Bioenergy

Bioenergy is energy derived from biomass.

Biomass is all organic material being either:

The direct product of photosynthesis (for example plant matter such as leaves, stems, etc.)

The indirect product of photosynthesis (for example animal mass resulting from the consumption of plant material).

The **photosynthesis** process uses solar energy to combine carbon dioxide from the atmosphere with water (and various nutrients) from the soil to produce plant matter (biomass).

The **carbon dioxide** (CO_2) emitted on combustion of biomass is taken up by new plant growth, resulting in zero net emissions of CO_2. However, it should be remembered that there are some net $C0_2$ emissions associated with bioenergy when looked at on a life-cycle basis – emissions from fossil fuels used in the cultivation, harvesting and transport of the biomass. These are generally small compared to the CO_2 avoided by displacing fossil fuels with energy from biomass. Consequently, bioenergy is a renewable energy resource with the added benefit of being CO_2 neutral.

Biomass Energy

Biomass resources are potentially the world's largest and most sustainable energy source

The annual bio-energy potential is about 2900 EJ, though only 270 EJ could be considered available on a sustainable basis and at competitive prices.

The expected increase of biomass energy, particularly in its modern forms, could have a significant impact not only in the energy sector, but also in the drive to modernize agriculture, and on rural development.

The share of biomass in the total final energy demand is between 7% and 27%.

Source: http://www.worldenergy.org/wec-geis/

Biomass (other than wood)

Agricultural and wood/forestry residues and herbaceous crops grown specifically for energy but excludes forest plantations grown specifically for energy.

Dedicated energy plantations: 3 million ha of eucalyptus plantations used for charcoal making (Brazil); Plantation program for 13.5 million ha of fuel wood by 2010 in China; 16000 ha of willow plantations used for the generation of heat and power in Sweden; and 50000 ha of agricultural land has been converted to woody plantations, possibly rising to as much as 4 million ha (10 million acres) by 2020 in USA.

Municipal Solid Waste (MSW) is potentially a major source of energy. This source of biomass will not be considered here due to the following reasons:

the nature of MSW, which comprises many different organic and non-organic materials

difficulties and high costs associated with sorting such material, which make it an unlikely candidate for renewable energy except for disposal purposes

re-used MSW is mostly for recycling, e.g. paper

MSW disposal would be done in landfills or incineration plants.

Bio energy challenge: to device systems to overcome low combustion efficiency and health hazards.

Biomass Sources

Agricultural residues: Amount of crop residues amounted to about 3.5 to 4 billion tones annually, with an energy content representing 65 EJ, or 1.5 billion tones oil equivalent. Hall et al (1993) estimated that just using the world's major crops (e.g. wheat, rice, maize, barley, and sugar cane), a 25% residue recovery rate could generate 38 EJ and offset between 350 and 460 million tones of carbon per year. For example, that over 2 billion tones of agricultural residues were burned annually world-wide, producing 1.1 to 1.7 billion tones/yr of CO_2. The most promising residues from the sugar cane, pulp and paper, and sawmill industrial sectors. Estimates are that about 1200 TWh/yr of electricity can be produced from this source.

Forestry residues: Forestry residues obtained from sound forest management can enhance and increase the future productivity of forests. Recoverable residues from forests have been estimated to have an energy potential of about 35 EJ/yr. A considerable advantage of these residues is that a large part is generated by the pulp and paper and sawmill industries and thus could be readily available.

Livestock residues: The use of manure may be more acceptable when there are other environmental benefits, e.g. the production of biogas and fertilizer, given large surpluses of manure which can, if applied in large quantities to the soil, represent a danger for agriculture and the environment, as is the case in Denmark; environmental and health hazards, which are much higher than for other biofuels.

Energy forestry/crops. Dedicated energy crops in land specifically devoted and intercropping with non-energy crops. This is a new concept for the farmer, which will have to be fully accepted if large-scale energy crops are to form an integral part of farming practices. Factors to be considered are: land availability, possible fuel versus food conflict, potential climatic factors, higher investment cost of degraded land, land rights, etc. The most likely scenario would be the use of about 100-300 million ha, mostly in developed nations, where excess food production exists.

Bioenergy Applications

Biomass-fired electric power plants/CHP (Combined Heat and Power)

Liquid fuels e.g. bio-ethanol and bio-diesel

Biogas production technology

Bio-energy production and use:

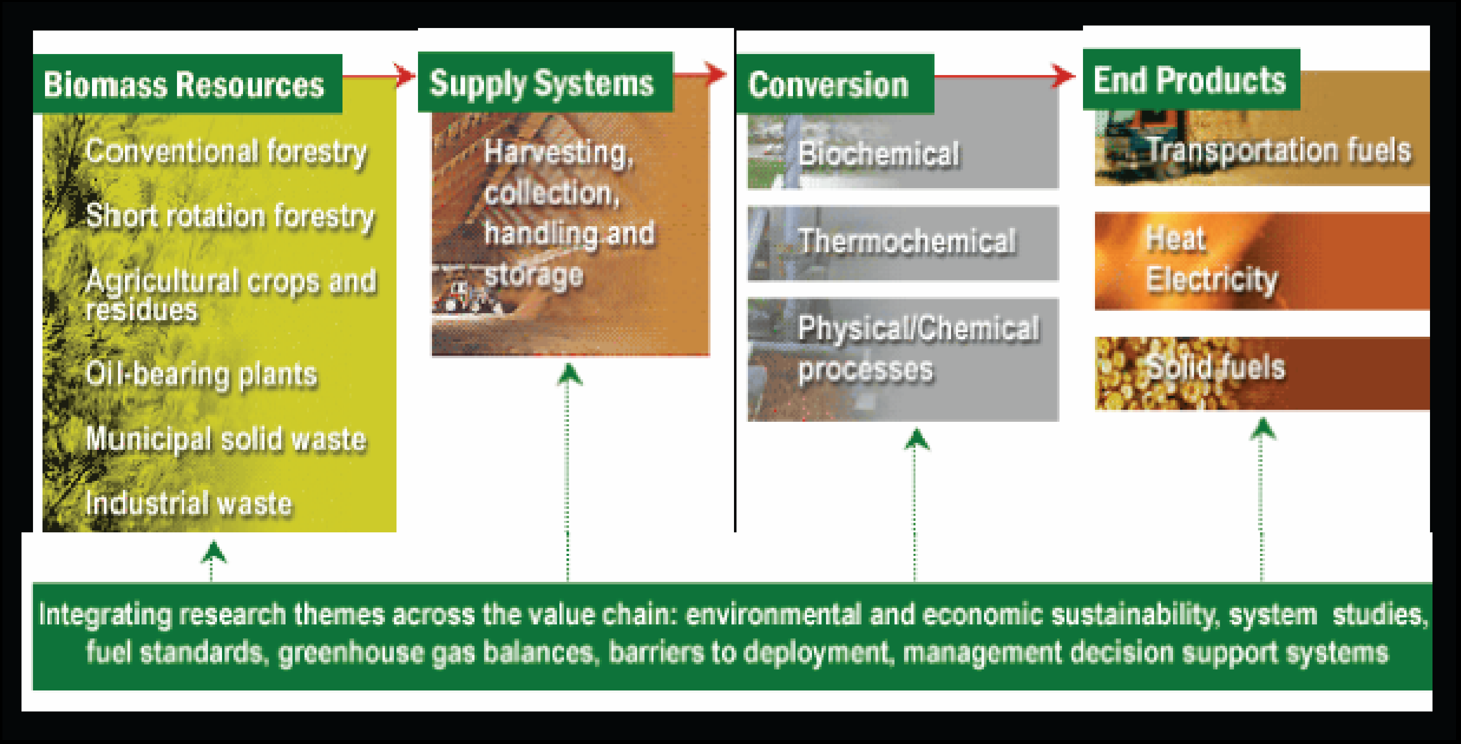
Improved integrated biomass gasifier/gas turbine (IBGT) systems for power generation and gas turbine/steam turbine combined cycle (GTCC)

