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Biomass Energy Systems Program Summary

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July 1980

Prepared for:

U.S. Department of Energy

Assistant Secretary Conservation and Solar Energy

Office of Solar Applications

Under Contract No. AC01-77ET21059

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PREFACE

On October 26, 1974, the Solar Energy Research, Development and Demonstration Act (Public Law 93-473) was signed into law, authorizing a vigorous Federal program of research, development and demonstration. Its goal was to provide the nation with the option of using solar energy as a new source for meeting future requirements. In response to the mandates of this act, major efforts were made within the Division of Solar Energy of the Energy Research and Development Administration (ERDA) to expeditiously develop and introduce economically competitive and environmentally acceptable solar energy systems.

These responsibilities were transferred to the newly organized U. S. Department of Energy (DOE) on October 1, 1977. At present, DOE's solar energy activities are divided into three distinct organizational components:

- o Division of Central Solar Technology
 - o Ocean Systems Program
 - o Solar Thermal Power Systems Program
- o Division of Distributed Solar Technology
 - o Biomass Energy Systems Program
 - o Photovoltaic Systems Program
 - o Wind Energy Systems Program
- o Office of Solar Applications
 - o Heating and Cooling of Buildings Program
 - o Agriculture and Industrial Process Heat Program
 - o Technology Transfer Program

Both the Division of Central Solar Technology and the Division of Distributed Solar Technology function as part of the Office of Assistant Secretary for Energy Technology (SOLAR/ET), while the Office of Solar Applications functions as a part of the Office of the Assistant Secretary for Conservation and Solar Applications (SOLAR/CS). An overview of the current DOE solar program organization is shown in figure 1.

Program planning continues under the guidelines established by PL 93-473 and by three other legislative acts passed by the 93rd Congress: the Solar Heating and Cooling Demonstration Act of 1974 (PL 93-409), the Energy Reorganization Act of 1974 (PL 93-438), and the Federal Non-nuclear Energy Research and Development Act of 1974 (PL 93-557). Together these four laws grant DOE and other Federal agencies the authority to pursue a research program aimed at effective solar energy use. Under this authority, SOLAR/CS and SOLAR/ET are working to develop solar energy technologies and to complement efforts in the private sector to develop solar energy resources.

A program summary is issued for each solar program annually. Each summary provides an overview of the ongoing research, development, and demonstration efforts of the preceding fiscal year (FY).

This program summary describes each of the DOE's Biomass Energy Systems projects funded or in existence, or both, during fiscal year 1978 (October 1, 1977 through September 30, 1978) and reflects their status as of September 30, 1978. This document is a follow-up to the FY 1977 Biomass Program Summary (DOE/ET0022/1) published in January 1978.

Figure 1. Current DOE Solar Program Organization

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INTRODUCTION

Biomass is organic matter produced by terrestrial and aquatic plants. For the purpose of producing energy from biomass, this definition includes plant derivatives such as agricultural and forest residues, and animal manures.

All terrestrial and aquatic plant life receives and transforms solar energy into stored chemical energy, which can be collected and recovered by direct burning or conversion to liquid and gaseous fuels. Biomass can be considered a partially renewable source of energy, because plant life renews itself or adds to its matter every year. This is in contrast to traditional fossil fuels. Biomass is only partially renewable, because nutrients and minerals have to be returned to the soil or aquatic environment to avoid depletion of these essential elements.

Biomass is highly dispersed and site specific. It is bulky and contains 50 to 90 percent water by weight. Because of its weight and bulk, transport over long distances is not economical and conversion into more portable energy materials must take place close to the biomass source.

Given the fact that the resources of traditional fossil fuels are limited, biomass is needed to produce:

- o Fuels
 - liquid
 - gaseous
 - solid
- o Petrochemical Substitutes and Other Energy-Intensive Materials
 - base industrial chemicals
 - intermediate chemicals

- o Heat
 - residential space
 - industrial process
- o Electricity

Appropriate conversion technologies are either commercial, near commercial, or are being developed. These technologies are:

- o Direct Combustion
- o Biochemical Conversion
- o Thermochemical Conversion

The number of different biomass resources and the number of feasible conversion processes permit a large number of approaches for the production, conversion, and use of biomass (see figure 2).

At present, biomass provides almost two percent of the energy consumed in the United States. The major portion of this is utilized by the forest products and paper and pulp industries for their own purposes.

Recent estimates indicate that the conversion of unused agricultural residues, forestry residues, and non-commercial timber growth could provide six to ten percent of the nation's energy needs on a sustained basis. Intensively managed growth of terrestrial and aquatic biomass crops on so-called "energy farms" could increase the contribution of biomass to about 16 percent of the energy needs of the U. S.

The Biomass Energy Systems (BES) Program of the Department of Energy is the focal point of the nation's efforts to harness biomass as a dependable, self-renewing source of energy. The projects listed in this Program Summary are those

Figure 2. Biomass Energy Systems Program Overview

to which funding commitments had been made as of September 30, 1978. Since that time, the program has been restructured to reflect an emphasis on matching market needs with regional biomass resources, on-farm use of biomass, and innovative means of producing and converting biomass. The program description which follows is structured to reflect the current and continuing emphasis of this new program plan. The conversion technologies and their applications have been grouped into program elements according to the time frame in which they are expected to enter the commercial market:

- o Technology Development and Applications. This program element provides engineering development support and environmental research support for biomass applications that are expected to be competitive in the marketplace by 1985.
- o Production Systems. This element supports exploratory and technology development to expand the biomass resource base by developing silvicultural, herbaceous, and aquatic energy farm technology.
- o Conversion Systems. This program element develops biochemical and thermochemical technologies that can convert biomass to clean fuels, petrochemical substitutes, and other energy-intensive products. These

products are expected to be on the market before the year 2000.

- o Research and Exploratory Development. This element supports applied research and exploratory development in advanced biochemical conversion techniques, plant breeding, photobiology, and land-based aquatic biomass production and conversion. Contributions to the nation's energy supply from these sources are likely after the year 2000.
- o Support and Other. This program element is responsible for mission analyses, environmental assessments and administration.

A cross reference between current program categories and those which existed during FY 1978 is given for each project in the Appendix.

Technologies expected to make significant near-term impact are (1) direct combustion of wood and wood residues to provide industrial process heat, electricity, and residential heat; (2) fermentation of grain and sugar crops into ethanol to extend supplies of gasoline and other liquid petroleum fuels; and (3) anaerobic digestion of manures to produce methane gas. Direct combustion of wood contributes the largest share of energy from these three solar technologies and its leadership is expected to continue through 1985. Involvement of the U.S. Government in these commercial and near-commercial technologies has the objective of increasing the rate of market penetration.

THE BIOMASS ENERGY SYSTEMS PROGRAM

The Biomass Energy Systems Program develops concepts from the stages of basic and applied research to those of technical engineering development in preparation for commercialization. The program contains the following elements and sub-elements;

- o Technology Development and Applications
 - Combustion Systems
 - On-Farm Biomass Conversion Systems
 - Alcohol Production Systems
- o Production Systems
 - Silvicultural
 - Herbaceous
 - Aquatic
- o Conversion Systems
 - Biochemical Conversion
 - Thermochemical Conversion
- o Research and Exploratory Development
 - Innovative Conversion Systems
 - Advanced Feedstocks
 - Aquatic Systems

Objectives

The overall objective of the Biomass Energy Systems Program is to assure

supplies of alternate fuels for the country. Specific objectives are to:

- o Develop appropriate production and conversion technologies
- o Recommend incentives for the production of needed fuels and chemicals to displace those derived from traditional sources of energy
- o Assist in the transfer of technology, so that industry and commerce will be able to produce biomass and convert it into products of greatest value.

It is essential to the long-term welfare of the nation to anticipate the need for certain technologies which may be called upon to alleviate future shortages of energy. These technologies should be developed even though they are too costly to be competitive in the near future. The assumption is that these standby technologies can always be improved in the period of time before their use becomes necessary.

Goals

The goal before 1985 (near term) is to add 0.5 Quads* of energy annually to our national needs by direct combustion of biomass and biomass-based alcohol fuels, as well as from small, on-farm gas production systems.

*A Quad is equal to a quadrillion (10^{15}) British thermal units and is approximately equal to 10^{18} joules. U. S. energy consumption in 1977 was approximately 75 Quads.

The goal before 2000 (mid term) is to produce an additional 3 to 4 Quads of energy annually through increased use of alcohol fuels and improved biochemical and thermochemical conversion technologies.

The goal after 2000 (long term) is to provide at least 10 Quads of energy annually from biomass as the result of research to be initiated or now in progress related to terrestrial and aquatic energy farms, photobiology, plant breeding, and exotic crops for the production of hydrocarbons.

Strategy

The overall strategy by which the Biomass Energy Systems Program will achieve its objectives and goals is to:

- o Mobilize the technical, industrial, and commercial resources of the nation
- o Direct scientific investigations
- o Procure engineering design and development
- o Assemble, update, and disseminate data
- o Assist industry and commerce to apply the results of the program efforts.

The specific strategy of the near term is to provide technology support for biomass applications that are economically competitive or nearly competitive. The Biomass Energy Systems Program will provide:

- o Engineering development and support
- o "Product Support" to make technologies more competitive

- o Information to industry and the public
- o Environmental investigations to identify and seek ways to avoid constraints.

The specific strategy for the mid term is to continue to identify markets, products, and biomass technologies which have the most potential for additional displacement of conventional fuels.

The Biomass Energy Systems Program will:

- o Continue to improve system and market analyses
- o Identify limitations on the use of biomass residues as resources
- o Continue development of a range of conversion technologies
- o Seek ways to substitute biomass for petrochemical-derived chemical feedstocks.

The specific strategy for the long term is to provide the technological basis for the maximum contribution of energy from biomass. The Biomass Energy Systems Program will:

- o Develop a strong applied research and exploratory development program
- o Encourage laboratory-scale experiments to obtain information that will form a firm basis for decisions on whether to proceed with large-scale activities.

Participants

The participants in the Biomass Energy Systems Program are the following:

- o Federal, state, and local government agencies
- o General industry
- o Engineering companies
- o Expert associations and consulting groups
- o Universities
- o National and private laboratories
- o Specific interest groups, e.g., farm cooperatives.

This listing does not imply any order of importance.

TECHNICAL STATUS

Technology Development and Applications

The purpose of this program element is to provide engineering development and environmental research for biomass applications. Support under this program is directed towards three areas of anticipated biomass applications: combustion systems, on-farm biomass conversion systems, and alcohol production systems.

o Combustion Systems

In this area, direct combustion of wood and wood residues is developed to produce industrial process heat, electricity, and residential space heat. Technologies available to expand the near-term use of wood fuel include direct combustion, low-Btu gasification, and wood densification.

