tent is inversely proportional to water content and combustion efficiency increases with fuel dryness.

- If biomass is burned in numerous, small, widely-dispersed combustion units, it is difficult to control or contain emissions.
- Biomass has a relatively high ash content.
- The incomplete combustion of biomass, such as occurs in most wood stoves and fireplaces, releases polycyclic organic matter (including benzo [a] pyrene and several other known or suspected cancer-producing agents) to the atmosphere.

1. ALCOHOL FUELS

There are two types of alcohol which have recently received attention as possible transportation fuels. These alcohols are methanol, characterized by the chemical formula CH_3OH, and ethanol, C_2H_5OH. Although the former is usually associated with the feedstock wood (methanol has long been referred to as wood alcohol), it can also be synthesized from other biomass feedstocks, as well as from natural gas and coal. Ethanol can similarly be derived from wood but the process has not yet reached the commercial stage and nearly all ethanol is produced from the fermentation of sugar- or starch-containing biomass.

Alcohols have long been considered attractive as liquid fuels. Henry Ford originally designed the Model T to run on alcohol and later modified the design to accommodate alcohol, gasohol or gasoline when petroleum-derived fuels became cheap and plentiful. Alcohols are well suited for use as fuels because they are completely biodegradable, are easily portable, have a relatively high Btu content per unit weight (Table 6-1), burn cleaner than petroleum-derived fuels, and have a higher octane rating than pure gasoline with no additives (octane number is a measure of a fuel's resistance to self-ignition). The combustion products of ethanol are discussed in the section on Nonconventional Propulsion.

Table 6-1: ENERGY CONTENT OF METHANOL, ETHANOL AND GASOLINE

	Btu/lb	MJ/kg
Methanol	8,570	20
Ethanol	11,500	27
Gasoline	18,900	44

Source: After Mathers, 1980, p. XXII-11.

A. ETHANOL

Ethanol (C_2H_5OH) is produced almost exclusively by fermentation and all such processes consist of four basic steps: (1) the feedstock is processed and/or treated to produce a sugar solution; (2) yeasts or bacteria convert the sugar to ethanol and carbon dioxide; (3) distillation is used to remove the ethanol from the fermentation solution, yielding an ethanol/water solution which is at best 95.6% ethanol at normal pressures; and (4) any remaining water is removed to produce "dry" or anhydrous ethanol. This latter step is usually accomplished by a second distillation in the presence of another chemical.

Distillation

Distillation is a physical process which consists in this application of heating an ethanol-water solution and passing the resultant vapour through a cooling column in which the vapour condenses and revapourizes numerous times — a process that concentrates the ethanol and removes the water.

Because the boiling points of ethanol and water are very close, however, a certain amount of water is entrained with the ethanol as it vapourizes and condenses; thus the ethanol cannot be made more pure than 95.6% by this process alone.

The main distinctions among fermentation processes utilizing different feedstocks arise primarily out of differences in the *pretreatment* steps to which the feedstock is subjected. Sugar-containing crops such as sugarcane, sweet sorghum, sugar beets and sugar mangels yield sugar directly upon processing, but the sugar must be concentrated or treated in some other fashion for storage to prevent it from being broken down by bacteria. Starch-containing feedstocks such as corn and other grains need to be broken down (hydrolyzed) with enzymes (biological catalysts) or acids to reduce or convert the starch to sugar. Similarly, cellulosic (woody or cellulose-containing) feedstocks such as crop residues, grasses, wood and municipal wastepaper require extensive hydrolysis (either acidic or enzymatic) to reduce their more inert, long-chain, cellulose molecules to sugar subunits. No commercial cellulose-to-ethanol installations exist at the present time but pilot plants have been established in Brazil using eucalyptus wood. Small-scale experiments are being carried out in Canada as well.

Ethanol can of course be produced from starch and sugar feedstocks with commercially available technology. Starch feedstocks are primarily grain crops such as corn, wheat and oats, but also include various root plants such as potatoes. The sugar feedstocks are