Circulating fluidized bed (CFB) and integrated gasification combined cycles (IGCC) cogeneration,

Bio-ethanol and bio-diesel production

Production of methanol and hydrogen from biomass

Bioenergy



Source: IEA

USA Bioenergy Sources

Biomass type:

Municipal solid waste/Landfills	quantity of raw material available	167 million tones
	electricity generating capacity	2,862 MW
	electricity generation	71,405 TJ
	direct use from combustion	217,722 TJ
	total energy production	289,127 TJ
Forestry/wood-processing	electricity generating capacity	6,726 MW
	electricity generation	124,712 TJ
	direct use from combustion	2,306,026 TJ
	total energy production	2,430,738 TJ
Agricultural residues - corn	quantity of raw material available	13.5 million tones
	ethanol fuel production capacity	152,376 TJ/year
	yield of ethanol	8.8 GJ/tone
	ethanol fuel production	118,010 TJ

USA Bioenergy Sources

Biomass type:

Agricultural residues - soy bean oil and waste food oils

biodiesel production capacity	6,708 TJ/year
yield of biodiesel	40 GJ/tone
biodiesel production	671 TJ

Wood pellets

quantity of raw material available	0.582 million tones
direct use from combustion	8,872 TJ

Other biomass

electricity generating capacity	10,602 MW
electricity generation	11,328 TJ
direct use from combustion	102,084 TJ
total energy production	113,412 TJ

Source: www.worldenergy.org

USA Biomass Consumption

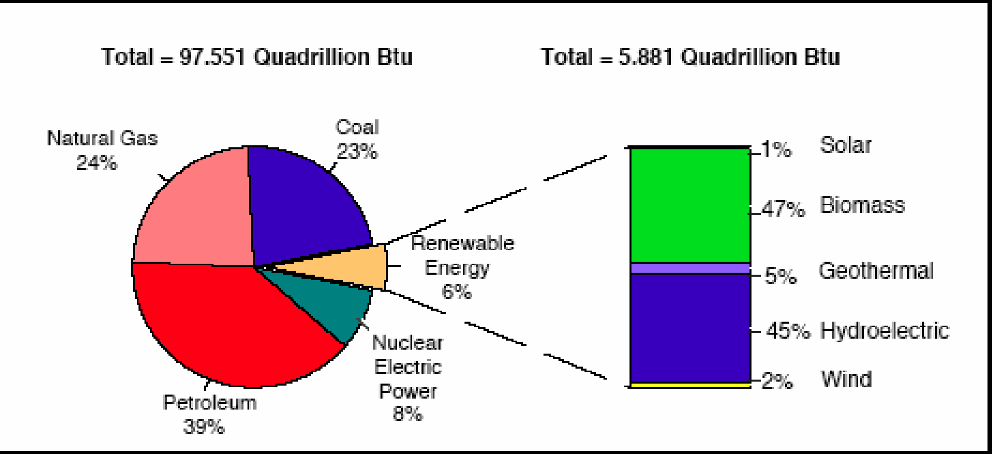


Table H1. U.S. Renewable Energy Consumption by Energy Source, 1998-2002
(Quadrillion Btu)

Energy Source	1998	1999	2000	2001	P2002
Renewable Energy	***6.549***	***6.587***	***6.145***	***5.310***	**5.881**
Conventional Hydroelectric	*3.297*	*3.268*	*2.811*	*2.201*	2.668
Geothermal Energy	*0.328*	*0.331*	0.317	*0.311*	0.304
Biomass	2.823	*2.873*	*2.893*	*2.663*	2.738
Solar Energy	0.070	0.069	0.066	*0.065*	0.064
Wind Energy	0.031	0.046	0.057	*0.068*	0.106

P=Preliminary.
Note: Revised data are in italics. The methodology for estimating electricity net imports is revised; see Appendix F. Totals may not equal sum of components due to independent rounding.
Source: Table 1 of this report.