Three technical, environmental, and marketing problems still need to be resolved. They are: (1) the availability of wood and wood residues, (2) the need for harvesting and collection technologies, (3) a requirement to reduce the bulk of wood through such techniques as densification, and (4) a necessity to understand the environmental effects of residue collection and direct burning.

o On-Farm Anaerobic Digestion Systems

These activities are conducted in collaboration with the USDA. They pursue the engineering development of anaerobic digestion of manures to produce medium- to high-Btu gas, and combustion of crop residues to produce heat and low-Btu gas. These technologies are well understood at present, but are only marginally competitive. However, the sale or use of by-products could make these technologies competitive in the near future.

An experimental anaerobic digestion facility has been built on a 10,000-head cattle feedlot in Bartow, Florida. The projected production of gas would be enough to provide nearly all of the energy requirements for the feedlot and its slaughter and packing plant. The facility is expected to become fully operational by late 1979. Digesters for on-farm use at small dairy farms are being tested at Cornell University.

In FY 1980, a decision will be made on the commercial readiness of anaerobic digestion. If it is viable in the market, lead management responsibilities would be shifted to the Office of Solar Applications. The Biomass Energy Systems Program would continue to support technology and engineering development.

o Alcohol Production Systems

The activities under this program focus on improving the process efficiency of conventional fermentation technologies and developing sugar crop feedstocks. The objective is to produce ethanol for blending with gasoline (gasohol) and diesel fuel. In FY 1980, the Biomass Energy Systems Program will complete preliminary analyses to determine whether an integrated facility for production and conversion of ethanol from biomass should be built in FY 1981. This facility would utilize the latest off-the-shelf fermentation technology and meld it with a fermentable crop production system.

Production Systems

The primary objective of this program element is to expand the resource base for the conversion technologies. The concept of silvicultural, herbaceous, and aquatic energy farms is being investigated.

A comprehensive system study has concluded that at least 30 million of the nation's 1.3 billion acres of grassland and forest could be made available for wood energy farms with an estimated productivity of from 5 to 13 dry tons per acre each year, depending upon species and site selection. Intensive crop management would be practiced, including fertilization, irrigation, and weed and disease control.

o Silvicultural

The U. S. Forest Service, various universities, and private industries are conducting studies to screen species and evaluate silvicultural systems for the production of woody plants. Projects range in size from greenhouse and field plots to large test farms. In addition, harvesting, storage, handling, and transportation methods are being developed and tested. Two regional silvicultural energy farms of about 1,200 acres each are planned. These farms are designed to evaluate the technical and economic feasibility of growing an assured supply of biomass in different parts of the country.

Supporting contracts have been made with 27 universities, small business, and industry to evaluate desirable species for energy farms, determine optimum production systems, and develop harvesting and transportation systems. Issues deserving further investigation involve the cumulative environmental effects of expanded silvicultural energy farming in the nation and the optimal roles to be played by the public and private sectors in the effort.

o Herbaceous

Efforts in herbaceous development are focused on crops that are easily converted into liquid or gaseous fuels.

Current studies are narrowing the number of suitable crop species and quantifying the resource potential. Planned thrusts involve further species screening and plant breeding, along with establishing reliable cost data and developing agricultural systems that increase yields and reduce production costs.

o Aquatic

Studies of aquatic production systems concentrate on marine farming technology. Completed marine production studies include a detailed physiological study of the growth of giant kelp, an analysis of growing and harvesting marine algae in a 100-square-mile system, and an investigation of the cultivation of microscopic marine algae. Further studies will concentrate on ocean-based production facilities.

Conversion Systems

The objective of this program element is to establish and develop technologies that can convert biomass feedstocks into clean fuels, petrochemical substitutes, and other energy-intensive products for market penetration before the year 2000. Biochemical and thermochemical conversion processes are included in this element.

o Biochemical Conversion—Anaerobic Digestion

The objective of this sub-element is to increase the resource base for anaerobic digestion from manures as a feedstock to crops grown for energy production. Research is underway to develop pretreatment methods, establish data on gas yields for various feedstocks, and confirm process economies. Planned activities include the design and construction of a Process Development Unit (PDU) for marine feedstock to scale up laboratory investigations.

o Biochemical Conversion—Fermentation

The objective of this sub-element is to develop the technology to convert agricultural and forest residues and woody energy crops into ethanol. Current efforts are concentrated on developing commercially feasible pretreatment and hydrolysis processes which yield fermentable sugars from woody materials. These investigations include both acidic and enzymatic techniques. A PDU, which will use three tons of biomass per day, has been designed at the Georgia Institute of Technology to provide scaled-up technical and economic feasibility information. Efforts will be made to bring the price of ethanol produced from woody biomass in line with ethanol derived from grains and sugar crops.

o Thermochemical Conversion—Gasification and Indirect Liquefaction

The overall objective of the gasification program is to develop a technology capable of producing synthesis gas or medium-Btu gas from biomass. Medium-Btu gas can be used directly, upgraded to substitute natural gas, or used as a feedstock for the production of methanol, ammonia, or petrochemical substitutes.

Several PDU-scale studies are currently operational or soon to be on stream. The major emphasis of the Process Development Units is to determine process chemistry and overall economics. The units range in daily capacity from 0.5 to 24.0 oven-dried tons of biomass. A contract is planned for the construction of a Large Experimental Facility (LEF) capable of handling 300 oven-dried tons a day. This facility will be sufficiently large to establish data on the availability and cost of supplying the biomass, and to evaluate the reliability and thermal efficiency of a

particular process of producing medium-Btu gas. In addition, the LEF will allow the determination of the cost of the gas and will establish a valid basis for comparing gasification with conventional means of energy production.

o Thermochemical Conversion—Direct Liquefaction

Direct liquefaction represents a technology that can convert biomass directly into oil for use as a turbine or boiler fuel. Research for up-grading the fuel may identify other end uses.

Current activities consist of the operation of the wood-to-oil PDU at Albany, Oregon, and a supporting exploratory and technology development program. This facility permits the testing of various raw materials and process conditions. The data collected will be used for the conceptual design of a large facility capable of using 1,000 oven-dried tons/day of feedstock.

Research and Exploratory Development

The objective of the program element is to identify and investigate areas of applied research and exploratory development in biomass production and conversion. The technologies are not expected to make major contributions to the energy supply until after the year 2000. Specific areas of study are advanced biochemical conversion systems (anaerobic digestion, fermentation, and biophotolysis), plant improvement, development of exotic plants for the production of hydrocarbons, and biomass production from land-based aquatic systems.

o Innovative Conversion Systems

Advanced conversion technology being investigated includes the single-step fermentation of woody (lignocellulosic) biomass into alcohols, as well as innovative

techniques of converting woody biomass by anaerobic digestion into synthetic natural gas and medium-Btu gas.

Another new conversion technology under investigation is biophotolysis, the direct production of hydrogen by algae in the presence of sunlight. Research efforts, including converter design and economic analyses, have concentrated on conditions known to promote hydrogen production from algae. Experiments are being performed on various algal species to establish sustained conversion of sunlight energy into hydrogen.

o Advanced Feedstock Development

Projects that support the development of advanced feedstocks include the breeding of new plant varieties and the evaluation of uncommon crops that produce hydrocarbons such as latex.

o Aquatic Systems

Aquatic systems studies include applied research and exploratory development of land-based aquatic production systems for fresh and brackish water. Algae resources are expected to be significant because of their high growth rate and conversion efficiency relative to terrestrial biomass resources. Some of the considerations are: species screening for increased yields, potential growth, nutrient assimilation, fermentability, and eco-

nomic feasibility. Completed aquatic production studies include an investigation of the growth of filamentous algae in ponds and the cultivation of fresh-water aquatic weeds.

Support and Other

This support element includes some systems studies and environmental assessments. An initial mission analysis has been completed. It projects that 19 biomass applications could penetrate the market before the year 2020. Mission analysis is a continuing effort since technologies and potential markets for their application are continually changing.

The other major portion of the support activity is the preparation of environmental and resource assessments. Projects have been implemented dealing with the issues of resource availability at both the national and regional level. To assure that environmental costs and effects will be considered prior to widespread deployment of near-term technologies, environmental assessments will be scheduled in close conjunction with developments in biomass energy technology.

Additional activities performed under this program element include program management, program planning, preparation and evaluation of program solicitations, and participation in the technical evaluations of the program as well as coordination and monitoring. A data bank on the cost of biomass production and conversion systems is under development.

BIOMASS APPLICATIONS

The technologies being pursued by the Biomass Energy Systems Program for the supply and conversion of biomass are at different levels of development. Three conversion technologies — direct combustion, anaerobic digestion, and fermentation — are commercial or near commercial with specific feedstocks and in specific markets. These technologies are being used in the private marketplace without any governmental intervention. Examples include the combustion of wood mill wastes in the forest products industry, the marketing of gasoline-ethanol fuel blends at gas stations in various parts of the country, and on-farm anaerobic digestion of manures. The Biomass Energy Systems Program will involve industry to the maximum extent possible in all research and development. Coordinated cost-shared and cooperative projects will receive higher priorities with the clear goal of commercialization. The branch will also

work closely with Resource Managers appointed within DOE for the purpose of commercializing technologies.

These Resource Managers work to create the economic, regulatory, and technical support necessary for the biomass applications.

As technologies move into the commercial phase, the role of the Biomass Energy Systems Branch in engineering development does not come to an end. Efforts continue to improve the economics, efficiency, safety, reliability, and environmental acceptability of biomass energy systems.

DOE has appointed a Resource Manager in the area of wood combustion. The commercialization effort will include the institutional and market environments as well as the barriers to user adoption. Appropriate actions to overcome barriers and constraints will be recommended.

ORGANIZATIONAL AND FUNCTIONAL RESPONSIBILITIES

The Biomass Energy Systems Branch of the Department of Energy manages the Biomass Energy Systems Program. This branch is part of the Division of Distributed Solar Technology which reports to the Program Director for Solar, Geothermal, Electric and Storage Systems. At the end of 1978, the

Program Director was within the organization of the Assistant Secretary for Energy Technology. The Resource Manager for wood combustion was within the Office of Solar Applications, in the organization of the Assistant Secretary for Conservation and Solar Applications.

PROGRAM FUNDING

In FY 1980, the program and funding levels (see table 1) will begin to be reoriented to match regional biomass energy feedstocks with regional and national energy-related needs. An updated assessment of regional biomass resources will be made. Existing or developing conversion systems will be used to match regional energy-related needs with biomass resources. New products from biomass will be identi-

fied, including chemical feedstocks to be used in place of oil-derived feedstocks. New efforts will be initiated to produce higher yields of biomass and to identify innovative, integrated, and efficient conversion processes. Integrated systems will be evaluated and developed to maximize the near-term contribution of the program. Emphasis will be increased on small systems to be used locally by individuals and small groups.

Table 1.

