 AET	D 1160	360 max	Degrees C
Sodium/Potassium, combined	EN 14538	5 max	ppm
Oxidation Stability	EN 14112	3 min	hours
Cold Soak Filterability	Annex to D6751	360 max	seconds
For use in temperatures below -12 C	Annex to D6751	200 max	seconds

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

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

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

SECTION: BIOFUELS
Specification for Biodiesel Blends B6 to B20

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

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

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

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

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

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

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

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

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

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

Section: BIOFUELS
Commercial Biodiesel Production Methods

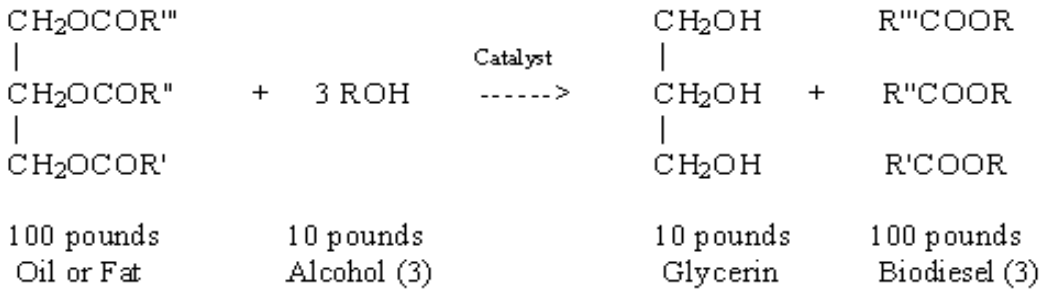
The production processes for biodiesel are well known. There are three basic routes to biodiesel production from oils and fats:

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

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

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

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



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

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

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

Section: BIOFUELS
Average Biodiesel (B100 and B20) Emissions Compared to Conventional Diesel

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

Source:
National Biodiesel Board, Biodiesel Fact Sheets, Emissions
http://www.biodiesel.org/resources/fuelfactsheets/
http://www.biodiesel.org/pdf_files/fuelfactsheets/emissions.pdf

Note: Testing was performed by the EPA. The full report titled "A comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions" can be found at:
www.epa.gov/otaq/models/biodsl.htm
http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf

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

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

Bio-oil Overview

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

DynaMotive Energy Systems is commercializing a proprietary fast pyrolysis process that converts forest and agricultural residue (non-food crops) into liquid bio-oil and char. The company opened their first bio-oil cogeneration facility in West Lorne, Ontario, in collaboration with Erie Flooring and Wood Products Company. The flooring company provides the wood residue and Dynamotive's 2.5-megawatt plant uses its fast pyrolysis technology and a gas turbine to supply power to the wood product company's mills and lumber kilns. A 200 ton-per-day plant in Guelph, Ontario was completed in 2007, along with a new pilot plant and test plant nearby.

Ensyn Group Inc. has commercialized a fast pyrolysis technology under the name of Rapid Thermal Processing RTP[tm]. This technology is based on the biomass refining concept, where value added chemicals are produced in addition to a consistent quality bio-oil. Ensyn has RTP[tm] facilities in commercial operation. Four of the commercial facilities are in Wisconsin and one is near Ottawa, Canada. The largest of these facilities processes about 75 green tons per day of mixed hardwood wastes. Commercial demonstration facilities in Belridge, California, and a Feedstock Test Facility in San Antonio, Texas, help the company continue research for future renewable fuels. Ensyn has several international projects as well – using pine residues in Italy and palm residues in Malaysia. A recent alliance with UOP (a Honeywell Company) is also expected to further the technologies to produce renewable liquid fuels for heat, power, and transport fuels.

