Biomass as a Nonfossil Fuel Source

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FOREWORD

The ACS SYMPOSIUM SERIES was founded in 1974 to provide a medium for publishing symposia quickly in book form. The format of the Series parallels that of the continuing ADVANCES IN CHEMISTRY SERIES except that in order to save time the papers are not typeset but are reproduced as they are submitted by the authors in camera-ready form. Papers are reviewed under the supervision of the Editors with the assistance of the Series Advisory Board and are selected to maintain the integrity of the symposia; however, verbatim reproductions of previously published papers are not accepted. Both reviews and reports of research are acceptable since symposia may embrace both types of presentation.

PREFACE

Excluding most of the contribution made by biomass, which is defined as organic waste such as agricultural residues and urban refuse, and land- and water-based plant material such as trees, grasses, and algae, the United States consumed about 78.2 quads (1 quad = 10^{15} Btu) of primary energy in 1979. The contribution of each energy component was 37.1 quads for petroleum, 19.8 quads for natural gas, 15.2 quads for coal, 3.2 quads for hydroelectric power, 2.8 quads for nuclear electric power, and 0.1 quad for electric power production from wood and waste and geothermal sources. Few realize that the biomass contribution, in all its forms, for the production of heat, steam, electric power, and synfuels for 1979 was about 1.9 quads, or a contribution of about 2.3% to the total primary energy consumption. Thus, biomass energy consumption is equivalent to about one million barrels of oil per day, so it is obviously a commercial reality now. Indeed, as the costs of fossil energy increase and the available supplies shrink, especially petroleum and natural gas, we will begin to return to a renewable source of fixed carbon in the form of biomass to assure a continuous supply of organic liquid and gaseous fuels and chemicals.

The concept of using biomass as a primary energy source is not new. Wood was a major source of primary energy and chemicals in the United States only a relatively few years ago. As late as 1880, over 50% of the U.S. energy demand was supplied by wood. After 1880, fossil fuels began to dominate as a primary energy supply and have continued to be our largest source of energy to the present time.

In the 1970s, a major effort was launched in the United States to develop modern technology for the utilization of biomass energy. The symposium on biomass as a nonfossil fuel source, presented in Honolulu, Hawaii in April 1979 by the Division of Petroleum Chemistry at the American Chemical Society/Chemical Society of Japan Joint Chemical Congress, was devoted to this subject. Twelve basic and applied research papers were presented at this symposium on biomass energy. This book contains updated versions of ten of these papers and fifteen additional papers to balance the treatment of the subject. These are grouped into the categories of biomass production, liquid fuels, gaseous fuels, economics and energetics, and systems analysis. It will become apparent to the reader who is being introduced to the subject for the first time that there are many routes for the utilization of biomass energy and that many activities are underway to develop commercial processes and systems. Substitute natural gas in the form of methane from landfills, liquid alcohol

fuels to replace gasoline, and direct biomass combustion for steam and electric power production are typical technologies now in use and under development. For the reader who already has been involved in biomass energy, many of the papers have extensive bibliographies that serve as a reference source.

It should be emphasized that, though this book is edited and all the papers reviewed by independent referees, I have not attempted to convert an author's views with which I disagree to my own way of thinking. However, these instances are in the minority. Universal agreement on a given biomass subject does not exist necessarily among those who have been in the field, mainly because some of the work has not yet progressed to the point where the ultimate answers are in hand.

Finally, I would like to briefly state my personal opinions on the present and future prospects of biomass energy. It is not a panacea for all of our energy problems, but it will find a logical place in the commercial energy market. Further, suitable biomass energy supplies, because of their generally dispersed nature, will be used initially in small-scale, localized applications. Large-scale central utility systems and synfuel plants supplied with biomass raw materials will be the exception rather than the rule in the 1980s and are not expected to reach commercial status to any significant extent until after 1990. Nevertheless, biomass will continue to contribute more to our energy and chemical needs as time passes.

Because of the multitude of organic residues and plant species, and the many processing combinations that yield solid, liquid, and gaseous fuels, the selection of the best technology and raw materials for specific applications seems very difficult. Many factors must be examined in depth to choose and develop systems that are technically feasible, energetically and economically practical, and environmentally acceptable. These factors are particularly important for large-scale biomass energy farms where continuity and efficiency of operation and synfuel production are paramount. The problem is not so intractable that it defies solution. But there are several major barriers to be overcome or at least reduced in size to facilitate commercial use of biomass energy technology on a scale that will satisfy a large portion of our energy demand. These barriers, none of which is insurmountable in my judgment, include such factors as excessive cost of biomass-derived synfuels, low or negative net energy production efficiencies for some systems, the problem of acquiring sufficient and suitable land for biomass production, conflicts with foodstuffs production, obtaining advance approvals and permits from state and federal agencies, and dependence on forgiven taxes and subsidies for economic success.