Summary for Baseline Funding
for the Biomass Energy Systems Program
(Millions of Dollars)

<u>Program Element</u>	<u>FY 79</u>	<u>FY 80</u>
Technology Development and Applications	16.2	16.0
Production Systems	4.3	5.7
Conversion Systems	15.9	24.0
Research and Exploratory Development	5.2	8.8
Support and Other	0.8	1.5
Personnel Resources	<u>0.6</u>	<u>0.8</u>
Total	43.0	56.8

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**Projected Contributions of Fiscal Year 1978
Biomass Projects Listed According to Program
Element and Sub-element**

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Projected Contributions of Fiscal Year 1978 Biomass Projects

Listed According to Program Element and Sub-element

Program Element: Technology Support

The goal of the Technology Support program element is to provide technical expertise and support, systems demonstration, and environmental research support for biomass conversion systems in order to achieve commercial competitiveness by 1985.

o Program Sub-Element: Direct Combustion Systems

The goal of the Direct Combustion Systems sub-element is the development and demonstration of direct combustion of wood and wood residues to produce industrial process heat, electricity, and residential heat.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
A-1	Wheelabrator Clean-fuel Corp.	Advanced System Demonstration for Utilization of Biomass as an Energy Source	Determine the availability and cost of biomass feedstocks, and demonstrate the feasibility of utilizing forest residues and trees to produce steam and electric power in a co-generation mode.
A-2	Aerospace Research Corp.	Development of Wood as an Alternative Fuel for Large Power Generation Systems	Provide the data for the design and fabrication of a prototype combustion module which will generate the design information for the retrofitting of large-scale oil- and gas-fired boiler systems to burn wood.
A-3	Nor'West-Pacific Corp.	Study of Wood-Fired Electric Power Generating Plants	Collect data concerning the burning of wood residues for generating electric power in the U.S., with emphasis on the forest products and pulp and paper industries.

Program Element: Technology Support

The goal of the Technology Support program element is to provide technical expertise and support, systems demonstration, and environmental research support for biomass conversion systems in order to achieve commercial competitiveness by 1985.

o Program Sub-Element: On-Farm Systems

The goal of On-Farm Systems activities is to pursue the development and demonstration of anaerobic digestion of manures to produce medium- to high-Btu gas, and the direct combustion of crop residues to produce heat and low-Btu gas.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
B-1	Cornell University	Anaerobic Digestion of Agricultural Residues: Potential for Improvement and Implementation	Develop and improve economic and technical factors which would lead to wide-spread implementation of digesters to produce biogas on small-scale agricultural operations.
B-2	Tracey & Brunstrom Co.	Engineering Feasibility of Fuels from Biomass Utilizing Dairy Farm Residue	Evaluate energy production by anaerobic digestion of agricultural wastes on dairy farms.
B-3	Ecotope Group	Monitor, Test, and Evaluate an Operational Digester for 350 Cattle Units	Optimize digester performance in terms of net energy and operator time for full-scale dairy farm operations.
B-4	United Technologies Corp.	Experimental Anaerobic Digestion Facility	Produce fuel gas and other products from animal residues, and promote commercialization of the process.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
B-5	United Technologies Corp.	Dirt Lot Residue Experiments	Evaluate the potential of using anaerobic digestion to produce fuel gas and a refeed product from dirt lot residues.
B-6	Dynatech R/D Co.	Engineering Evaluation of the Recovery of the Energy Value of Animal Residues	Evaluate various methods of methane production and monitor technical anaerobic digestion projects.
B-7	U.S. Department of Agriculture	Anaerobic Digestion of Beef Cattle Manure and Crop Residues	Recover high protein biomass and methane from beef cattle manure and crop residues through anaerobic digestion.
B-8	SRI International	Evaluation of the Proposed Bio-gas Project at Lamar, Colorado	Review the report to the Four Corners Regional Commission on a proposed anaerobic digestion facility at Lamar, Colorado.
B-9	Touche Ross & Co.	Economic Analysis of Proposed Bio-conversion Facility - Lamar, Colorado	Provide an independent economic evaluation of the proposed bioconversion facility at Lamar, Colorado, in order to gain an understanding of its economic viability and the factors influencing it.

Program Element: Technology Support

The goal of the Technology Support program element is to provide technical expertise and support, systems demonstration, and environmental research support for biomass conversion systems in order to achieve commercial competitiveness by 1985.

o Program Sub-Element: Alcohol Production Systems

Alcohol Production Systems activities are focusing on improving process efficiency of current fermentation technology and the use of higher yield sugar crops such as sweet sorghum.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
C-1	Louisiana State University	The Potential for Producing and Harvesting Sugarcane and Sweet Sorghum as a Renewable Biomass Energy Resource	Develop harvesting machinery necessary to increase yields of sugarcane and sweet sorghum as energy crops.
C-2	Science Applications, Inc.	Conversion of Biomass Resources to Methanol	Evaluate alternative concepts for the conversion of biomass to methanol and the commercialization of biomass-based methanol productions.
C-3	U.S. Department of Agriculture	Sugarcane Spacing Study and High-Fiber Sugarcane Selection	Determine the effect of narrow-row spacings on sugarcane yield, determine the feasibility of employing commercial harvesters on narrow-spaced planting, and breed and select cultivars of high-fiber sugarcane for energy production.
C-4	U.S. Department of Agriculture	Sweet Sorghum Energy Research	Evaluate yield and quality of sweet sorghum cultivars and increase seed supplies for energy research.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
C-5	Battelle Columbus Laboratories	Carbohydrate Crops as a Renewable Resource for Fuel Production	Evaluate methods of increasing the availability and reducing the cost of fermentable sugars to be converted to liquid fuels, leading to decisions on utilization of sweet sorghum and sugar cane.
C-6	Battelle Columbus Laboratories	Feasibility of Integrating Corn Agriculture with the Manufacture of Fermentation Fuels	Determine earning forecasts and cost estimates for a plant producing 46.3 million gallons of alcohol from corn stover using dry milling.
C-7	Battelle Columbus Laboratories	Evaluation of Feasibility of Sequential Fermentation for the Production of Ethanol	Identify yeast strains with ethanol tolerance or osmo-tolerance and reduce to practice an invention of a sequential semi-continuous fermentation process.
C-8	Battelle Columbus Laboratories	Economics of Manufacturing Liquid Fuels from Corn Stover	Create a conceptual design to convert corn stover to anhydrous ethanol and furfural at a cost of about \$15 per million Btu.
C-9	Bernard Wolnak & Associates	Economics of Conversion of Cellulose (Wood) and Corn Starch to Sugars, Alcohol, and Yeast	Analyze all technological and economic information available on various processes to (1) convert wood and corn starch into glucose and sugars, and (2) convert these sugars to ethyl alcohol and yeast.
C-10	University of Florida	Sugarcane Growth for Use as an Energy Crop	Increase the biomass, sugar, and fiber yields from sugarcane with various spacing.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
C-11	The MITRE Corp.	Biomass-Based Alcohol Fuels	Conduct two studies: the first, to determine the potential of implementing a nationwide biomass-derived alcohol/gasoline fuel system and, the second, to compare economic aspects of 28 ethanol facilities.
C-12	Arthur G. McKee & Co.	Preliminary Engineering and Cost Analysis of Purdue/Tsao Cellulose Hydrolysis Process	Develop cost estimates for the Purdue/Tsao Process for the conversion of cellulose to glucose and pentose.

Program Element: Production Systems

The goal of the Production Systems program element is to expand the biomass energy resource base by developing specific species and management techniques for intensive biomass energy production. These efforts will focus on production systems which can make an impact before the year 2000.