Source: www.eia.doe.gov/cneaf/solar.renewables

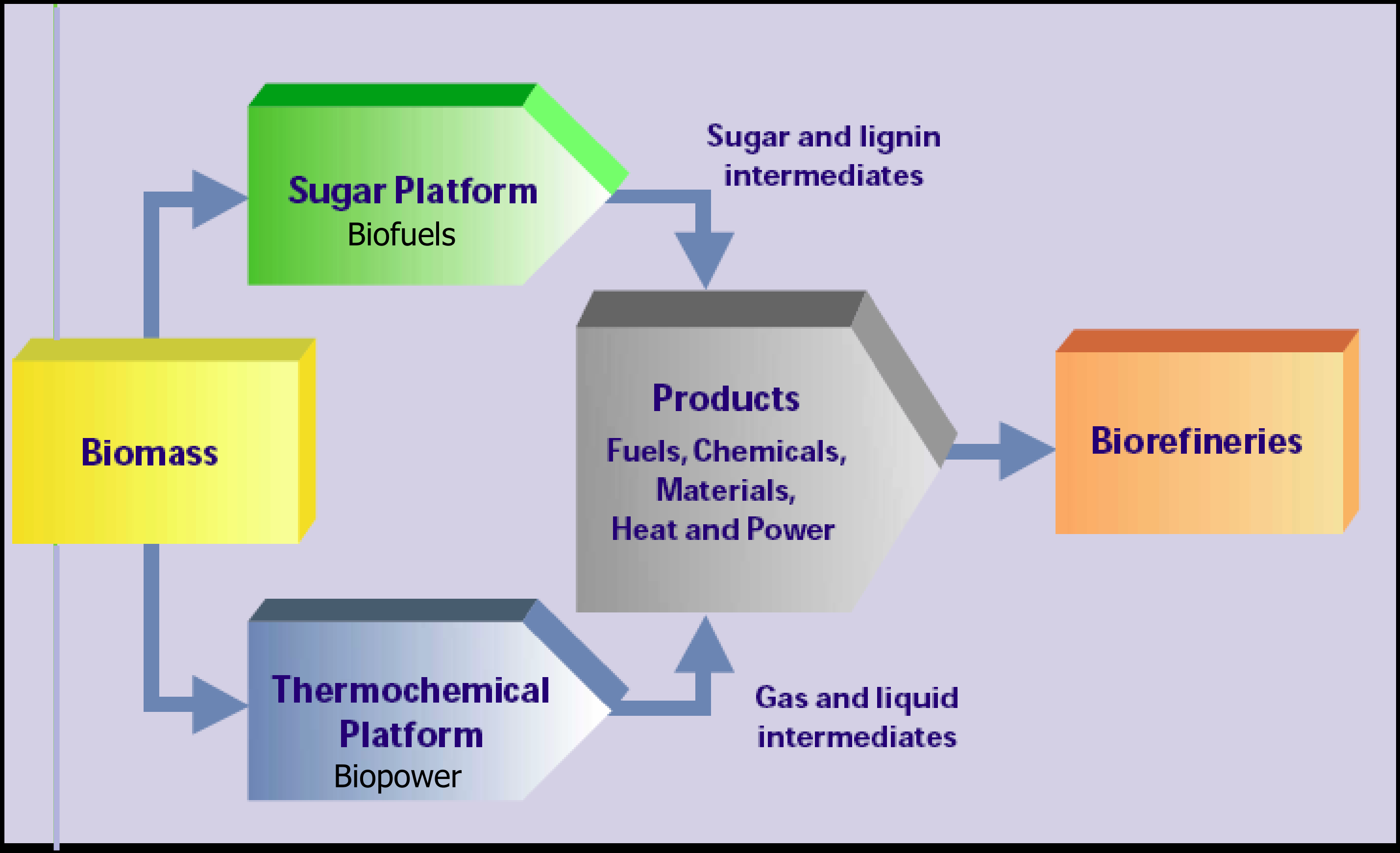
Biomass Fuel Heat Content

Fuel Type	Heat Content	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
Methane	0.841	Million Btu/Thousand Cubic Feet
Municipal Solid Waste	9.945	Million Btu/Short Ton
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
Tires	26.865	Million Btu/Short Ton
Utility Poles	12.500	Million Btu/Short Ton
Waste Alcohol	3.800	Million Btu/Barrel
Wood/Wood Waste	9.961	Million Btu/Short Ton

Source: Energy Information Administration, Form EIA-860B (1999), "Annual Electric Generator Report - Nonutility 1999."

Source: www.eia.doe.gov/cneaf/solar.renewables

US DOE Roadmap



Biopower

Direct-fired Systems: The biomass fuel is burned in a boiler to produce high-pressure steam. The steam is used to produce electricity in steam turbine generators. Biomass boilers are typically 20 - 50 MW range. The energy in biomass is converted to electricity with a efficiency of about 35% - a typical value of a modern coal-fired power plant.

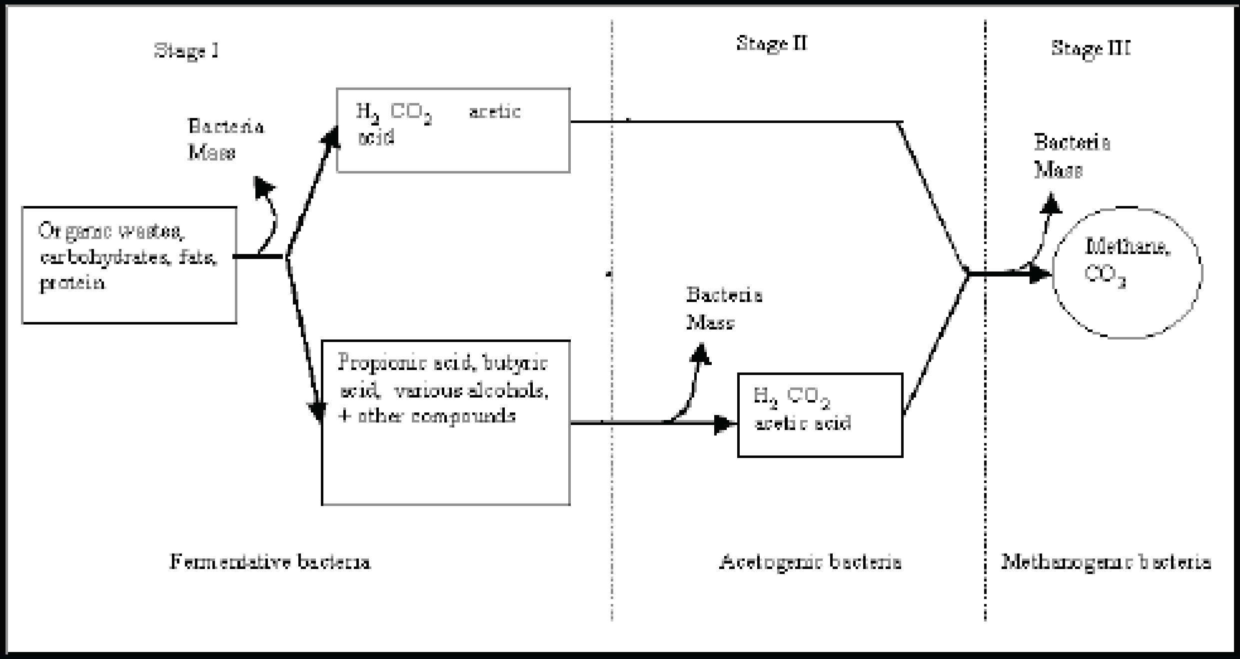
Biomass gasifiers: Operate by heating biomass in an environment where the solid biomass breaks down to form a flammable low calorific gas. The biogas is then cleaned and filtered to remove problem chemical compounds. The gas is used in more efficient power generation systems called combined-cycles, which combine gas turbines and steam turbines to produce electricity. The efficiency of these systems can reach 60%. Gasification systems may also be coupled with fuel cell systems using a reformer to produce hydrogen and then convert hydrogen gas to electricity (and heat) using an electro-chemical process.

Pyrolysis: Biomass pyrolysis refers to a process where biomass is exposed to high temperatures in the absence of air, causing the biomass to decompose. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide).