At the present time, the commercialization of biomass energy is proceeding at the proverbial snail's pace. The excessive cost of synfuels from biomass in integrated growth, harvesting, and conversion systems, and from integrated waste collection and conversion systems, is the prime

reason for the low commercialization rate. Although synfuel production capacity (plant size) and financing conditions impact directly on synfuel costs, the estimated and actual manufacturing costs of most biomass-derived synfuels are not presently competitive with fossil fuels. Examples are SNG from manure and natural gas, and ethanol from sugarcane for gasohol and gasoline. As the price of crude oil continues to increase, I expect the cost of fuels and chemicals from biomass will become competitive with conventional petroleum derivatives.

At this time, the major factor influencing synfuel costs from biomass is biomass cost itself; conversion and other associated costs are often a smaller part of the total cost. Plant biomass production costs are affected most by independent inputs such as the costs of planting, fertilization, irrigation, and harvesting. An incremental increase in biomass yield often cannot be justified based on the additional cost of achieving this yield improvement. For organic wastes that are debited against conversion process cost, the delivered cost of the waste, which includes the costs of collection and transport, is sometimes too high to justify synfuel manufacture. Credits must be taken for the by-products and if they cannot be sold at certain minimum prices, the operation is not profitable. Finally, alternative biomass uses such as those for materials of construction, foodstuffs, animal feeds, and soil conditioning that offer a higher profit margin than synfuel must be considered. The potential owners and operators of a biomass energy system cannot be expected to undertake a business venture to commercialize biomass energy if the profits are too small in comparison with other alternatives. Tax incentives and other forms of subsidy already have been suggested to reduce synfuel costs and thereby stimulate the investment of private capital. Whether or not this approach can be effective remains to be established. In any case, biomass costs should be reduced to help make commercial synfuel manufacture economically attractive on its own merits.

I would like to express my appreciation to the Division of Petroleum Chemistry for sponsoring this somewhat "alien" symposium. (After all, biomass will displace a significant portion of petroleum if my projections are accurate.) I especially want to thank all of the speakers who somehow managed to be in Hawaii at the appointed time despite the airline travel problems prevalent during the symposium, and also all of the contributors of other articles that I requested to try to provide a more balanced treatment of biomass energy. The authors' individual efforts were indispensable in assembling a book of this type.

Institute of Gas Technology
Chicago, Illinois

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INTRODUCTION

Industrial Development of Biomass Energy Sources

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A wide diversity of companies has entered into the development of biomass resources to solve non-energy and energy-related problems. These companies can be grouped as follows:

- Companies currently utilizing or producing biomass or biomass-derived materials and products (e.g., paper, lumber, food, and distilled spirits) are attempting to recover and use greater amounts of the resources and by-products available to them to reduce costs, develop new products, and produce energy.

- Companies which have large amounts of wastes (e.g., animal manures) are developing new ways of reducing and disposing of the wastes, reducing operating costs, and producing energy.

- Manufacturers and entrepreneurs are conducting research and development, production, and marketing of equipment to convert biomass feedstocks into energy. The goal of these activities, primarily, is to develop new products and processes which can be marketed to potential biomass users.

- Utilities which have large demands for fuels on a continuing basis are supporting the development of new, renewable, supply sources to help satisfy this demand.

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The composition of these companies and their motivations are important to government policy makers and companies considering entry into the industry, for the motivations provide a framework with which to evaluate alternative options. It is important to know, for example, that the development of energy from biomass is of secondary importance to many companies when developing a new marketing plan or tax incentive program.

In recognition of this factor, the Office of Policy and Analysis within the U.S. Department of Energy (DOE) asked Booz, Allen & Hamilton Inc. to assess the nature of industrial activities in the utilization of biomass for energy. This assessment, performed in the summer and fall of 1979, focused upon identifying the structure of the industry, the types of companies active in the industry, what they are doing, and what the motivations are for these activities.