o Program Sub-Element: Silviculture

Under the Silviculture sub-element, species screening studies, field test plot studies, regional silviculture energy farms, harvester development, and supporting research studies are aimed at maximizing crop yields while minimizing production cost of silvicultural biomass.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
D-1	Purdue Research Foundation	Species Selection for Silvicultural Energy Farms on Reclaimed Mineland	Select species which show the greatest potential for use in silviculture energy farms.
D-2	General Electric Co.	Energy Biomass Production Study	Optimize seedling growth in controlled environments to supply silviculture energy farms with planting stock.
D-3	Hawaiiana Investment Co., Inc. (C. Brewer)	Eucalyptus Farms for Energy Production in Hawaii	Increase biomass production through intensive cultural treatments and evaluate a complete production collection/conversion system in relation to costs.
D-4	Michigan Technological University	Application of Sugar Maple and Black Locust to the Biomass Energy Farm Concept	Convert pole-sized sugar maple stands into short-rotation energy farms using coppice as a regeneration technique.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
D-5	North Carolina State University	Species Selection and Silvicultural Systems for Producing Fuels from Woody Biomass in the Southeastern United States	Determine optimum silvicultural systems for maximizing energy yields using species most suitable for short-rotation management.
D-6	North Carolina State University	Economics and Operating Characteristics of Various Materials Handling Systems and Wood Fuels in Small- to Medium-Sized Boiler Facilities	Evaluate economics of harvesting, collection, and transportation of wood fuels for use in wood boilers.
D-7	Alabama A&M University	Recovery of Above-Ground Woody Biomass (Logging Residue) Using Operational Modifications of Conventional Harvesting Systems	Modify conventional harvesting systems to economically remove and utilize presently unmerchantable woody biomass.
D-8	Virginia Polytechnic Institute and State University	An Integrated Investigation of Procurement, Harvesting, Drying, Transportation, and Storage of Woody Biomass	Evaluate, mathematically and experimentally, alternative handling strategies to assist decision making and to highlight the tradeoffs involved.
D-9	Washington State University	Evaluating and Modelling Tree Biomass Yields From Small-Diameter Conifer Stands in the Inland Northwest	Provide biological data and simulation models for accurate assessments of energy potential in forest stands in the inland Northwest.
D-10	University of Illinois	Woody Biomass Production for Solar Energy Conversion	Optimize production of sycamore, autumn olive, alder, and eastern cottonwood on marginal lands in central and southern Illinois.
D-11	Kansas State University	Great Plains Energy Forest Study	Optimize growth and yield of cottonwood, black locust, and catalpa on underutilized land in Kansas.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
D-12	University of Kentucky	Production of Black Locust Biomass on Surface-Mined Sites in the Southern Appalachians	Determine optimum management strategies to produce black locust on silviculture energy farms.
D-13	Pennsylvania State University	Feasibility of Using Municipal Wastewater and Waste Heat to Maximize Biomass Production on Silvicultural Energy Farms	Maximize the production of hybrid poplars using waste water for irrigation and waste heat for soil warming of energy farms.
D-14	Pennsylvania State University	Energy Sensitivity and Variability Analysis of <u>Populus</u> Hybrid Short-Rotation Silvicultural Energy Farms in the Northeastern United States	Recommend management strategies for the growth of hybrid poplars based on overall energy analysis.
D-15	University of Washington and Washington State University	Evaluation and Genetic Improvement of Black Cottonwood for Short-Rotation Coppice Culture	Identify superior clones of <u>Populus trichocarpa</u> and its hybrids with <u>P. deltoides</u> for fuel and for chemical uses.
D-16	U.S. Department of Agriculture	Establishment of <u>Populus</u> Silvicultural Energy Farms	Establish field plots to determine optimal stand establishment and management strategies for using hybrid poplar in energy farms.
D-17	U.S. Department of Agriculture	Construction and Field Trials of a Prototype Forestland Residue Machine (Mobile Hog) to Harvest Fuel from Forest Residues or from Energy Farms	Evaluate a prototype harvesting machine designed to collect forest residues to be utilized as a fuel.
D-18	Emory University	Screening of Non-commercial Woody Plants as Biomass Fuel Producers	Identify and field-test woody plant species suitable for fuel production on marginal soils of the Southern Piedmont and Upper Coastal Plain.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
D-19	Michigan State University	Tree Species for Biomass Production in Northern Michigan	Determine species and management strategies to optimize growth on predominantly marginal sites in the North Central U.S.
D-20	Garrett Energy Research and Engineering Co.	Investigation of Woody Biomass Species for Fuel Production in Warm-Climate, Non-agricultural Land Irrigated by Brackish or Saline Water	Optimize growth of salt cedar and tamarisk shrubs under the influence of saline water and under intensive management techniques.
D-21	Utah State University	Selection of High-Producing Shrubs of the Western United States for Energy Biomass Production	Propagate and measure productivity of selected shrub biotypes, for use as an energy feedstock, under low-cost cultural treatments.
D-22	University of Massachusetts	Assessment of Tree-Harvesting Machinery for Non-commercial Timber	Evaluate current, commercially available wood chippers with consideration of their use in harvesting systems on problematic terrain and submarginal timber stands.
D-23	University of Houston	Cultural and Management Practices for the Chinese Tallow Tree as a Biomass Fuel Source	Optimize growth of Chinese tallow on marginal or non-agriculture lands, and in plantations and natural stands.
D-24	University of Vermont and State Agricultural College	The Production of Biomass for Energy on Abandoned Farmlands in the Northeast	Evaluate native and introduced tree and shrub species, as well as management, harvesting, and storage techniques for the production of biomass for energy.
D-25	The MITRE Corp.	Structuring Pilot Silvicultural Biomass Farm Development	Develop a detailed plan for a pilot-scale silviculture energy production/conversion facility.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
D-26	The MITRE Corp.	Near-Term Use of Wood as a Fuel	Compare commercially available technologies (i.e., direct combustion, gasification, pyrolysis, and densification) for converting wood into usable forms of energy.
D-27	U.S. Department of Agriculture	Fuel Farm Research (Chemically Induced Oleoresin as a Petrochemical Substitute)	Increase chemically induced light-wood formation in pines and test commercial-scale processing.
D-28	University of Georgia	Biomass Production of Short-Rotation Coppice Forests	Obtain high-yield biomass production from sycamore, sweetgum, and alder trees in field trials.
D-29	University of Minnesota	Use of Wetlands for Production of Woody Plants for Fuels and Petrochemical Substitutes	Select suitable species and determine their establishment, management, and productivity problems on wetland soils.
D-30	University of Florida	Energy from Woody Species in Florida	Optimize growth and yield of <u>Melaleuca</u> , <u>Eucalyptus</u> , and <u>Pinus</u> on infertile sandy soils.
D-31	SRI International	Land and Water Availability for Energy Farming	Rank selected water areas possessing favorable land and water availabilities according to their overall potential for biomass production.
D-32	Oak Ridge National Laboratory	Management Support to the Fuels from Woody Biomass Program	Provide technical management support to DOE in the areas of species screening, stand establishment, and management strategies.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
D-33	Mathtech, Inc.	Harvesting of Close-Spaced Short-Rotation Woody Biomass	Evaluate alternative strategies and techniques of harvesting which appear commercially viable for use on closely spaced short-rotation biomass farms.
D-34	Seattle City Light	Cultural Treatment of Selected Species for Woody Biomass Production in the Pacific Northwest	Evaluate the performance of red alder and black cottonwood under intensive management at different sites.
D-35	University of California	Collection, Propagation, and Evaluation of <u>Prosopis</u> Species for Growth Rate Under Controlled Moisture and Nitrogen Treatments	Determine vegetative propagation techniques for mesquite and identify genotypes with greater growth rates, higher heat tolerances, and cloning capabilities.

Program Element: Production Systems

The goal of the Production Systems program element is to expand the biomass energy resource base by developing specific species and management techniques for intensive biomass energy production. These efforts will focus on production systems which can make an impact before the year 2000.

● Program Sub-Element: Herbaceous

The projects supported under the Herbaceous sub-element include species screening studies and herbaceous energy farming.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
E-1	University of Puerto Rico	Production of Sugarcane and Tropical Grasses as a Renewable Energy Source	Determine the agronomic and economic feasibility of mechanized, year-round production of sugarcane and napier grass, as well as screen and breed desirable energy crop progeny.
E-2	Arthur D. Little, Inc.	Herbaceous Species Screening Program (Phase I)	Screen previously unexploited, terrestrial annual and perennial plants to identify those with the greatest potential for energy farm application.

Program Element: Conversion Systems

The goal of the Conversion Systems program element is to establish technologies which can convert biomass into clean fuels, petrochemical substitutes, and other energy-intensive products. Emphasis will be placed on the production of those products which have the potential to make market impacts before the year 2000.

● Program Sub-Element: Anaerobic Digestion

The goal of research efforts within the Anaerobic Digestion sub-element is to broaden the resource base for anaerobic digestion beyond manures, namely the utilization of agricultural and forest residues to produce Synthetic Natural Gas (SNG).

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
F-1	University of Illinois	Biological Conversion of Biomass to Methane	Obtain experimental data on conversion efficiency to predict the cost of methane produced from various organic feedstocks, including corn stover and wheat straw.
F-2	Dynatech R/D Co.	Engineering Evaluation of Programs in the Area of Methane from Residues/Biomass	Evaluate and coordinate technical projects in the area of methane production by anaerobic digestion.

Program Element: Conversion Systems

The goal of this program element is to establish technologies which can convert biomass into clean fuels, petrochemical substitutes, and other energy-intensive products. Emphasis will be placed on the production of those products which have the potential to make market impacts before the year 2000.

● Program Sub-Element: Fermentation

The objective of the Fermentation sub-element is to concentrate primarily on the utilization of agricultural and forest residues to produce ethanol. Emphasis is placed on developing pretreatment and hydrolysis techniques which increase the yield of fermentable sugars from lignocellulosic materials, optimizing processes for ethanol production, and investigating other fermentation processes.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
G-1	Purdue University	Selective Solvent Extraction in Utilization of Stored Solar Energy in Cellulosic Biomass	Develop selective solvents for the fractionation of cellulose, hemicellulose, and lignin components of lignocellulosic waste material.
G-2	Dartmouth College	Acid Hydrolysis of Concentrated Slurries of Cellulosic Biomass	Optimize glucose yields from the acid hydrolysis of lignocellulosic biomass.
G-3	University of California, Lawrence Berkeley Laboratory	Process Development Studies on the Bioconversion of Cellulose and Production of Ethanol	Produce ethanol from fermentable sugars derived from the enzymatic hydrolysis of lignocellulosic biomass.
G-4	Rensselaer Polytechnic Institute	Coordination of Fermentation Contractors	Perform technical monitoring and coordination of fermentation research and development.

Program Element: Conversion Systems

The goal of the Conversion Systems program element is to establish technologies which can convert biomass into clean fuels, petrochemical substitutes, and other energy-intensive products. Emphasis will be placed on the production of those products which have the potential to make market impacts before the year 2000.

o Program Sub-Element: Thermochemical — Gasification

The goal of the Gasification sub-element is to develop technology to produce medium-BTU gas (MBG) from biomass. A key issue is to select market applications in which biomass gasification-derived products can compete with products derived from large-scale oil, natural gas, or coal facilities.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
H-1	Catalytica Associates, Inc.	Catalytic Conversion of Biomass to Fuels and Chemicals	Review potential biomass conversion processes, identify key problems, and conduct a detailed assessment of the role of catalysts in the conversion of biomass.
H-2	Texas Tech University	Application of SGFM Technology to Other Feedstocks (Phase II)	Optimize production of synthesis gas from manure and other biomass feedstocks, including wood and corn stover.
H-3	Battelle Pacific Northwest Laboratories	Investigation of Gasification of Biomass in the Presence of Catalysts	Investigate the technical and economic feasibility of achieving the complete gasification of biomass using a catalyst and a special feed gas composition.
H-4	Battelle Columbus Laboratories	Conversion of Forest Residues to a Methane-Rich Gas	Develop the design base for a high throughput, catalytic reactor to convert wood residues to MBG.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
H-5	Gilbert Associates, Inc.	Research and Evaluation of Biomass Resources Conversion - Utilization Systems (Market/Experimental Analysis for Development of a Data Base for a Fuels from Biomass Model)	Develop a linear programming model which will be useful in determining the most profitable combination of biomass feedstocks and conversion processes to produce a desired fuel. Characterize at least 100 typical biomass feedstock materials.
H-6	Garrett Energy Research and Engineering Co.	Conversion of Biomass Materials into Gaseous Products	Demonstrate the feasibility of gasifying biomass materials in a specially designed multiple-hearth reactor.
H-7	Gorham International, Inc.	Assessment of Technical and Economic Feasibility of Converting Wood to Fuels Using Coal Conversion Technology	Determine which coal gasification processes can be used most advantageously for the conversion of biomass to liquid and gaseous fuels.
H-8	Wright-Malta Corp.	Catalyzed Water/Steam Gasification of Biomass	Develop and quantify process parameters for the gasification of biomass using a rotary-kiln gasifier.

Program Element: Conversion Systems

The goal of the Conversion Systems program element is to establish technologies which can convert biomass into clean fuels, petrochemical substitutes, and other energy-intensive products. Emphasis will be placed on the production of those products which have the potential to make market impacts before the year 2000.

● Program Sub-Element: Thermochemical — Liquefaction

The goal of the Liquefaction sub-element is to develop technology for converting biomass directly into liquid fuels.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
I-1	University of Arizona	Modified Extruder for Feeding Fine-Ground Cellulosic Slurries to Pressure Systems	Demonstrate the feasibility of a modified screw extruder for feeding biomass into a pressurized reactor for use in the Albany, Oregon, process development unit (PDU).
I-2	Battelle Pacific Northwest Laboratory	Bench-Scale Research in Thermochemical Conversion of Biomass to Liquids in Support of the Albany, Oregon, Experimental Facility	Determine process changes, and provide routine and specialized analytical support to facilitate fuel oil production at the Albany Biomass Liquefaction Experimental Facility (PDU).
I-3	Wheelabrator Cleanfuel Corporation	Operations of the Biomass Liquefaction Facility at Albany, Oregon	Obtain definitive process information, sufficient for commercial design and economic evaluation purposes, for the conversion of biomass to fuel oils.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
I-4	Bechtel National, Inc.	Experimental Program for the Albany, Oregon, Wood-to-Oil Experimental Facility	Prepare a conceptual design for a commercial biomass-to-oil process. Calculate projected cost of product oil and proportional cost of product for capital recovery, raw materials, utilities, and operation.
I-5	University of California, Lawrence Berkeley Laboratory	Albany, Oregon, Process Developmental Unit/Biomass Conversion into Oil	Assess the technical and economic feasibility of converting lignocellulosic materials into liquid fuels in support of the Albany facility.

