Biomass Gasification

Principles and Technology

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BIOMASS GASIFICATION

Foreword

This detailed review of biomass gasification principles and technology was written to aid in determining the areas of gasification which are ready for commercialization and those areas in which further research and development will be most productive. The book presents relevant scientific background information, surveys the current status of gasification activities, and examines various questions concerning the uses of the product gases.

Biomass (any material derived from growing organisms) has the potential for being an energy source with few significant environmental drawbacks and some important environmental benefits. Direct use of biomass as a fuel offers a limited field of application because of problems of distribution, combustion, and emissions. Gaseous fuels, however, have been used for more than a century because they are clean burning and easy to distribute. In addition, the gases can be converted to other (liquid) fuels or can serve as feedstocks for strategic chemicals. Thus, gasification could continue to supply the "convenience" gaseous and liquid fuels that the nation has come to depend on during the age of low-cost fossil fuels.

The book is structured to serve as a handbook on topics pertinent to gasification, as well as to provide reviews of past and present activities which will be of use to both the generalist and the specialist.

The information in the book is from: *A Survey of Biomass Gasification. Volume I—Synopsis and Executive Summary* (SERI/TR-33-239-V.1, July 1979), *Volume II—Principles of Gasification* (SERI/TR-33-239-V.2, July 1979), and *Volume III—Current Technology and Research* (SERI/TR-33-239-V.3, April 1980) edited by T.B. Reed of the Solar Energy Research Institute (SERI), prepared for the U.S. Department of Energy.

The table of contents is organized in such a way as to serve as a subject index and to provide easy access to the material contained in the book.

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Contents and Subject Index

PART III: TECHNOLOGY AND RESEARCH

Part I

Summary

The information in Part I is from *A Survey of Biomass Gasification. Volume I–Synopsis and Executive Summary* (SERI/TR-33-239), edited by T.B. Reed of the Solar Energy Research Institute, prepared for the U.S. Department of Energy, July 1979.

Executive Summary

The production of energy from biomass (any material derived from growing organisms) is now seen by many to be a leading near-term solar energy technology. Already, 1% to 2% of U.S. energy is generated by combustion of biomass, and this established technology is being commercialized wherever possible and with as much speed as possible. However, solid fuels have limited applications in modern industrial society and many environmental problems as well.

Fortunately, biomass can be gasified by a number of existing or developing processes. Air gasification (burning with a limited amount of air) is already being commercialized, but much engineering and scientific work remains before oxygen gasification (burning with limited oxygen) or pyrolytic processes (breaking down of matter, usually by heat) for gasification are ready for commercialization. SERI believes that gasification will be the leading edge of thermal biomass development for at least a decade. Therefore, before beginning specific projects a survey was made of existing knowledge and present work in this area and in adjoining technologies (fuel synthesis, gas cleanup) whose development will enable gasification to have maximum impact.

The survey has a number of important goals:

- to examine the properties and potential of the biomass resource relevant to gasification (Chapters 1 to 4);
- to summarize the basic science of biomass gasification (Chapters 5 to 7);
- to look at the present state of research, development, and commercialization of gasifiers (Chapters 8 to 10);
- to examine processes associated with gasification for gas cleanup and synthesis of other fuels from biomass-gas (Chapters 11 to 13);
- to determine means by which gasification technology can be introduced more rapidly (Chapter 14); and
- to identify the areas where research and development will be needed in an intensified gasification development program (Chapter 15).

The survey fills over 400 pages and assembles in one place a wide range of technical and institutional information as an aid to engineers and decisionmakers in this field. The background and conclusions that are believed to be of interest to policymakers and the larger nontechnical audience involved in energy policy are highlighted in this summary. Those interested in greater technical depth are referred to the main body of the survey.

INTRODUCTION (Chapter 1)

Gaseous fuels have many advantages over solid fuels. Gases can be burned more efficiently and with less emissions; the gas flame is more easily controlled for sensitive industrial processes such as glassmaking and drying; gases can be distributed easily for domestic and industrial use; gases can be used to operate engines for power generation and transport; modern gas/oil burners can be retrofitted easily to use gas generated from biomass residues or coal but not solid fuels; some gases can be used for chemical synthesis of liquid fuels and chemicals such as methanol, gasoline, or ammonia. Solid fuels can be gasified efficiently in central plants, the cleaned gas can be distributed in pipelines, and the ashes and pollutants can be disposed of efficiently. This type of fuel distribution is necessary to the continued existence of our large cities, where local burning of solid fuels would entail enormous distribution and emission problems.

The gasification of coal and biomass began in about 1800 and the superior properties of gaseous fuels relative to solid fuels caused this technology to develop so fast that by about 1850 gas light for streets was commonplace. Before the construction of natural gas pipelines in the United States between 1935 and 1960, there were about 1,200 municipal "gasworks" serving larger towns and cities. During the petroleum shortages of World War II in Europe, almost a million small gasifiers were used to run cars, trucks and buses, using primarily wood as fuel. Although coal has been the preferred fuel for larger gasifiers in the past, technical and environmental changes are likely to give biomass a larger role in gasification in the future.