Biopower

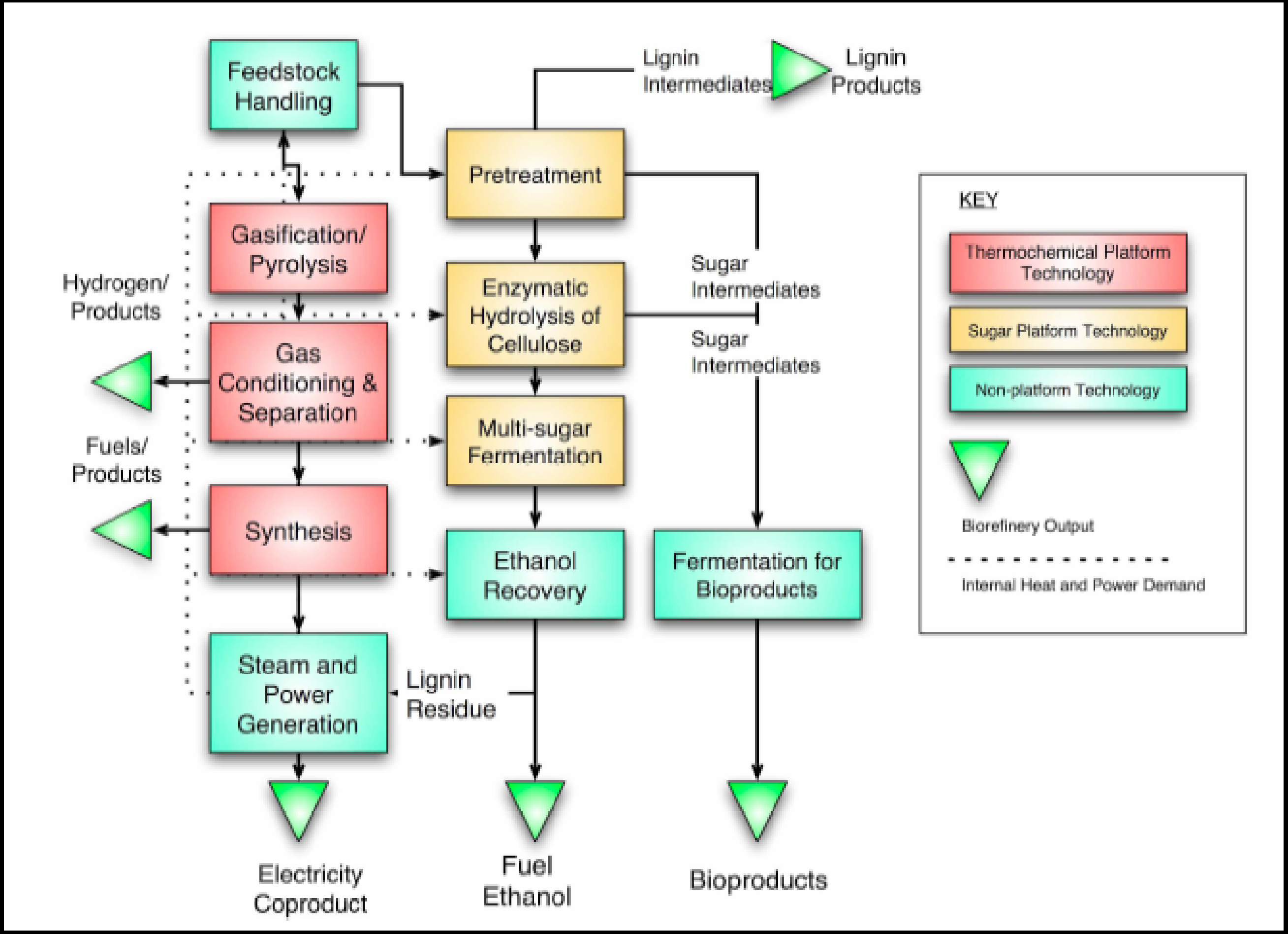
Anaerobic digestion: Anaerobic digestion is a process by which organic matter is decomposed by bacteria in the absence of oxygen to produce methane and other byproducts. The primary energy product is a low to medium calorific gas, normally consisting of 50 to 60 percent methane.

Modular systems (micro-power) : Employ some of the same technologies mentioned above, but on a smaller scale that is more applicable to villages, farms, and small industry.



The process of methanogesis

Bioenergy Integrated System



Biofuels

Ethanol: It is made by converting the carbohydrate portion of biomass into sugar, which is then converted into ethanol in a fermentation process similar to brewing beer. Ethanol is the most widely used biofuel today with current capacity of 1.8 billion gallons per year based on starch crops such as corn. Ethanol produced from cellulose* biomass is currently the subject of extensive research, development and demonstration efforts.

Biodiesel: It 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 soybean or Canola oils or waste vegetable oils.

Syngas: Biomass can be gasified to produce a synthesis gas composed primarily of hydrogen and carbon monoxide, also called syngas or biosyngas. Hydrogen can be recovered from this syngas, or it can be catalytically converted to methanol. It can also be converted using Fischer-Tropsch catalyst into a liquid stream with properties similar to diesel fuel, called Fischer-Tropsch diesel.

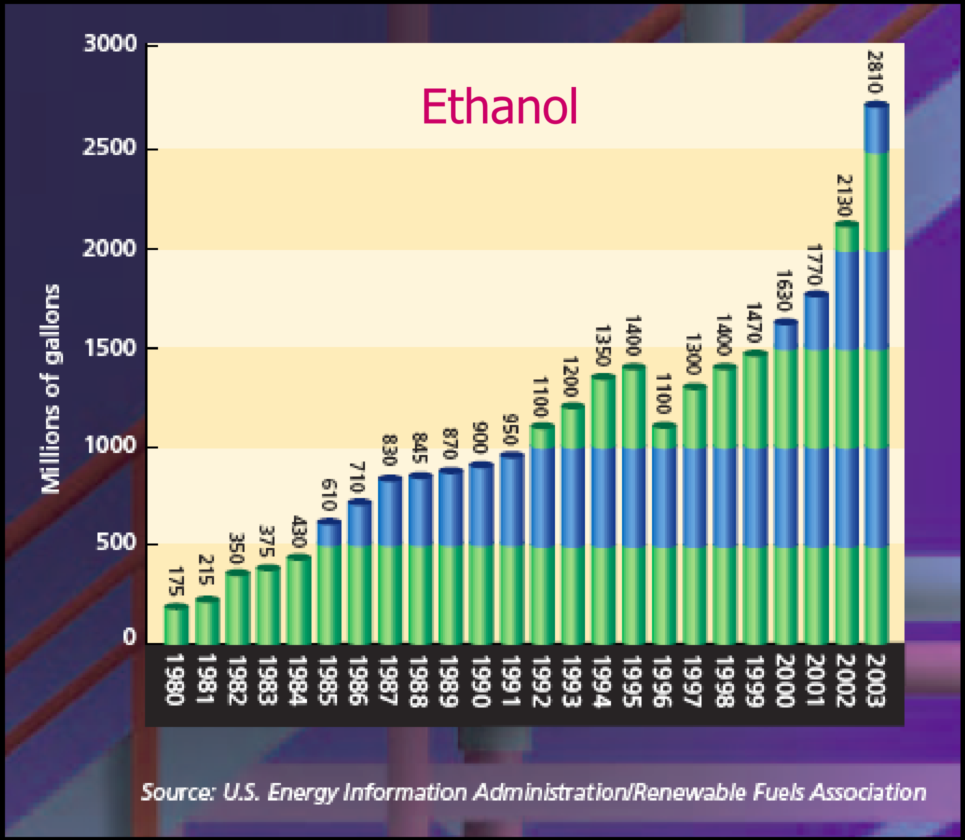
*Cellulose($C_6H_{10}O_5$) is a long-chain polysaccharide carbohydrate of beta glucose. It forms the primary structural component of plants and is not digestible by humans.

Ethanol - Octane Boost

Ethanol provides an octane boost, both for conventional and reformulated gasoline.In the absence of ethanol, gasoline suppliers use alkylates and other petroleum-based compounds to increase the octane of gasoline. Ethanol is particularly desirable as an octane enhancer since it can substitute for benzene and other aromatic hydrocarbons, such as toluene, xylene, and other 'benzene-ring'-based compounds in gasoline. This substitution reduces emissions of benzene and butadiene, both of which are carcinogenic.