Program Element: Research and Development (R&D)

The goal of the Research and Development element is to identify and investigate those biomass production and conversion technology R&D areas which are expected to contribute to the energy supply after the year 2000.

● Program Sub-Element: Innovative Conversion

The emphasis of the Innovative Conversion sub-element is on advanced biochemical processes and photo-electrolysis.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
J-1	General Electric Co.	Bioconversion of Plant Biomass to Ethanol	Develop the two-stage biological delineation and mixed culture fermentation process to produce ethanol from cellulose.
J-2	Massachusetts Institute of Technology	Degradation of Cellulosic Biomass and Its Subsequent Utilization for the Production of Chemical Feedstocks	Degrade cellulosic biomass and convert it directly to ethanol.
J-3	Exxon Research and Engineering Co.	Sensitized Photoelectrolysis of Water with Sunlight	Use heterogeneous catalyst for the sensitized photodecomposition of water to oxygen and hydrogen.
J-4	University of Pennsylvania	The Biological Production of Liquid Fuels from Cellulosic Residues	Determine the economic potential of a multi-step fermentation process and derive glucose by enzyme hydrolysis of cellulosic materials.
J-5	Dynatech R/D Co.	Liquid Fuels from Biomass	Produce acetic acid and other products from biomass feedstocks based on controlled anaerobic fermentation.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
J-6	Rutgers University	Producing Mutants of Trichoderma	Produce higher yields of cellulase enzymes through the development of mutant strains of <u>Trichoderma</u> .
J-7	Stanford University	Heat Treatment of Organics for Increasing Anaerobic Biodegradability	Increase the yield and reduce the cost of methane gas from the anaerobic digestion of cellulosic biomass.
J-8	University of California	Solar Energy Conversion Through Biophotolysis	Determine the feasibility of using nitrogen-fixing heterocystous blue-green algae in solar energy converters to produce hydrogen by biophotolysis of water.

Program Element: Research and Development (R&D)

The goal of the Research and Development element is to identify and investigate those biomass production and conversion technology R&D areas which are expected to contribute to the energy supply after the year 2000.

● **Program Sub-Element: Advanced Feedstocks**

The thrust of the Advanced Feedstocks sub-element is to advance the breeding and evaluation of exotic crops and basic research on plant improvement.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
K-1	University of California, Lawrence Berkeley Laboratory	Hydrocarbons from Plants	Evaluate the potential of (1) growing later producing <u>Euphorbia</u> plants and (2) economically extracting hydro- carbons.

Program Element: Research and Development (R&D)

The goal of the Research and Development element is to identify and investigate those biomass production and conversion technology R&D areas which are expected to contribute to the energy supply after the year 2000.

o Program Sub-Element: Aquatic Systems

Efforts within the Aquatic Systems sub-element are aimed at developing freshwater and marine algae production and harvesting techniques, as well as large-scale marine biomass farming technology.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
L-1	Woods Hole Oceanographic Institution	Cultivation of Macroscopic Marine Algae and Freshwater Aquatic Weeds	Cultivate aquatic plants for the production of methane by anaerobic digestion.
L-2	Woods Hole Oceanographic Institution	Bioengineering Aspects of Inorganic Carbon Supply to Mass Algal Cultures	Determine the inorganic carbon requirements for the production of algae under mass culture conditions.
L-3	California Institute of Technology	Biological Investigation of Marine Farms	Determine chemical and physical environmental requirements for kelp production.
L-4	CSO International, Inc.	Cost Analysis of Aquatic Biomass Systems (Fresh Water Micro-Algae)	Develop the design of a 100-square-mile freshwater system for the production and harvest of algae.
L-5	Dynatech R/D Co.	Cost Analysis of Algal Biomass Systems	Obtain operating and harvesting costs for several algal biomass systems.
L-6	Columbia University	Algal Concentration by Ultra-filtration	Harvest microalgae by a non-fouling membrane system.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
L-7	Columbia University	Permselective Membrane Control of Algal and Wood Digesters for Increased Production and Chemical Recovery	Investigate permselective membrane control of algal and wood digesters.
L-8	University of California	Large-Scale Freshwater Microalgae Biomass Production for Fuel	Develop cultivation technology of microalgae biomass for conversion to fuel using municipal sewage as the growth medium.

Program Element: Support

The goal of the Support program element is to provide cross-cutting analyses and assessments of the Biomass Energy Systems Program.

● Program Sub-Element: Analyses

The goal of the Analyses sub-element is to provide cross-cutting analyses of the Biomass Energy Systems Program.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
M-1	InterTechnology/Solar Corp.	Follow-on Studies of the Photosynthesis Energy Factory	Make the Photosynthesis Energy Factory (PEF) model applicable to a variety of site situations; make PEF more cost-effective.
M-2	SRI International	Mission Analysis for the Federal Fuels from Biomass Energy Program	Prepare a broad-based biomass energy systems technology and cost data bank.
M-3	SRI International	Preparation of a Cost Data Bank for DOE/Biomass Energy Systems Branch	Determine which fuels from biomass conversion routes are most likely to lead to economically viable market penetration within the competitive fuels environment.

Program Element: Support

The goal of the Support program element is to provide cross-cutting analyses and assessments of the Biomass Energy Systems Program.

● Program Sub-Element: Assessments

The goal of the Assessments sub-element is to provide cross-cutting assessments of the Biomass Energy Systems Program.

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Projected Contribution</u>
N-1	University of Arkansas	Evaluation of a Cellulose Waste Converter and Pyrolytic Process	Obtain pyrolytic conversion data, develop engineering design data, and conduct an engineering evaluation.

PROJECT SUMMARIES

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ELEMENT: Technology Support

SUB-ELEMENT: Direct Combustion Systems

A-1

Contractor and Address Wheelabrator Cleanfuel Corp. 1050 17th St., N.W., Suite 1100 Washington, D.C. 20036	Title Advanced System Demonstration for Utilization of Biomass as an Energy Source Contract No. EG-77-R-06-1036
Principal Investigator S. Brown Milligan (205) 254-4000	Period of Performance October 1977 to May 1979 Obligated Fiscal Year 1978 Funding
Work Location Maine	\$1,750,000 Cumulative Funding thru Fiscal Year 1978 \$2,500,000

Project Summary

This contract covers a Phase I study which is intended to demonstrate the technical and economic feasibility of utilizing forest residues, and/or plant non-commercial timber growth for conversion to cogenerated steam and electric power.

The objective of Phase I is the selection and design of systems. This phase requires six tasks:

- a. Locating a reliable, long-term source of biomass fuel, sufficient to provide at least 1,000 oven-dried tons per day to a conversion site.
- b. Selecting an existing harvesting and/or collection system to ensure the daily gathering and delivering to the conversion site; developing specifications for harvesting systems equipment where appropriate.
- c. Preparing detailed estimates of the costs for operations in task "b" and determining the price of the biomass fuel delivered to the conversion site.
- d. Selecting a suitable location for a conversion site to burn the biomass fuel. (This site will raise steam and generate electric power.)
- e. Preparing an engineering design of the conversion site, which includes heat and material balances, process flow diagrams, equipment selection, and specifications that include materials of construction, etc.
- f. Preparing an environmental impact statement, including socio-economic impacts.

ELEMENT: Technology Support

SUB-ELEMENT: Direct Combustion Systems

A-2

Contractor and Address Aerospace Research Corporation 5454 Jae Valley Road, S.E. Roanoke, Virginia 24014	Title Development of Wood as an Alternative Fuel for Large Power Generation Systems Contract No. ET-78-C-05-5682
Principal Investigator J.T. Hamrick (703) 342-2961	Period of Performance December 1, 1977 to July 31, 1978 Obligated Fiscal Year 1978 Funding \$130,171
Work Location Roanoke, Virginia	Cumulative Funding thru Fiscal Year 1978 \$130,171

Project Summary

The objective of this project was to develop a system for retrofitting oil and natural gas-fired boilers to burn wood. This effort provided the data for the design and fabrication of a prototype combustion module which will generate the design information for the retrofitting of large-scale boiler systems. Two specific goals were sought:

- a. To determine if combustion rates for wood slivers comparable to those obtained in boilers when firing powdered coal, oil, or natural gas were achievable by increasing primary air and secondary air temperatures.
- b. To increase the use of woody biomass as an energy source to produce steam and electric power in retrofit situations.

To achieve this objective, a small combustion module was designed, fabricated, and run as an integral part of this effort. This apparatus was used for parametric studies of wood pyrolysis and combustion with hot air. Tests showed that green wood, when pulverized to pass a half-inch screen, burns in much the same manner as natural gas or oil when the primary and secondary air temperature is 1000°F. A report on the test results was prepared.

ELEMENT: Technology Support

SUB-ELEMENT: Direct Combustion Systems

A-3

Contractor and Address	Title
NorWest-Pacific Corporation Plaza 600 Building Seattle, Washington 98101	Study of Wood-Fired Electric Power Generating Plants
	Contract No. RL-E-77-0626
Principal Investigator	Period of Performance
Donald W. Pingrey (206) 627-7224	July 1, 1977 to June 30, 1978
	Obligated Fiscal Year 1978 Funding
Work Location	\$17,029
Seattle, Washington	Cumulative Funding thru Fiscal Year 1978
	\$17,029

Project Summary

This project entailed a study of the burning of wood wastes for generating electric power from 74 different power plants in the U.S. A summary of the findings by industry follows:

Statistic	Pulp & Paper	Forest Products	Other
Number of mills with generators in service	36 (39)	11 (27)	7 (8)
Number of plants using only wood as fuel	3 (33)	19 (22)	1 (6)
Percent of total fuel that oil comprises	34.6 (28)	1.0 (17)	.6 (5)
Percent of total fuel that gas comprises	7.2 (28)	.9 (17)	0 (5)
Percent of total fuel that coal comprises	12.7 (28)	0 (17)	.4 (5)
Total number of turbine generators	99 (39)	35 (22)	24 (8)
Number of condensing turbines	22 (39)	27 (22)	11 (8)
Number of extraction condensing turbines	22 (39)	2 (22)	4 (8)
Number of noncondensing turbines	32 (39)	6 (22)	3 (8)
Number of extraction noncondensing turbines	16 (39)	0 (22)	0 (8)
Number of mills burning product waste	39 (39)	26 (26)	8 (8)
Number of mills purchasing waste	25 (38)	8 (23)	5 (8)
Average number in 1000's of tons/plant burned annually	166.4 (28)	33 (12)	105 (5)
Average cost paid per ton for wood residue	\$6.05 (11)	\$7.75 (4)	\$6.75 (4)
Average electric power production in MW/plant	23.4 (29)	2.8 (15)	7.3 (6)
Percentage of electricity produced used in-house	99.4 (33)	87 (20)	66 (7)
Average selling price as surplus power per kWh	1.18¢ (2)	1.1¢ (5)	2.1¢ (3)

Note: Data base given in parentheses.