Gasification of solid fuels is accomplished in high-temperature processes similar to combustion that convert the fuel to a gas with minimal loss (typically 10 to 30%) of the energy of the solid fuel. The methods used for gasification can be divided into the four categories shown in Figure S-1. Air gasification is the simplest process but gives a gas of low energy content that must be "close-coupled" to its immediate use for heat or power. Air gasification is already being commercialized. Oxygen gasification gives a gas of higher energy content that can be distributed in industrial pipelines or used for chemical synthesis of a variety of fuels and chemicals such as methanol, ammonia, methane, and gasoline. Commercial prototypes have been operated successfully. Pyrolysis also can yield gas of medium energy but in addition yields oils and chars that have a utility of their own. Pyrolytic processes are still in the development stage.* Fast pyrolysis can yield a gas especially rich in unsaturated hydrocarbons that can form the basis of gasoline or alcohol synthesis. The energy contents of various gases are listed in Table S-1 along with their uses. [We have used the terms "low energy gas" (LEG) etc., as more descriptive than "low Btu gas" (LBG) etc., and as compatible with international usage and the SI system.]

THE POTENTIAL BIOMASS RESOURCE BASE (Chapter 2)

The importance of biomass conversion technologies depends on the quantity of biomass that can be made available for conversion to gas. The existing resource base is comprised of agricultural residues, manures, wood and bark mill residues, logging residues, noncommercial (cull) trees in the forests, and the organic fraction of municipal solid wastes. The quantities potentially available are summarized in Table S-2, which shows an enormous total potential of about 15 quads. Not all of this resource can be collected, and the amount used will depend on energy costs, competition from other fuel and solar energy sources, environmental and ecological factors, etc.

In addition to these forms of existing biomass, there are several other large reservoirs of biomass energy that are even more difficult to quantify. A number of "biomass mines," consisting of past residues, have accumulated over the years. These include municipal wastes, sometimes even now digesting to give methane; food processing plant residues; and bark piles. Though only available on a one-time basis, the biomass mines are a potentially low-cost and environmentally attractive energy source.

A second unexploited category of biomass is that available through land improvement. Many acres of land have been laid waste by man and can support only the growth of such plant species as scrub, mesquite, and chapparal. Harvesting of these plants for their biomass energy and conversion of this energy to fuels could pay for the cost of improving the land.

Finally, there is the large potential of "energy plantations," in which land or even oceans and lakes could be used to raise biomass for energy purposes. Again, the economics of these processes, and energy needs, will determine the degree to which they are developed.

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*Hydrogen can be used under pressure to give higher energy gases or liquids, but hydrogasification of biomass is still in its infancy.

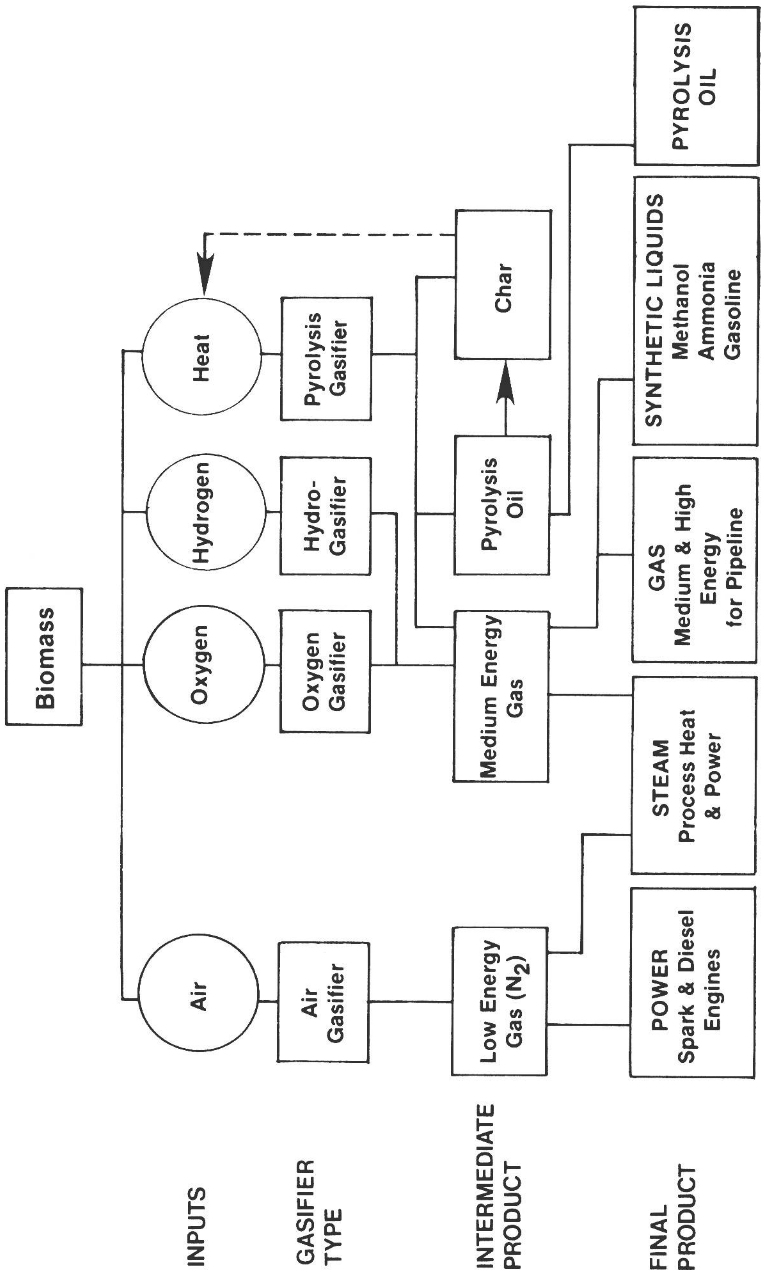

Figure S-1. Gasification Processes and Their Products