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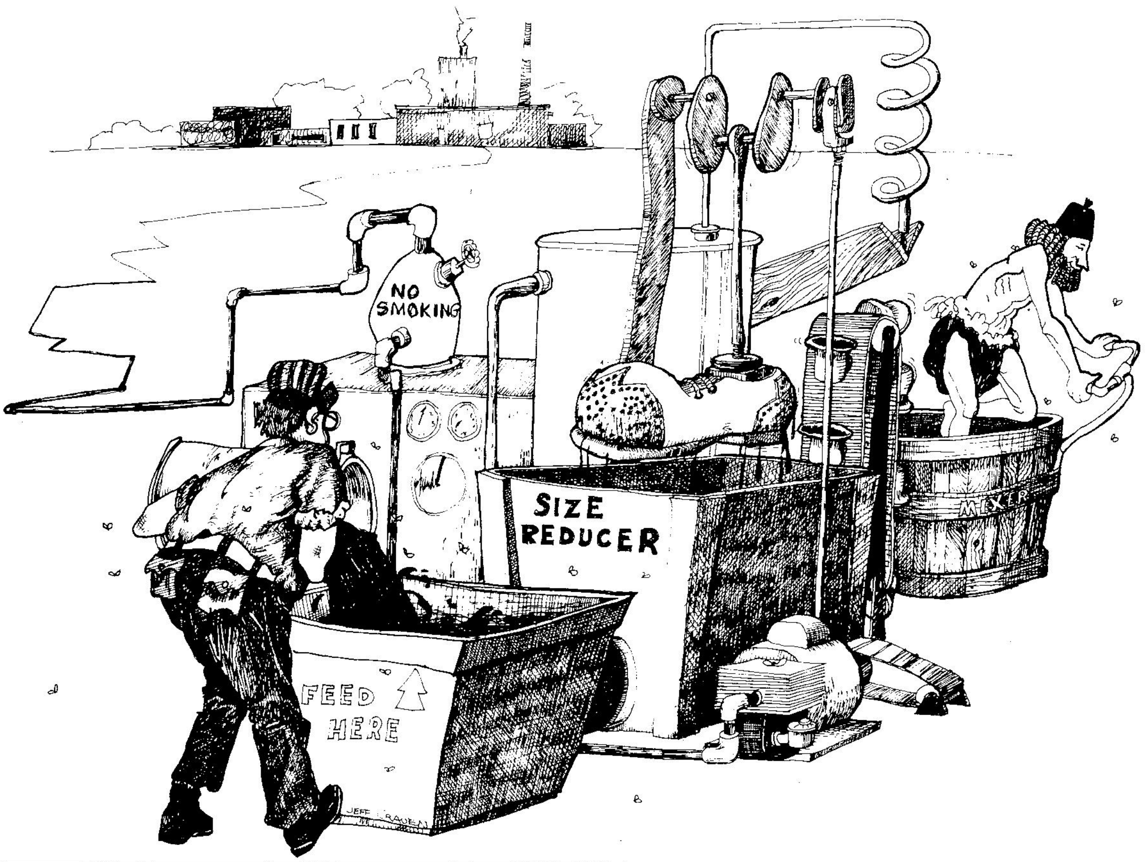

ENERGY FROM BIOMASS —COMING FULL CIRCLE

"The oil embargo and subsequent drastic increases in the cost of energy have resulted in increased utilization of biomass wastes at pulp and paper mills."

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MOST OF US have forgotten or never realized how much this country depended on energy from biomass during its first 100 years. The earliest uses of such energy in this country involved wood for heating and cooking, grass and hay for animal power, and, in certain areas, conversion of wood into charcoal or coke for industrial use. As late as 1850, biomass provided for over 70% of the U.S. primary energy requirements.

During the 19th century, a major (and probably an unfortunate) consumption of wood biomass produced charcoal and coke for use in making iron, steel, and copper. This practice denuded hundreds of square miles of forests in many locations. Wood used to be almost the only source of energy for heating and cooking in this country. This use of wood continued through most of the 19th century. In forested areas, wood still provided all or the majority of the heat for many homes.

Oxen and horses are both forms of power which are derived from biomass. Lancaster County, Pa., is an area where this form of energy from biomass is still utilized extensively for farming. It was not until 1947 that the number of tractors exceeded the number of horses and mules on farms in this country.

Around the turn of the century, the use of energy from biomass decreased as oil and coal became the predominate sources of energy. During this era, a few locations produced what was called "town gas" manufactured from wood and coal. This gas had a low energy content, but could be used satisfactorily for cooking and heating. By the 1920's, there were over 20,000 coal gasifiers producing gas in the U.S. This process for producing "town gas" was pyrolysis-gasification, which can convert any organic material into a clean-burning fuel.