ELEMENT: Technology Support

SUB-ELEMENT: Direct Combustion Systems

A-3

Contractor and Address	Title
Nor'West-Pacific Corporation Plaza 600 Building Seattle, Washington 98101	Study of Wood-Fired Electric Power Generating Plants
Principal Investigator	Contract No. RL-E-77-0626
Donald W. Pingrey (206) 627-7224	Period of Performance
Work Location	July 1, 1977 to June 30, 1978
Seattle, Washington	Obligated Fiscal Year 1978 Funding
	\$17,029
	Cumulative Funding thru Fiscal Year 1978
	\$17,029

Project Summary (continued)

This study concluded that (1) the forest products industry was not fully using its electrical power production capability or wood wastes, (2) the energy-deficient pulp and paper industry was using co-generation and buying wood wastes, and (3) most of the electrical energy produced by industry was used in-house.

ELEMENT: Technology Support

SUB-ELEMENT: On-Farm Systems

B-1

Contractor and Address Cornell University College of Agriculture and Life Sciences Department of Agricultural Engineering Ithaca, New York 14853	Title Anaerobic Digestion of Agricultural Residues: Potential for Improvement and Implementation
	Contract No. EY-76-S-02-2981
Principal Investigator William J. Jewell (607) 256-4533	Period of Performance June 1, 1976 to May 31, 1979
	Obligated Fiscal Year 1978 Funding \$455,000
Work Location Ithaca, New York	Cumulative Funding thru Fiscal Year 1978 \$891,000

Project Summary

This study is in the last year of a three-year effort. It has had an overall goal of developing and improving economic and technical factors which could lead to widespread implementation of anaerobic digestion to produce biogas on small-scale agricultural operations. Data is now being obtained from simplified pilot- and full-scale digesters operated on dairy cow manure.

The following reactor types have been constructed and are operating:

- A pilot-scale randomly fed and mixed reactor, having a three-cow residue handling capacity when operated at a 30-day hydraulic retention time (HRT).
- A pilot-scale plug flow reactor, having a three-cow residue handling capacity when operated at a 30 HRT.
- A full-scale plug flow reactor, having a 65-cow residue handling capacity when operated at a 10-day HRT.
- A full-scale conventional completely mixed control reactor, having the same residue handling capacity as the full-scale plug flow digesters.

The lower limits on design criteria, construction materials, and operation are being defined with the above reactors. In general, the full-scale unmixed plug flow reactor is operating as well or better than the conventional completely mixed reactor. However, documentation of the heat balance in the winter (1978-79) will be a critical area for evaluation in early 1979. Finally, a feasibility manual for evaluating the role of methane in smaller agricultural operations is presently under development.

Bibliographic Reference No.: 16

ELEMENT: Technology Support

SUB-ELEMENT: On-Farm Systems

B-2

Contractor and Address Tracey and Brunstrom Company 1214 John St. Seattle, Washington 98109	Title Engineering Feasibility of Fuels from Biomass Utilizing Dairy Farm Residue
	Contract No. ET-78-X-01-2404
Principal Investigator Rolf T. Skrinde (206) 682-4640	Period of Performance February 10, 1978 to May 31, 1978
	Obligated Fiscal Year 1978 Funding \$9,878
Work Location Seattle, Washington	Cumulative Funding thru Fiscal Year 1978 \$9,878

Project Summary

The objective of this project was to evaluate energy production by anaerobic digestion of agricultural wastes on dairy farms. The scope of work required three reports:

- a. An evaluation of small digesters in India and other countries.
- b. A report on related papers presented at the International Solar Energy Society Congress in New Delhi, India.
- c. An engineering feasibility study of an anaerobic digester program at a dairy farm near Monroe, Washington.

It was found that small, individual household biogas plants can supply substantial amounts of energy for home use in rural areas of developing countries if plants are compatible with the culture and economy of these areas. Their use in the United States will depend primarily on three factors:

- a. Developing designs which have lower capital and operating costs.
- b. Integrating the process so as to be compatible with other dairy farm operations.
- c. Developing more uses of the fuel gas to supplant other forms of energy.

Bibliographic Reference No.: 19

ELEMENT: Technology Support

SUB-ELEMENT: On-Farm Systems

B-3.

Contractor and Address Ecotope Group 2332 East Madison Seattle, Washington 98112	Title Monitor, Test, and Evaluate an Operational Digester for 350 Cattle Units
	Contract No. EG-77-C-06-1016
Principal Investigator Elizabeth Coppinger (206) 322-3753	Period of Performance June 21, 1977 to June 20, 1979
	Obligated Fiscal Year 1978 Funding \$79,532
Work Location Monroe, Washington	Cumulative Funding thru Fiscal Year 1978 \$186,879

Project Summary

The objective of this project is to monitor, test, and evaluate an operational digester for 350 cattle units and to optimize system performance in terms of net energy and operator time.

Project tasks include system automation, heat exchanger evaluation, examination of the impact of reduced mixing, investigating electrical generation, and laboratory analysis of the substrate.

Based on the results of this work, a report will be prepared which discusses the system components performance, energy production and consumption, and economic viability.

ELEMENT: Technology Support

SUB-ELEMENT: On-Farm Systems

B-4

Contractor and Address United Technologies Corporation Hamilton Standard Division Windsor Locks, Connecticut 06096	Title Experimental Anaerobic Fermentation Facility
	Contract No. EG-77-C-01-4015
Principal Investigator Daniel J. Lizdas, Project Manager Warren B. Coe, Engineering Manager (203) 623-1621	Period of Performance September 30, 1977 to February 29, 1980
	Obligated Fiscal Year 1978 Funding \$336,000
Work Location Windsor Locks, Connecticut and Bartow, Florida	Cumulative Funding thru Fiscal Year 1978 \$1,274,014

Project Summary

The objectives of this program are (1) to determine the technical and economic viability of producing fuel gas and other useful products from animal residues through the anaerobic fermentation process and (2) to promote early commercialization of the process. In addition, the feasibility of utilizing the protein-rich fermenter discharge as an animal feed ingredient will be evaluated.

To accomplish this objective, the system and its operational program will demonstrate the utilization of the products produced and will monitor their quantity and quality. Specifically, the fuel gas will be utilized in a meat packing plant boiler, and the fermenter contents will be used as a feed ingredient for several thousand cattle.

System design and construction has been completed. After startup and acceptance testing, an operational evaluation is expected to begin in March 1979. This information will support an evaluation of the commercial potential of the anaerobic fermentation process relative to existing alternate energy sources.

ELEMENT: Technology Support

SUB-ELEMENT: On-Farm Systems

B-5

Contractor and Address United Technologies Corporation Hamilton Standard Division Windsor Locks, Connecticut 06096	Title Dirt Lot Residue Experiments
	Contract No. EY-76-C-02-2952
Principal Investigator Daniel J. Lizdas, Program Manager Warren B. Coe, Engineering Manager (203) 623-1621	Period of Performance May 1, 1976 to August 31, 1978
	Obligated Fiscal Year 1978 Funding \$177,000
Work Location Windsor Locks, Connecticut and Greeley, Colorado	Cumulative Funding thru Fiscal Year 1978 \$466,267

Project Summary

Hamilton Standard has been operating its mobile anaerobic fermentation system at a dirt feedlot owned by Monfort of Colorado in order to evaluate, on a pilot-plant scale, the potential of using the anaerobic fermentation process to produce fuel gas and a refeed product from dirt feedlot residues. These residues are of a lower quality than the fresh residue available from an environmental feedlot, since they are aged and contain considerable amounts of sand and grit.

Stable fermentation has been achieved and methane yields have averaged 2.0 to 3.5 cubic feet per pound of volatile solids loaded. Refeeding trials have been successfully completed using both the liquid fermenter effluent and dewatered fermenter effluent. Separate studies evaluated several residue degritting techniques. The operations of the mobile system were completed in June 1978. A final report was scheduled for completion.

Bibliographic Reference No.: 20

ELEMENT: Technology Support

SUB-ELEMENT: On-Farm Systems

B-6

Contractor and Address Dynatech R/D Company Division of Dynatech Corporation 99 Erie St. Cambridge, Massachusetts 02139	Title Engineering Evaluation of the Recovery of the Energy Value of Animal Residues
	Contract No. EY-76-C-02-2991
Principal Investigator D.L. Wise R.L. Wentworth (617) 868-8050	Period of Performance May 17, 1976 to October 31, 1978
	Obligated Fiscal Year 1978 Funding \$80,649
Work Location Cambridge, Massachusetts	Cumulative Funding thru Fiscal Year 1978 \$291,469

Project Summary

The objective of this project has been to coordinate the research and development efforts of those projects evaluating biomass feedstocks and methods of methane production.

To facilitate the presentation of results in a consistent format, project tasks have included assisting in information exchange, evaluating engineering design and systems analyses, and reducing economic analyses to a common set of assumptions. This has helped identify areas in which additional or more accurate data are required to produce a complete, reliable assessment of methane production from biomass.

A comprehensive mathematical model of anaerobic digestion of animal residues has been developed, taking into account material and energy balances, kinetics, and economics of the process. A computer program for this model includes a routine to minimize unit gas cost. The sensitivity of unit gas cost to changes in the major contributions to unit gas cost has been analyzed, and results point to areas in the anaerobic digestion system design where reasonable improvements could be expected to make gas production economically feasible. The continuously stirred tank reactor system is already considered to be commercially feasible.

Bibliographic Reference No.: 17

ELEMENT: Technology Support

SUB-ELEMENT: On-Farm Systems

B-7

Contractor and Address U.S. Department of Agriculture Science and Education Administration P.O. Box 166 Clay Center, Nevada 68933	Title Anaerobic Digestion of Beef Cattle Manure and Crop Residues
	Contract No. EX-76-A-29-1058
Principal Investigator Dr. Andrew G. Hasimoto (402) 762-3241	Period of Performance December 10, 1976 to December 30, 1978
	Obligated Fiscal Year 1978 Funding \$60,000
Work Location Clay Center, Nevada	Cumulative Funding thru Fiscal Year 1978 \$110,000

Project Summary

The objective of this project is to evaluate the technical and economic feasibility of the anaerobic digestion process for recovering high-protein biomass and methane from beef cattle manure and crop residues. Specific contract tasks are required:

- To develop design criteria for optimum production of methane.
- To determine the capital and operating costs, plus energy, manpower and safety requirements for anaerobic fermentation systems associated with livestock operations.