Initially, an extensive literature research was performed to determine the companies actively pursuing biomass energy development, the issues critical to the expansion of the industry, and market perspectives which exist. Based upon the data collected, Booz, Allen interviewed 100 executives of companies nationwide to determine the scope of private sector involvement in biomass energy development. These companies, shown in Figure 1, represent a cross section of companies active in the development of energy from biomass and are representative of companies in the field.

The interviews were performed by two-person teams utilizing a standardized interview form developed by Booz, Allen and reviewed by the client. They were conducted on-site and were considered confidential. The interviews focused upon the current and planned activities of the companies in the development of energy from biomass, the motivations for their activities, the financial commitments which the companies were making, and their market outlook.

The data collected indicate that private sector involvement in biomass energy development is extensive despite industry's perception that federally sponsored work has had little impact. Another key finding was that government regulatory policies generally had a greater effect upon industry than DOE and these policies often contradicted DOE's position.

INDUSTRY STRUCTURE

There is no single biomass for the energy industry. Rather, many companies are active in utilizing a variety of biomass resources. In most cases, the principal line of business of these companies is not biomass development but agricultural production, wood products manufacturing, distilling, and similar

FOREST PRODUCTS COMPANIES

- Boise-Cascade
- Champion Paper
- Crown-Zellerbach
- Georgia-Pacific
- International Paper
- Interstate Paper
- Scott Paper
- Union Camp
- Weyerhaeuser

AGRICULTURAL PRODUCTS COMPANIES

- Anheuser-Busch
- Archer-Daniels-Midland
- Brown & Williamson
- Cajun Sugar Cooperative
- Castle and Cook
- C. P. Brewer
- Dekalb AgResearch
- Diamond-Sunsweet
- First Colony Farms
- Grain Processing Corporation
- Jack Daniels
- Kaplan Industries
- Kelco Corporation
- Land O'Lakes
- National Distillers
- New Life Farm
- Pioneer Hi-Bred International
- Publicker Distillers
- Smith Bowman Distillers
- Sunny Time Foods

EQUIPMENT MANUFACTURERS

- American Can
- American Fry-Feeder
- Bio-Gas of Colorado
- Bio-Solar R&D
- Chromoloy Corporation
- Combustion Power
- Evans Products
- Forest Fuels
- General Electric
- Halcyon
- Hamilton-Standard
- Johnson Energy Systems
- Oneida Heater
- PyroSol
- Rexnard-Envirex
- A. O. Smith
- A. E. Stanley
- Thermonetics
- Vermont Wood Energy Corporation
- Wheelabrator Clean-fuels
- Yukon Industries

ELECTRIC AND GAS UTILITIES

- Bonneville Power Administration
- Burlington Electric
- Eugene Water and Electric Board
- Lamar Utility Board
- Pacific Gas & Electric
- Seattle Power & Light
- Southern California Edison
- University of Oregon
- Natural Gas Pipeline
- San Diego Water and Utilities Department
- Southern California Gas
- United Gas Pipeline

PETROLEUM COMPANIES AND DISTRIBUTORS

- American Oil Company
- Bohler Brothers
- Fannon Oil
- Gulf Oil
- MarCom Industries
- Mid-West Solvents
- Mobil Oil
- Occidental Petroleum

RESEARCH & ENGINEERING

- Arthur D. Little
- CPR Forest Products
- Energy Resources Company
- Garrett Energy R&D
- Gas Research Institute
- IE Associates
- Institute of Gas Technology
- Intertechnology
- Marelco, Inc.
- Oasis 2000
- SRI International
- Touche-Ross
- WED Enterprises
- Wright-Malta
- Bechtel
- Chemapac
- Ultrasystems

TRADE ORGANIZATIONS

- Alternative Alcohol Fuels Institute
- Distilled Spirits Council of the U.S.
- National Gasohol Commission
- Northwest Pine Association
- Western Wood Products Association
- Wood Energy Corporation
- Wood Energy Institute

Figure 1. Companies interviewed for the study

endeavors. In this assessment, these companies were examined according to the types of biomass energy products which they produce. Based upon the data and information collected, the industry was divided into four parts:

- Alcohol fuels
- Thermal energy from wood
- Thermal energy from agricultural wastes
- Gaseous fuels.

Each segment has a different set of feedstocks, conversion technologies, and products associated with it, as shown in Figure 2.