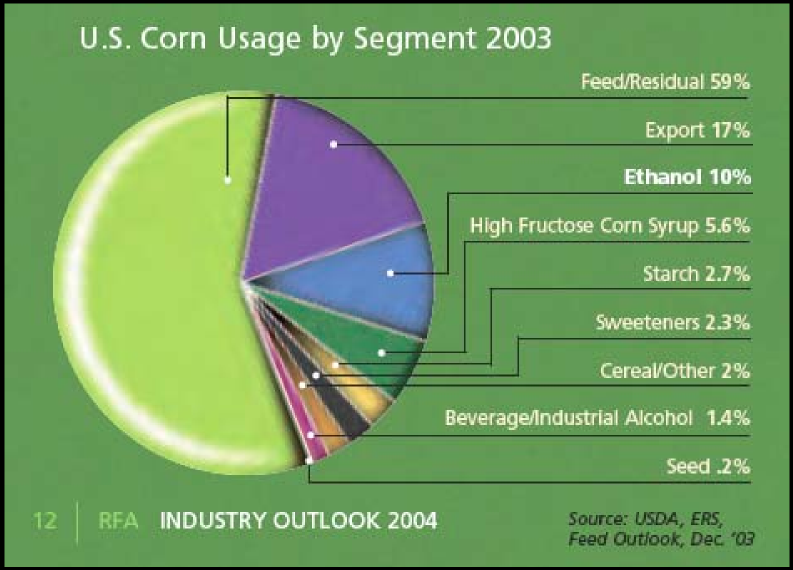
Example: Mixture with 92 octane premium
10% ethanol will boos to 94.3 - 94.7 octane

Renewable Fuels



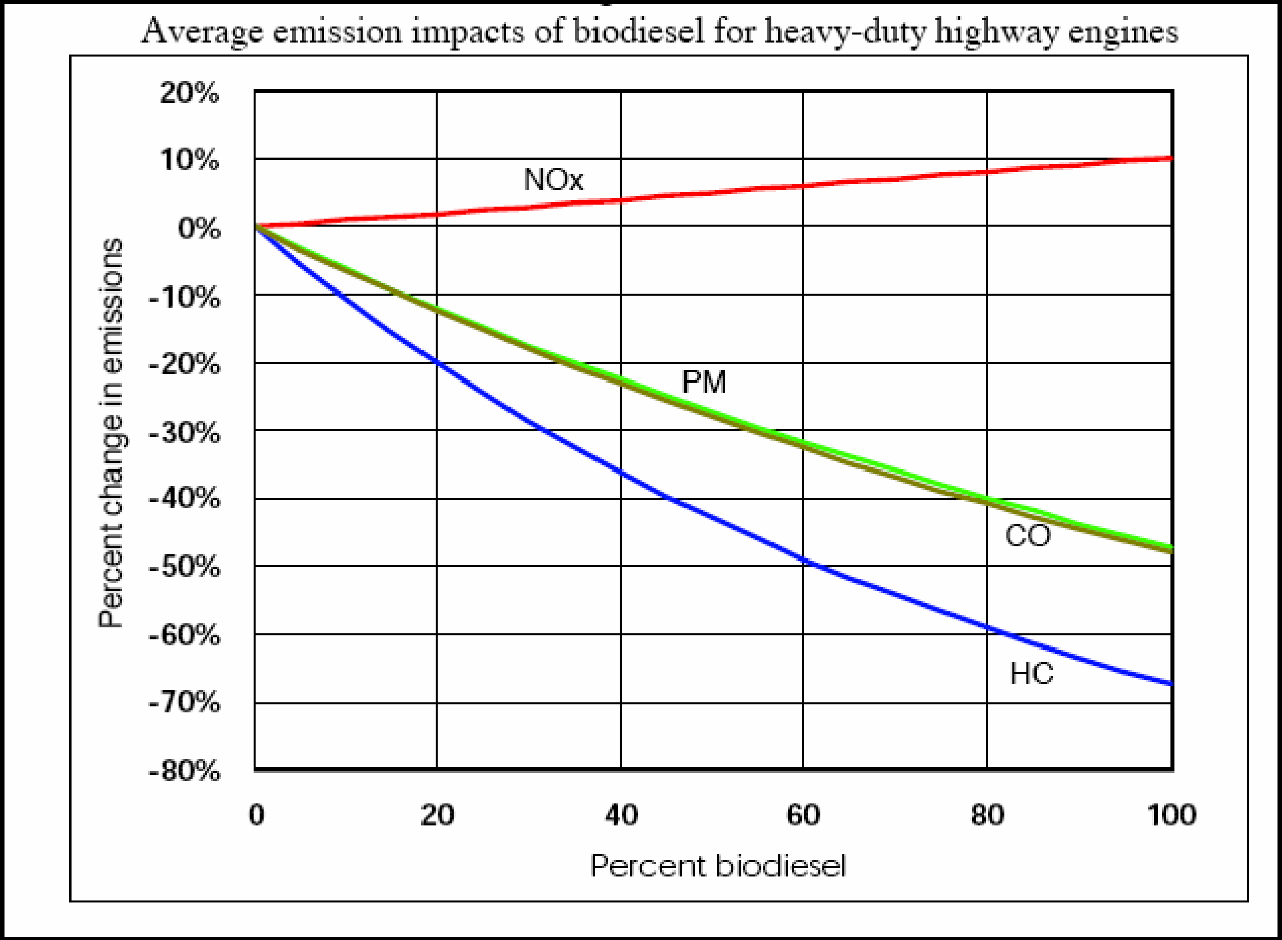
E85 - 85% ethanol and 15% Gasoline

E diesel - blending ethanol with diesel fuel, used primarily in heavy-duty urban vehicles