The pilot-scale (5.7 meters³), thermophilic (55°C) fermenter has been in operation for about two years. It has operated at retention times ranging from 4 to 20 days and loading rates ranging from 3.4 to 17 kilograms/meters³/day. Three results have occurred:

- The total solids, volatile solids, and chemical oxygen demand (COD) reduction decreased as the retention time decreased.
- The fixed solids and total nitrogen did not decrease during fermentation.
- The volumetric methane production rate (L CH₄/L fermenter/d) increased as the retention time decreased.

An economic assessment was performed on the anaerobic fermentation process for hypothetical beef feedlots ranging from 1,000 to 100,000 head. The total capital costs decreased from \$220/head for the 1,000-head feedlot to \$61/head for the 100,000-head feedlot. The value of the net energy production was \$9.9/head/hr. Based upon these figures, the feedlot size at which the credits equal the total annual costs ranged between 1,000 to 2,000 head.

Bibliographic Reference No.: 21

ELEMENT: Technology Support

SUB-ELEMENT: On-Farm Systems

B-8

Contractor and Address SRI International 333 Ravenswood Ave. Menlo Park, California	Title Evaluation of the Proposed Bio-gas Project at Lamar, Colorado Contract No. EW-78-X-03-0357
Principal Investigator Jerry L. Jones (415) 326-6200	Period of Performance May 1, 1978 to June 30, 1978
Work Location Menlo Park, California	Obligated Fiscal Year 1978 Funding \$9,800 Cumulative Funding thru Fiscal Year 1978 \$9,800

Project Summary

This contract entailed conducting a review of a project report entitled, "Energy Potential through Bioconversion of Agricultural Wastes, Phase II." The report, submitted by Bio Gas of Colorado, Inc. on October 15, 1977 to the Four Corners Regional Commission, concerned a proposed anaerobic digestion facility at Lamar, Colorado. SRI's evaluation of this proposal is contained in a final report to be published and available through the National Technical Information Service (NTIS).

ELEMENT: Technology Support

SUB-ELEMENT: On-Farm Systems

B-9

Contractor and Address	Title
Touche Ross & Co. 1700 Broadway Denver, Colorado 80290	Economic Analysis of Proposed Bio-conversion Facility - Lamar, Colorado
Principal Investigator	Contract No. ET-78-X-01-4337
James R. Cwelich Daniel G. Morgan (303) 861-4462	Period of Performance
Work Location	April 15, 1978 to August 15, 1978
Denver, Colorado	Obligated Fiscal Year 1978 Funding
	\$13,225
	Cumulative Funding thru Fiscal Year 1978
	\$13,225

Project Summary

The purpose of this project was to provide an independent economic evaluation of the proposed bio-conversion facility as described in the report to the Four Corners Regional Commission, "Energy Potential Through Bio-Conversion of Agricultural Wastes, Phase II," and in the revised pro forma operating statement prepared by Bio-Gas of Colorado, Inc.

The approach involved (1) analyzing the proposed facility as an independent enterprise, (2) comparing the economic aspects of the proposed facility with other biomass conversion projects, and (3) reviewing potential benefits and costs from the perspectives of the City of Lamar and the Federal Government.

The primary emphasis of the project was on the economic analysis of the proposed facility as an enterprise. The results of this analysis indicated that development of the proposed facility would involve a substantial degree of risk, that operations might not be profitable, and that a high percentage of the initial investment could be lost.

As of the date of the analysis, the primary product (refeed) was still in the development stage. At the completion of product development and testing, a more definitive analysis of the economic viability of the project can be accomplished.

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-1

Contractor and Address Louisiana State University Agricultural Engineering Department Baton Rouge, Louisiana 70803	Title The Potential for Producing and Harvesting Sugarcane and Sweet Sorghum as a Renewable Biomass Energy Resource
	Contract No. EG-78-G-04-5046
Principal Investigator B.J. Cochran (504) 388-3153	Period of Performance August 1, 1978 to July 31, 1979
	Obligated Fiscal Year 1978 Funding \$50,000
Work Location Baton Rouge, Louisiana	Cumulative Funding thru Fiscal Year 1978 \$50,000

Project Summary

This project entails the pursuit of two major objectives:

- a. To evaluate methods of mechanically harvesting sugarcane and sweet sorghum grown from multiple drill and wide furrow treatment to increase plant population and yields.
- b. To study commercial mechanical systems available for harvesting maximum sugarcane biomass in the sugarcane production areas of the United States.

Agronomic data from multiple drill and wide furrow methods of planting have shown significant increases in yields of sugarcane and sweet sorghum. The production of these non-conventional methods requires the modification or development of machinery.

Five types of mechanical harvesters are being evaluated to determine their potential for harvesting sugarcane and sweet sorghum for biomass.

A workshop on the mechanization and harvesting of biomass for energy was held; results indicate a substantial need for more research and development in the area of biomass mechanization.

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-2

Contractor and Address Science Applications, Inc. 1764 Old Meadow Lane McLean, Virginia 22101	Title Conversion of Biomass Resources of Methanol
	Contract No. ET-78-C-01-3002
Principal Investigator Edward Wan (703) 821-4300	Period of Performance May 4, 1977 to May 4, 1978
	Obligated Fiscal Year 1978 Funding \$217,500
Work Location McLean, Virginia	Cumulative Funding thru Fiscal Year 1978 \$217,500

Project Summary

The principal objective of this project was fourfold:

- To develop alternative concepts for the production and introduction of methanol from biomass.
- To develop a system model to assess the economic feasibility of alternative methanol production and markets.
- To assess the technical and economic feasibility of alternative methanol production and markets.
- To develop recommendations for an RD&D plan to minimize the economic impacts of the introduction of methanol as a new fuel into our national economy.

To achieve this objective the following tasks were required:

- Identification of alternative systems for the production of methanol from biomass resources.
- Development of an empirical model to describe the methanol from biomass systems so that parametric analyses and sensitivity studies can be made.
- Determination of critical paths, plant siting criteria, and logistics.
- Recommendation of a number of ideas for technology development scenarios for methanol production from biomass.

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-2

Contractor and Address Science Applications, Inc. 1764 Old Meadow Lane McLean, Virginia 22101	Title Conversion of Biomass Resources of Methanol
	Contract No. ET-78-C-01-3002
Principal Investigator Edward Wan (703) 821-4300	Period of Performance May 4, 1977 to May 4, 1978
	Obligated Fiscal Year 1978 Funding \$217,500
Work Location McLean, Virginia	Cumulative Funding thru Fiscal Year 1978 \$217,500

Project Summary (continued)

A technical progress report summarizing the results of evaluation of the state-of-the-art biomass methanol processes has been submitted to DOE for review. Program tasks have involved construction of alternative process flowsheets, performing process analysis, and development of biomass to methanol system algorithms and models.

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-3

Contractor and Address U.S. Department of Agriculture Agricultural Research Service U.S. Sugarcane Field Laboratory P.O. Box 470 Houma, Louisiana 70361	Title Sugarcane Spacing Study and High-Fiber Sugarcane Selection Contract No. EG-77-A-29-1077
Principal Investigator James E. Irvine (504) 872-6326	Period of Performance April 17, 1977 to September 30, 1979 Obligated Fiscal Year 1978 Funding \$40,000
Work Location Houma, Louisiana	Cumulative Funding thru Fiscal Year 1978 \$40,000

Project Summary

Work on this project is being carried out on two levels:

- a. Farm-scale activities have been initiated. Large field plots, totaling 18 acres in area, have been planted with three configurations to determine the effect of narrow-row spacings on the yield of sugarcane. Preliminary results indicate yields increase on the order of 50 percent by decreasing the row spacing from 6 feet to 2 feet. Secondly, harvesting studies have been carried out to determine the feasibility of employing commercial harvesters on narrow-spaced material.
- b. Work has been initiated to breed and select cultivars of high-fiber sugarcane for energy production. Crosses were made and material was planted in nursery tests in the fall of 1978. Data will be collected during the fall of 1979.

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production

C-4

Contractor and Address U.S. Department of Agriculture Sugar Crops Field Station USDA-SEA-FR-SR Route 10, Box 152 Meridian, Mississippi 39301	Title Sweet Sorghum Energy Research Contract No. ET-78-I-01-3148
Principal Investigator Kelly C. Freeman (601) 482-0611	Period of Performance August 1, 1978 to July 31, 1979 Obligated Fiscal Year 1978 Funding \$5,000
Work Location Meridian, Mississippi	Cumulative Funding thru Fiscal Year 1978 \$5,000

Project Summary

The objectives of this project are as follows:

- a. Compare varieties and compare row spacings of sweet sorghum for biomass production.
- b. Plant, produce, and harvest 10 sweet sorghum cultivars within a randomized complete block design with four replications. Seed increase is to be obtained by bagging panicles on border rows. Yield and measurement data at harvest will include weight, stalk height and diameter, weight of component plant parts (seed, leaves and stalks), juice extraction percentage, and juice analysis data (measurement of Brix, sucrose, purity, and starch).
- c. Plant, produce, and harvest two varieties of sweet sorghum from 18-, 24-, 30-, 36-, and 42-inch-spaced rows and two on 42-inch-spaced rows for biomass yield comparison. Green weight and dry matter yields will be obtained for seed heads, leaves, and stalks. Mill samples will provide juice for determining extraction percentage, Brix, sucrose, purity, and starch components.

Harvesting has been completed. Results will be reported upon completion of milling, drying, and tabulation of acquired data.

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-5

Contractor and Address Battelle Columbus Laboratories 505 King Avenue Columbus, Ohio 43201	Title Carbohydrate Crops as a Renewable Resource for Fuel Production
	Contract No. W-7405-ENG-92
Principal Investigator Edward S. Lipinsky (614) 424-6526	Period of Performance June 15, 1975 to April 30, 1979
	Obligated Fiscal Year 1978 Funding \$580,000
Work Location Belle Glade, Florida; Houma, Louisiana; Baton Rouge, Louisiana; Weslaco, Texas; and West Jefferson, Ohio	Cumulative Funding thru Fiscal Year 1978 \$1,520,357

Project Summary

The primary objective of this project is to evaluate proposed methods of increasing the availability and reducing the cost of fermentable sugars that could be converted into liquid transportation fuels, while increasing the availability and reducing the cost of fibrous co-products for use as fuels and/or construction materials.

Evaluations of the influence of row spacing, variety selection, and the planting date on sweet sorghum and sugarcane yields, composition, and potential cost are being carried out in Ohio, Texas, Louisiana, Mississippi, and Florida. These studies will provide input for go, no-go decisions regarding sweet sorghum and sugarcane, both in the Midwest and in the South.

The Tilby Process is being critically evaluated on its ability to generate co-products that reduce the net cost of fermentable sugars while consuming less energy than conventional milling. The other process development effort will focus on reduction to practice and preliminary exploration of a new juice preservation process.