Alcohol Fuels

The alcohol fuels segment is receiving significant attention from the public and private sectors at the present time. The use of biomass resources — primarily herbaceous crops, such as corn, wheat, grain sorghum, and wood mill residues — is viewed as a means for reducing our dependence on imported oil and for using excess crops. The key characteristics of the companies active in this segment are that they have:

- Access to ethanol feedstocks
- Access to existing gasoline marketing systems
- Experience in designing and building fermentation units
- An interest in reducing dependence upon others for fuel.

By utilizing standard fermentation and distillation processes, companies in this sector are producing anhydrous ethanol. It can be blended with unleaded gasoline to form gasohol, which is currently marketed throughout the nation, although most sales are in the Midwest.

Thermal Energy From Wood

More biomass-derived energy is produced from wood than any other source. The use of wood for thermal energy production is motivated primarily by a desire to reduce waste disposal problems and oil and gas usage. Companies active in this sector generally have:

- Experience in handling biomass materials and/or solid fuels
- Access to wood and wood wastes
- Experience in building and utilizing direct combustion units
- External support for, or entrepreneurial interest in, developing particular equipment.

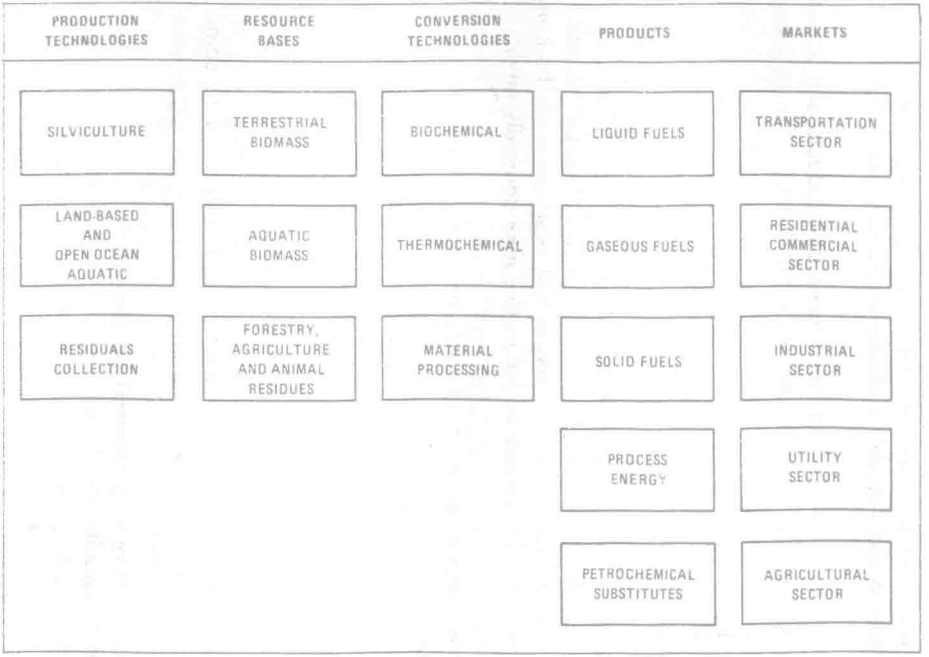

Figure 2. Biomass overview (nonfossil, primary organic materials)

The direct combustion of wood to produce thermal energy, which can be used as process steam or heat, is the most frequent application in this sector. Some research and development is being performed in other areas, especially on the gasification of wood.

Thermal Energy From Agricultural Residues

The use of agricultural residues for thermal energy is very similar to the thermal-energy-from-wood segment. Companies active in this segment have:

- A need to dispose of agricultural process by-products and access to a centrally located stock of residues or by-products
- A need for low-cost process heat or steam
- Experience in building or utilizing direct combustion systems.

Gaseous Fuels

The development of gaseous fuels from biomass is the least developed of the biomass industry sectors. Most efforts in this sector are experimental and the commercial use of gases from biomass is still years away in the opinion of industry executives. Companies active in this area generally have:

- Access to a resource base — primarily manures — which present a disposal problem
- Experience with constructing conversion equipment, such as anaerobic digesters
- Need for gaseous fuels.

The most widespread approach to gasification is the anaerobic digestion of manures and land-based aquatic biomass. This conversion process produces either a medium-Btu gas, which can be used on-site, or in some cases, upgraded to a substitute natural gas (SNG).

The biomass industry is composed of groups of companies active in the development of specific products or uses for biomass. The focus of their activities is generally not to develop processes or equipment which can be used in a wide range of applications. Rather, industry has focused its efforts on particular applications suited to their circumstances. The specific types of companies and their activities are described in the following section.