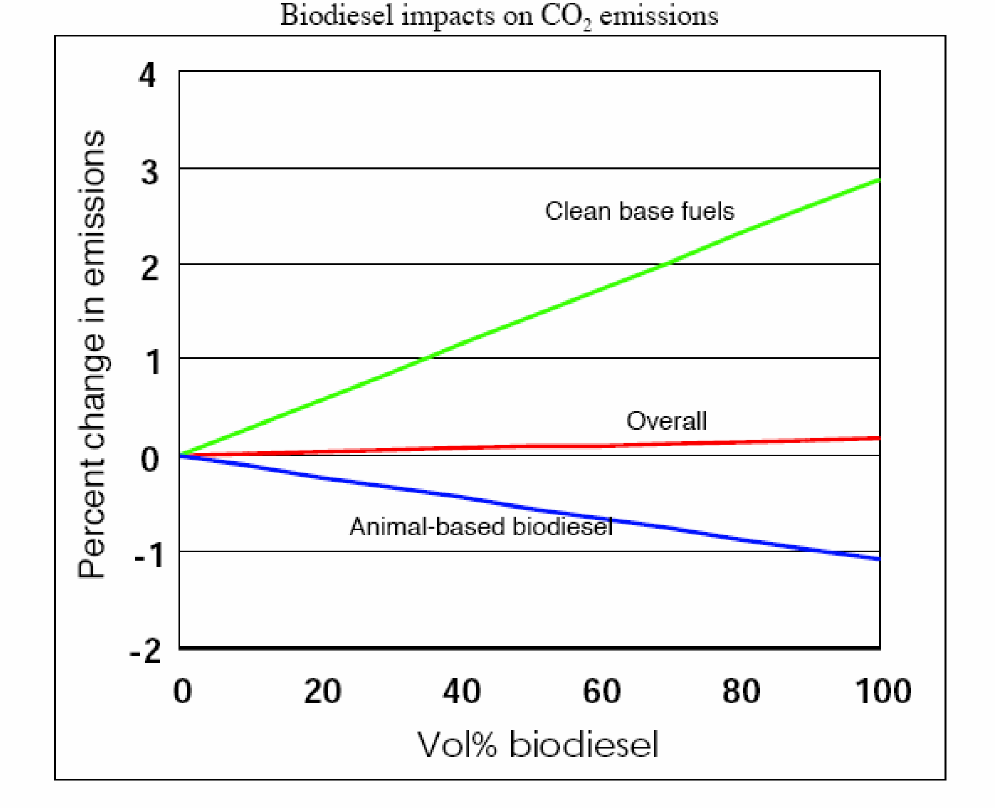
Source: Renewable fuels association

Biodiesel Emissions



Source: EPA420-P-02-001

Biodiesel CO_2 Emissions

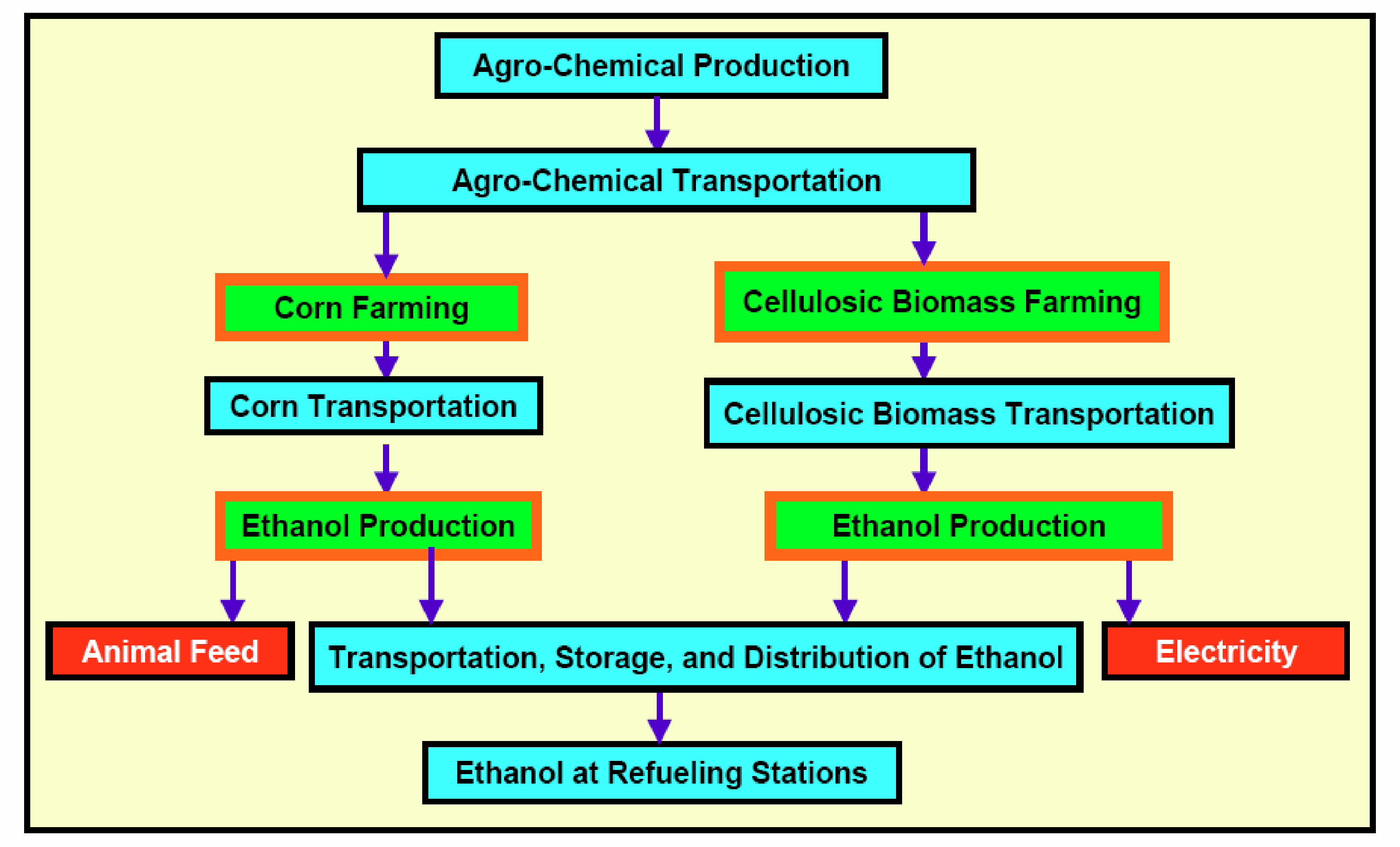


Fuel economy impacts of biodiesel use

	% reduction in miles/gallon
20% biodiesel	0.9 - 2.1
100% biodiesel	4.6 - 10.6

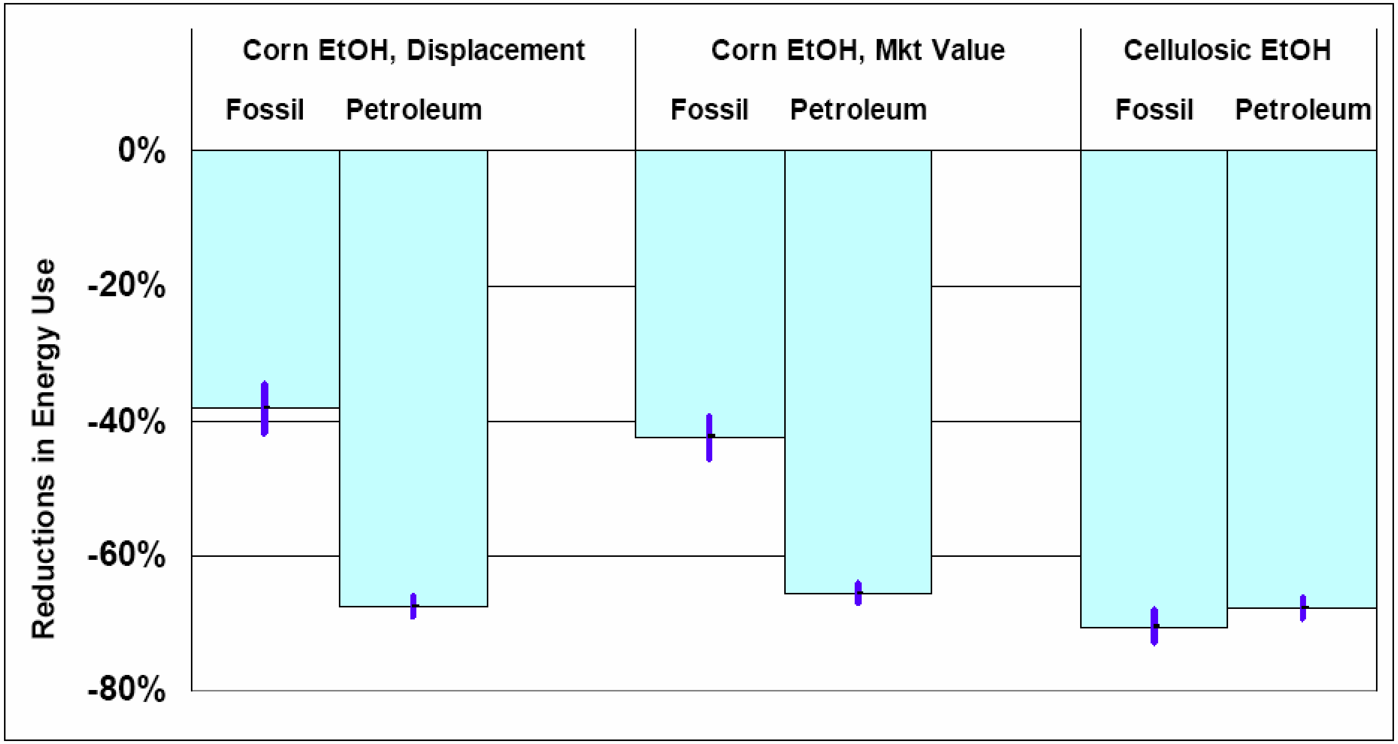
Source: EPA420-P-02-001

Ethanol Energy



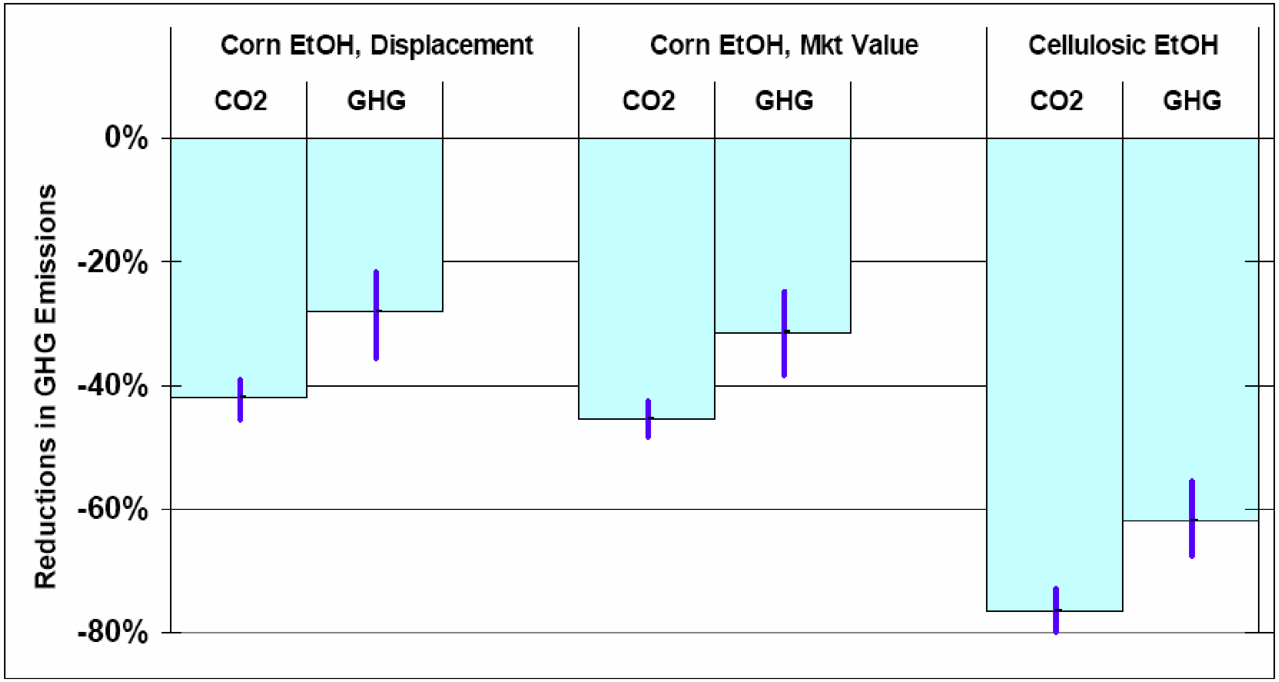
Source: Michael Wang, Argonne National Laboratory

E 85 Energy Use



Note: Based on per-mile results of E85 use in FFVs. Fossil fuels here include petroleum, natural gas, and coal.

E85 Greenhouse Gas Emissions



Note: Based on per-mile results of E85 use in FFVs. GHG emissions are CO2-equivalent emissions of CO2, CH4, and N2O.

Ethanol Fuel Cycle

- **Chemicals Production**
  - Energy use for producing:
    - Fertilizers (N, P_2O_5, K_2O)
    - Herbicides
    - Insecticides
- **Farming**
  - Yield per acre: corn and biomass
  - Chemicals use intensity
  - Soil N_2O emissions
  - Energy use intensity
  - Soil CO_2 emissions
- **Ethanol Production**
  - Corn ethanol: wet vs. dry milling
  - Ethanol yield per unit of feed
  - Energy use intensity
  - Co-products
- **Vehicle Fuel Economy**
  - Gasoline vehicles for E10
  - Flexible-fuel vehicles for E85