Another old technology which is still in significant use today is the production of methane gas at sewage treatment plants. Methane is the primary ingredient of natural gas and can be substituted on a one-for-one basis. This process is the anaerobic [without air] digestion of organic material by specific microorganisms. Nature has done this since before the coming of man. There is strong evidence that the first living organisms on Earth were anaerobic bacteria. It is due to the effort of these little bugs for hundreds of millions of years that we are able to take advantage of the enormous quantities of natural gas and oil that we do today. The Indians in America were aware of this natural process. This digestion was, and is, common in swamps, where the decaying materials produce bubbles of gas. This gas contains methane and can be readily burned.

Perhaps the oldest method in continuous use for conversion of biomass into useful energy is fermentation. When suitable bacteria are used, grains, fruits, and many other kinds of biomass can be converted into a useful fuel. However, most cultures have chosen to use it as a beverage. Many call it beer, wine, or spirits, all of which contain ethanol. If different types of bacteria are used with other feedstocks, usually a form of wood, then the product is methanol. Both of these alcohols are exceptionally clean-burning fuels.

Technologies for conversion of biomass

The pulp and paper industry has always been a large user of biomass. During the 1890's and early in this century, some plants in the U.S. were energy self-sufficient, producing all of their electricity from wood waste. Today, a typical pulp and paper mill will generate half of its power by burning biomass to produce steam, which is then used to turn steam turbine electrical generators.

The earliest pulp and paper plants burned hog fuel—waste wood products such as bark, trimmings, and other unusable parts of the tree. The boilers used to burn the hog fuel were very large and costly to build. Later, the amount of available hog fuel decreased due to improved utilization of the tree. As a result, black liquor boilers were added to provide electricity and process steam. Black liquor is a waste byproduct from the conversion of wood chips into paper pulp.

Another method of converting biomass into a useful fuel is pyrolysis-gasification. This process produces a gas that can be utilized in steam boilers, many gas-fired ovens, and large internal combustion engines. Variations in the design and operation of the equipment will result in other combustible products, such as a thick oil or charcoal. Depending on the specific design, a low-, medium-, or high-energy content gas can be produced. Some of each of these systems are in operation today.

Pyrolysis-gasification may be described as a combination of two well-known and extensively used processes from the wood and coal industries. The char gasification reactions are chemically the same as those used for the production of gases with low-energy contents, known as "coal gas," "manufactured gas," or "water gas." The last term was coined to identify one of the major reactions, which is the steam (water)-carbon reaction. The second process, destructive distillation, is used in the production of coke from certain types of coal and is also used in the production of charcoal from wood. All chemical processes that occur in pyrolysis-gasification of wood also occur in a wood-burning fireplace in a home.

Anaerobic digestion of biomass consists of two distinctly different stages. In the first stage, bacteria act upon the complex organics in the biomass to change them into simple, soluble organic material called volatile acids. The second stage involves a different group of bacteria, which converts the volatile acids by a process called fermentation into a mixture of methane gas and carbon dioxide gas. There are a number of different strains of bacteria in each of these stages. As a result, some methane and considerable carbon dioxide is produced in the initial stage. By selecting and maintaining specific bacteria for the final stage of fermentation, pure methane could also be produced. The chemistry of this process is quite complex and not well-understood. It is very difficult to obtain optimum yields, while, at the other extreme, it is almost impossible not to get some burnable gas from the most crude experiment, which anyone can perform in the backyard.

To maintain continuous production at reasonably high levels of efficiency, a proper balance between the two groups of bacteria is required. To maintain this balance, five environmental parameters must be controlled —temperature, anaerobiosis, acidity, nutrients, and toxicity of input. The two major groups of microorganisms require a different range of temperatures for optimum production. Maintenance of anaerobiosis [life without air] in the digester is essential. Even small amounts of air can almost totally disrupt the production of methane. Acidity must be maintained over a fairly narrow range. This is a difficult task since, in the first stage, the bacteria are producing acid and, in the second stage, different bacteria are converting acid to gas. Another requirement is provision of adequate nutrients for the various bacteria. The rate of methane production is closely related to the ratio between carbon and nitrogen in the digester feedstock.

For successful production of gas from biomass, the fifth environmental parameter, that of toxicity, must be maintained at a low level. Compared to the other four variables, very little is understood about how much and what combinations of unhealthy trace substances in the feedstock will produce a toxic level for the different bacteria in the digester. Fortunately, with most biomass, other than municipal garbage and sewage sludge, toxicity is not a problem and some gas will be produced over a wide range of each of the other parameters. It is only when optimization is attempted that high technology is required. For example, in India, farmers and other rural families have been using biomass digesters for over 40 years. These have been made at the local level with materials that are readily available. It was estimated that, in 1970, well over 250,000 of these units were in use in India.

Another country which has gone to biomass fuel in a big way is China. Only a few digesters were in operation before 1970. By 1975, over 200,000 units were in use just in the province of Szechwan. By 1977, there were an estimated 4,300,000 digesters in use in China.

Sources of biomass

All agriculture crops that are grown

for food which will be used for human consumption produce many times as much waste as they do an edible portion. Most of the crops grown for livestock feed also produce large quantities of waste material. Significant quantities of organic wastes result from the processing of fruits, vegetables, cereal grains, and other foods.