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

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

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

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

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

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

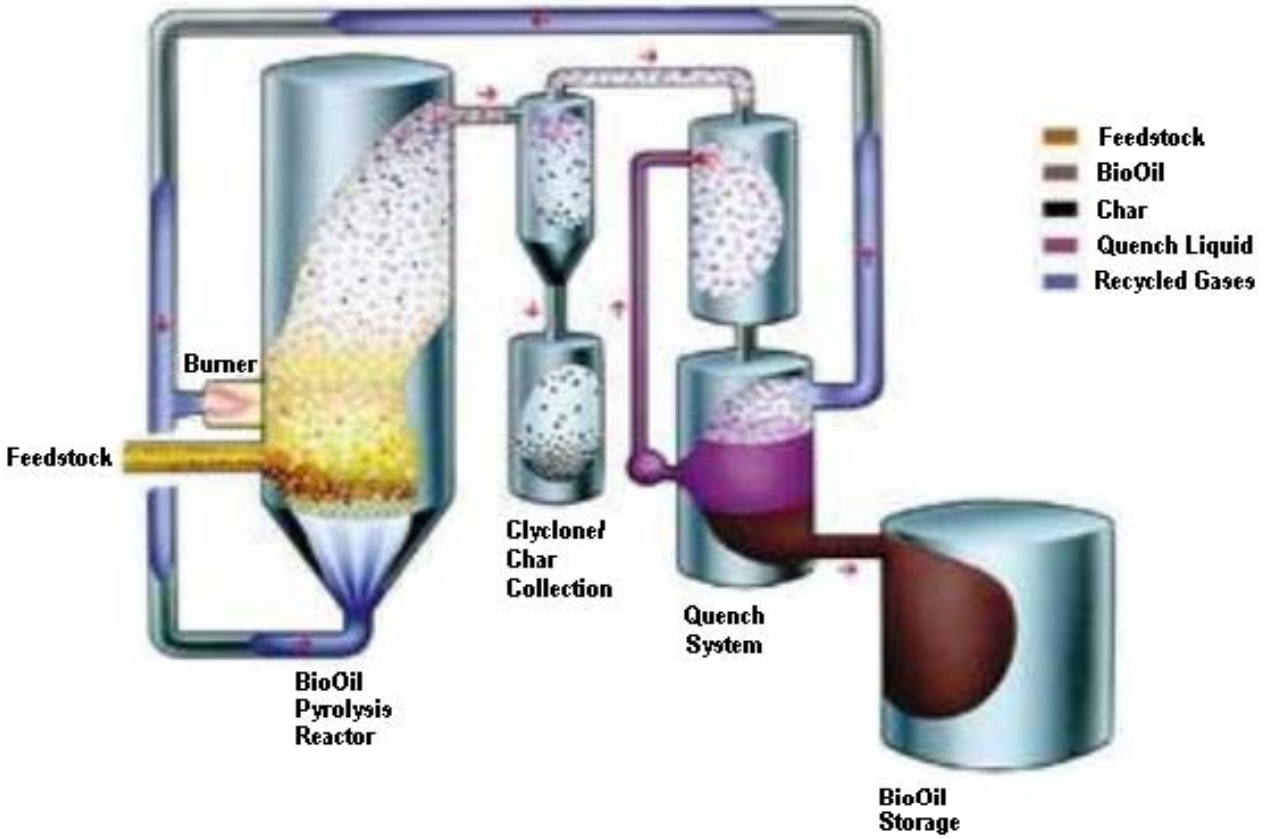
Section: BIOFUELS
Output Products by Method of Pyrolysis

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

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

Bio-oil has many of the advantages of petroleum fuels since it can be stored, pumped and transported. It is currently being combusted directly in boilers, gas turbines, and slow and medium speed diesels for heat and power applications.

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



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

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

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

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

Section: BIOFUELS
Bio-oil Characteristics

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

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

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

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

Section: BIOFUELS
Bio-oil Fuel Comparisons

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

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

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

Section: BIOFUELS

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

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

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

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

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

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

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

Energy Efficiency and Renewable Energy State Activities and Partnerships

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

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

DSIRE - Database for State Incentives for Renewables & Efficiency

http://www.dsireusa.org/

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

American Wind Energy Association

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

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

Renewable Fuels Association. Renewable Fuels Standard

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

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

Cantwell M. Comprehensive Guide to Federal Biofuel Incentives. 2006

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

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

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

Section: BIOFUELS
Federal and State Alternative Fuel Incentives, 2011

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

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

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