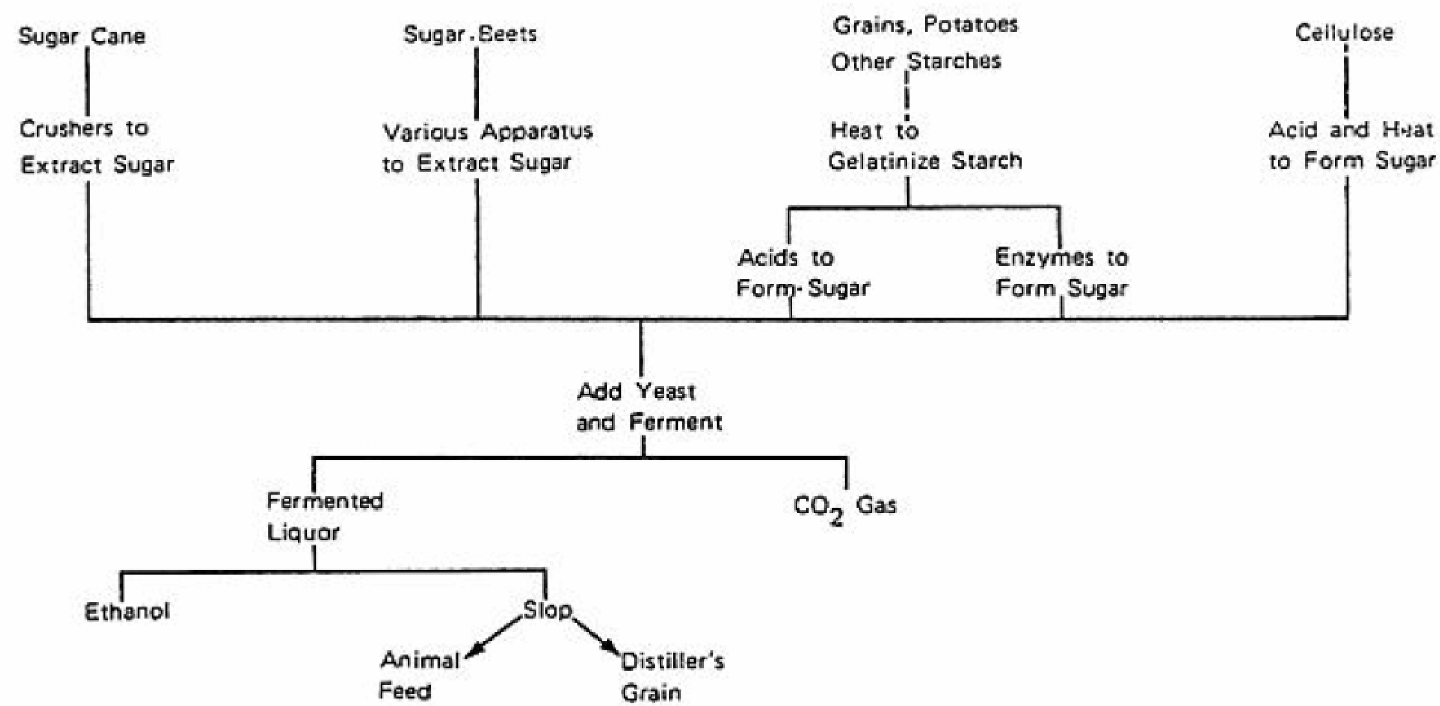
Ethanol Production

Starch and Sugar based feedstock: Corn and Barley and food processing waste streams such as potato and brewery waste

Cellulosic feedstock: Agricultural crop residues, forestry wood wastes, mill residues, urban wood waste, paper manufacturing wastes, waste paper and energy crops.

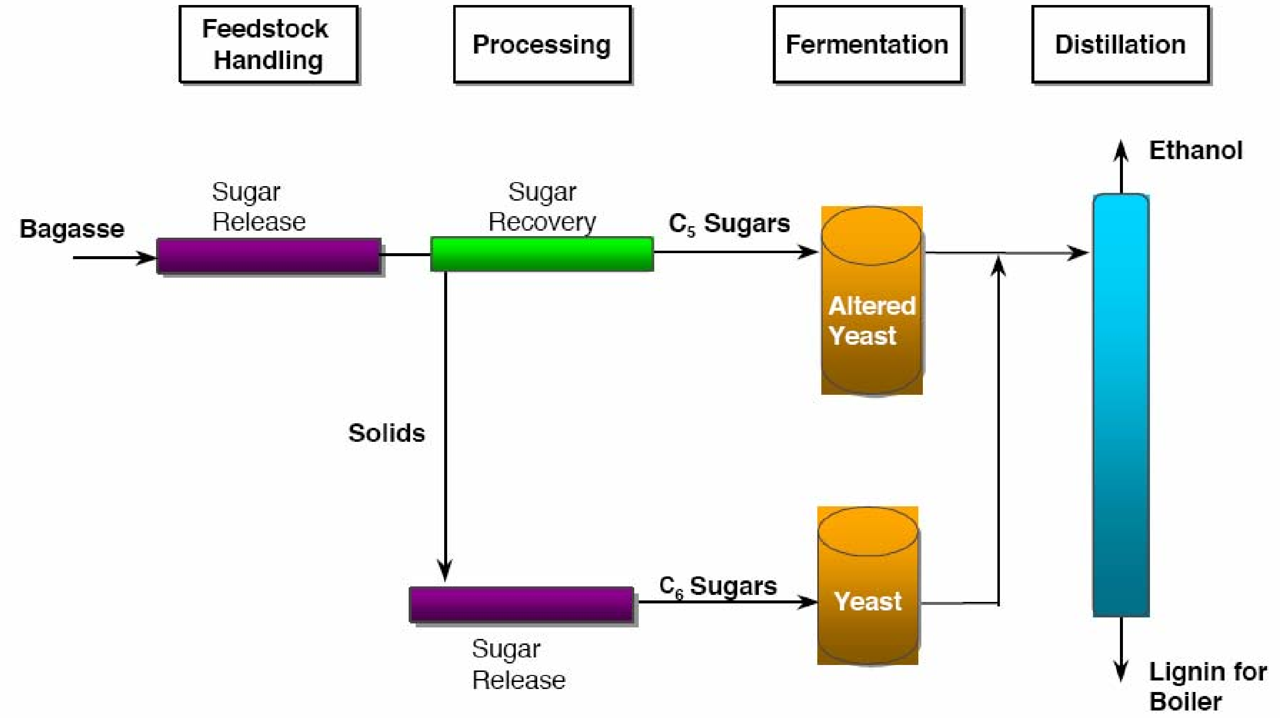
Cellulosic biomass ethanol provides about four units of energy for every unit of fossil fuel energy used to produce it – a significantly higher ratio than for other renewable fuels, such as corn ethanol. The large positive net energy balance for cellulosic biomass ethanol compared to corn ethanol is due to the fact that relatively little fossil energy is used in the creation of cellulosic biomass and in the biomass to ethanol conversion process. However, unlike starch based crops, such as corn, this biomass waste is often burned (ethanol production solves this problem), and does not have market value other than as feedstock for energy production. In addition, biomass resources such as wood waste, and certain dedicated biomass ethanol crops (such as switch grass) are not nearly as energy intensive to produce as starch crops.

Starch and Sugar Based Ethanol



Source: University of Florida Cooperative Extension Service, Institute of Food and Agricultural Service.

Cellulose Ethanol Production

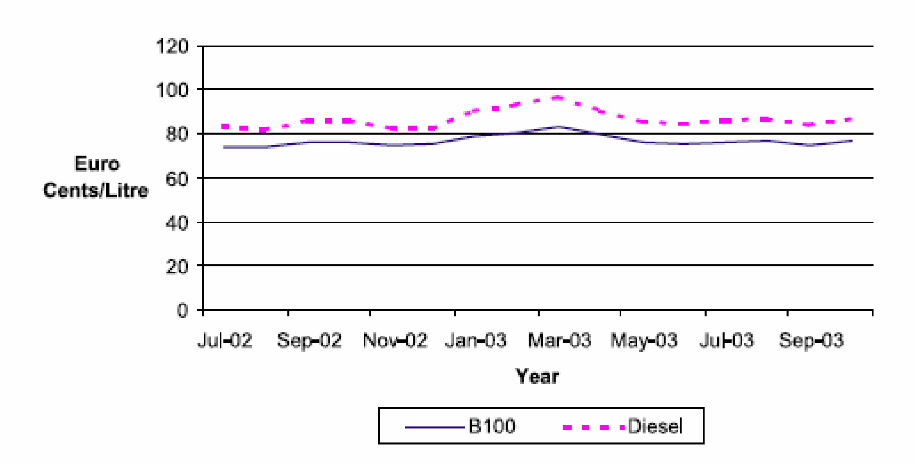


Source: BC International Corporation

Biofuel Costs

Fuel	Spot Price, US$/litre*
Ethanol from grain	$ 0.35
Mid-grade gasoline	$ 0.28
Biodiesel	$ 0.55
Petroleum diesel	$ 0.27

* January 2004



Renewable Liquid Fuels

Biomass is the only source of *renewable liquid* fuels. Engines utilizing biofuels produce fewer emissions. From an economic standpoint, the local production and use of biofuels creates jobs, creates cash flow back into rural communities. Greatest potential for widespread production and use will occur from using feedstocks not in the food chain. feedstocks such as trees, grasses, and other plant materials high in cellulosic content.

Direct substitution of fossil fuels, which seems to be the most advantageous and appropriate strategy, with its greater environmental, energy, and ecological benefits.