Not all of the wastes left in the field can or should be considered as available for conversion into energy. To do so would deplete soil nutrients and cause subsequent loss of crop yield. There are methods of conversion of these wastes into a burnable fuel that allow most of the essential nutrients to be returned to the soil. Under these conditions, 75% or more of the crop (biomass) wastes would be usable for conversion to other energy forms.

A different form of agriculture is marine farming or aquaculture for the production of very large quantities of biomass. One method which is under development off the California coast is giant kelp farming. Yields are very high—35-60 dry tons per acre per year. The kelp will be harvested and converted to a pipeline-quality gas by anaerobic digestion. A similar project is being considered in Florida by growing water hyacinths in canals. The yield per acre per year is also very high—about 60 dry tons. An additional benefit may be the reduction of the $15,000,000 annual cost to the state of Florida for water hyacinth control in existing waterways.

Other water-based farming methods proposed for production of biomass include algae grown in the ocean, in cooling ponds of electrical power generating plants, or in converted dry lake beds. The algae would be converted to useful energy either by anaerobic digestion or fermentation. Until the Solid Waste Disposal Act was passed in 1965, mixed municipal solid wastes (MMSW) were considered a nuisance and were disposed of in the cheapest way possible. Much of the industrial and most of the commercial burnable solid wastes end up in the municipal solid waste stream. Later, the act was amended as the Resource Recovery Act of 1970. Since that time, various technologies have been developed or improved which can recover the biomass (organic) portion of the MMSW and convert it into useful energy (fuel).

Approximately, 40% of MMSW is paper and other forest products. In addition, there is another 40% that consists of yard wastes, food wastes, and other organic materials. On a national basis, 80% of MMSW is one form or another of biomass and can be converted to energy with one or more technologies.

Recent environmental awareness has resulted in significantly improved utilization of the "total tree" by the forest products industry. Many articles in forest product industry literature emphasize total tree utilization. Some of these suggest that 80-90% conversion of the tree is possible. This high utilization refers only to that portion of the tree normally harvested and delivered to the mill.

Work at the University of Maine has been performed to do a complete biomass inventory of the forest. Using the total biomass as the basis, only about 50% of it is delivered to the mill and utilized under so-called total tree utilization. The remaining 50% is a very large source of biomass that could be converted to useful energy.

The oil embargo and subsequent drastic increases in the cost of energy have resulted in increased utilization of biomass wastes at pulp and paper mills. Some authorities predict that, if or when a new grass roots mill is built, it would be energy independent from outside sources and utilize 100% of all the organic (biomass) material delivered to the plant site. Therefore, any estimates of available biomass should exclude those forest materials that can be utilized for energy at the mill.

Projected quantities of biomass

Most biomass sources are not considered a waste and disposal is not a factor. For this reason, collection and transportation of existing biomass residues is the primary economic consideration. The table below gives an estimate of biomass wastes generated in the U.S., but does not consider how much of it is economical to recover.

The approximate nine quads (one quadrillion or 10^{15} BTU) of net gas potential for 1971 was equal to two times the amount of gas used for heating and hot water for all residences in the U.S. in 1970. In fact, this amount of gas could have replaced all the natural gas, oil, and electricity used for household heating in 1970!

In addition to the existing wastes, a very large potential exists for growing biomass on idle crop land. According to the Department of Agriculture, 10% of class I through class IV lands (lands that can be cultivated and are not arid) were idle in 1974. Biomass grown on these 20,000,000 acres could have produced 3.9 quads of energy.

An example of how drastic a change in thinking has occurred is a study by the Governor's Energy Advisory Council for the State of Texas made between 1973 and 1975. Texas oil production in 1976 was about six quads. They estimate that, by the year 2000, there will be 0.67 quads produced from biomass and three quads from other solar methods. The largest oil-producing state is predicting that, by the end of this century, the amount of energy its citizens will be using that is derived from direct sunlight, in one form or another, will be equal to over one-half their current oil production. The old expression "make hay while the sun shines" will take on new meaning if that ever comes to pass.

Estimates of Organic Wastes Generated in the United States, 1971 and 1980

Waste Type	1971	1980
	(Million of tons per year)	
Agricultural Crops & Food Wastes[a]	390	390
Manure	200	266
Urban Refuse	129	222
Logging & Wood-Manufacturing Residues	55	59
Miscellaneous Organic Wastes	50	60
Industrial Wastes[b]	44	50
Municipal Sewage Solids	12	14
Total	880	1061
Net Oil Potential, (million barrels)[c]	1098	1330
Net Gas Potential, (billion cubic feet)[d]	8800	10600

[a] Assuming 70% dry organic solids in major crop-waste solids.
[b] Based on 110,000,000 tons/yr. of industrial wastes in 1971.
[c] Based on an oil yield of 1.25 bbl/ton of dry organic waste.
[d] Based on a methane yield of 5 CF/lb. dry organic waste.