Studies of the implications of current U.S. agricultural policy legislation for use of sugar crops and corn as energy resources have been initiated. Alternative policies for stimulating energy production from carbohydrate crops are also being identified and examined.

The economics of replacing corn grain for livestock feed with a mixture of corn grain and distillers dried grains with solubles (DDGS), a by-product of corn grain fermentation, is also being investigated.

Bibliographic Reference No.: 7

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-6

Contractor and Address Battelle Columbus Laboratories 505 King Ave. Columbus, Ohio 43201	Title Feasibility of Integrating Corn Agriculture with the Manufacture of Fermentation Fuels
	Contract No. W-7405-ENG-92
Principal Investigator T.A. McClure (614) 424-6534	Period of Performance January 15, 1978 to September 30, 1978
	Obligated Fiscal Year 1978 Funding \$50,451
Work Location Columbus, Ohio	Cumulative Funding thru Fiscal Year 1978 \$50,451

Project Summary

This project has required a study of the feasibility of making corn grain available for conversion into motor fuel ingredients without undue disruption of the price structure for beef and other meat products. The theoretical basis for the study has been to replace corn grain for cattle feed with corn stover (stalks, cobs, and other lignocellulose portions of the corn plant), supplemented with distillers dried grains and solubles (DDGS), a by-product of ethanol fermentation from corn grain.

The consumption of corn grain by cattle occurs primarily in feedlots where high daily weight gains are required. The nutritional value of corn stover in mixtures with DDGS would not satisfy the needs of feedlot operators without the upgrading of the stover. With the processes now available, the cost of the cellulose material would also increase. The theoretical estimates need to be tested by feeding experiments.

Production of 1 billion gallons of ethanol from corn would lead to six times the present production of DDGS; this would compete with soybean meal, depressing prices for the soybean farmers. At the same time, the price of corn would be expected to rise. Because of the anticipated changes in corn and soybean prices through implementation of this system, attractive beef prices may not result. Furthermore, the rise in corn prices and decline in DDGS prices are the opposite of what is needed for production of inexpensive ethanol.

An appendix of the final report for this project presents earning forecasts and cost estimates for a 46.3 million gallon per year alcohol production facility. (This facility utilizes corn grain as the raw material and employs conventional dry-milling technology.)

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-7

Contractor and Address Battelle Columbus Laboratories 505 E. King Ave. Columbus, Ohio 43201	Title Evaluation of Feasibility of Sequential Fermentation for the Production of Ethanol
	Contract No. W-7405-ENG-92
Principal Investigator J.H. Litchfield (614) 424-7624	Period of Performance August 1, 1978 to September 30, 1979
	Obligated Fiscal Year 1978 Funding \$93,575
Work Location Columbus, Ohio	Cumulative Funding thru Fiscal Year 1978 \$93,575

Project Summary

The objectives of this research are (1) to obtain suitable strains of yeast having either ethanol tolerance or osmo-tolerance and (2) to reduce to practice a Report-of-Invention assigned by Battelle-Columbus to DOE on a sequential, semi-continuous fermentation process.

Four strains of osmophilic yeasts and five strains of ethyl-alcohol-tolerant yeasts have been obtained and evaluated for fermentation densities. These yeasts have been investigated for their applicability to the sequential fermentation process utilizing concentrated sugar solutions.

The results obtained to date indicate that selected osmophilic yeasts ferment concentrated glucose and sucrose solutions to ethanol at good rates, and that ethanol-tolerant yeasts can produce up to 15 percent ethanol readily.

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-8

Contractor and Address Battelle Columbus Laboratories 505 E. King Ave. Columbus, Ohio 43201	Title Economics of Manufacturing Liquid Fuels from Corn Stover
	Contract No. ET-78-X-01-3992
Principal Investigator D.M. Jenkins (614) 424-4734	Period of Performance May 1, 1978 to September 30, 1978
	Obligated Fiscal Year 1978 Funding \$9,960
Work Location Columbus, Ohio	Cumulative Funding thru Fiscal Year 1978 \$9,960

Project Summary

The objective of this study was to evaluate the economic feasibility of manufacturing fuels from agricultural residues.

To achieve this objective, a conceptual design to convert corn stover to anhydrous ethanol and furfural was made for a plant converting 1427 tons/day dry corn stover into 209 tons/day anhydrous ethanol and 161 tons/day furfural. Results indicate that the estimated manufacturing cost, including profit, would be about \$15/million Btu.

Several research areas for the purpose of reducing cost were identified.

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production

C-9

Contractor and Address Bernard Wolnak & Associates 75 E. Wacker Drive, Room 1400 Chicago, Illinois 60601	Title Economics of Conversion of Cellulose (Wood) and Corn Starch to Sugars, Alcohol, and Yeast
	Contract No. ET-78-X-02-5007
Principal Investigator Bernard Wolnak (312) 782-4926	Period of Performance May 1978 to August 1978
	Obligated Fiscal Year 1978 Funding \$10,000
Work Location Chicago, Illinois	Cumulative Funding thru Fiscal Year 1978 \$10,000

Project Summary

The purpose of this project has been to develop and analyze all of the technological and economic information available on the various processes proposed or available to convert (wood) cellulose and corn starch into glucose and sugars and, in turn, to convert these sugars to ethyl alcohol or yeast.

This project required the following tasks:

- Estimating costs of various wood conversion processes and the potential of their success.
- Citing the potential uses of products that are obtained from cellulosic materials.
- Assessing the possible regulatory problems from the FDA and EPA which could affect cellulosic processes.
- Creating cost and production estimates for corn starch processes.
- Assessing the comparative costs of (1) producing glucose from each process and (2) the raw materials.
- Determining additional costs involved in the production of ethyl alcohol and yeasts from the sugars derived from cellulose or from starch.

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-10

Contractor and Address University of Florida AREC - P.O. Drawer A Belle Glade, Florida 33430	Title Sugarcane Growth for Use as an Energy Crop
	Contract No. ET-78-G-05-5890
Principal Investigator G.J. Gascho S.F. Shih (305) 996-3062	Period of Performance December 1, 1976 to November 30, 1978
	Obligated Fiscal Year 1978 Funding \$4,500
Work Location Belle Glade, Florida	Cumulative Funding thru Fiscal Year 1978 \$8,820

Project Summary

Sugarcane is very effective in utilizing radiant energy once canopy development is complete. Narrow-spaced rows result in more rapid canopy development. The objective of the study is to determine if narrower spacing also results in increased biomass, sugar, and fiber yields on sandy soils. Sugarcane was planted at 0.5, 1.0, and 1.5 meter row spacings in five replications. Monthly harvests indicate that biomass increases with decreasing row spacings due, for the most part, to increased stalk populations in immature cane. Differences in biomass, total sugars, and fiber for mature cane are not yet available. This research is a portion of a larger program being funded by DOE through contract W-7405-ENG-92 with Battelle Columbus Laboratories.

Bibliographic Reference No.: 8

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-11

Contractor and Address The MITRE Corporation Metrek Division 1820 Dolley Madison Boulevard McLean, Virginia 22101	Title Biomass-Based Alcohol Fuels
	Contract No. ET-78-C-01-2854
Principal Investigator Wayne Park David Salo (deceased 3/4/79) (703) 827-7192	Period of Performance August 1, 1978 to April 1, 1979
	Obligated Fiscal Year 1978 Funding \$51,049
Work Location McLean, Virginia	Cumulative Funding thru Fiscal Year 1978 \$51,049

Project Summary

This project has resulted in two studies.

The first study addressed the potential of implementing a nationwide alcohol-gasoline fuel system based on alcohols derived from biomass resources. The technological and economic factors of the production and use of ethanol and methanol were calculated for 5 and 10 percent alcohol/gasoline blends by 1990. Although the cost would be substantially greater than gasoline, up to 5 percent methanol or ethanol blends with gasoline could be achieved by 1990, according to this study.

The second study compared the economic aspects of 14 studies which were carried out between late 1976 and early 1978 by Battelle Columbus Laboratories, F.R. Schaeffer Associates, the University of Nebraska, the University of California at Berkeley, the MITRE Corporation, and SRI International. Twenty-eight ethanol facilities, previously described in published reports and papers, were considered. Major parameters such as production costs, method of financing, by-product credits, process efficiency, and capacity factors were determined from these reports for each facility. In some cases it was necessary to supplement published data with information obtained directly from authors of the reports. All cost data were reported in 1977 dollars, and units of measure were standardized to facilitate comparison of similar facilities. The "Systems to Project the Utilization of Renewable Resources" life-cycle costing model, developed by MITRE, was used in the evaluation.

Bibliographic Reference No.: 33

ELEMENT: Technology Support

SUB-ELEMENT: Alcohol Production Systems

C-12

Contractor and Address Arthur G. McKee & Company 10 S. Riverside Plaza Chicago, Illinois 60606	Title Preliminary Engineering and Cost Analysis of Purdue/Tsao Cellulose Hydrolysis Process Contract No. ET-78-X-01-4641
Principal Investigator E.A. Kirchner (312) 454-3600	Period of Performance June 27, 1978 to September 27, 1978
Work Location Chicago, Illinois	Obligated Fiscal Year 1978 Funding \$9,500 Cumulative Funding thru Fiscal Year 1978 \$9,500

Project Summary

The objective of this project has been to make a capital investment and operating cost estimate of the Purdue/Tsao Process for the conversion of cellulose to glucose and pentose.

A final report of this analysis was sent to DOE in September 1978.

PRODUCTION SYSTEMS

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ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-1

Contractor and Address Purdue Research Foundation Division of Sponsored Programs West Lafayette, Indiana 47907	Title Species Selection for Silvicultural Energy Farms on Reclaimed Mineland
	Contract No. ET-78-G-01-3196
Principal Investigator Walter F. Beineke (317) 749-2114	Period of Performance June 1, 1978 to May 31, 1979
	Obligated Fiscal Year 1978 Funding \$38,037
Work Location West Lafayette, Indiana	Cumulative Funding thru Fiscal Year 1978 \$38,037

Project Summary

This project is designed to select the optimum species for silvicultural energy farms in the Midwest. The Indiana Department of Natural Resources (Division of Forestry) and the Peabody Coal Company were solicited to locate farms and natural stands for sampling in Indiana. This task has been completed with the location of four sites. Two sites are on reclaimed mineland in southwestern Indiana. The other two are on old fields in the southeastern and northeastern part of the state. Eighteen species will be investigated initially.

Harvesting and sampling of five trees of each species at each location will begin after the growing season is complete. Field measurements will include height, diameter at breast height (4.5 feet above ground level), basal diameter, and green weight. Sample discs from each stem as well as branch wood will be returned to the laboratory for determination of tree age, moisture content, and Btu values.

Further effort includes the selection of four species which show the greatest potential for use in energy farms based on growth rate and wood characteristics. The inherent rootability of cuttings of the selected species will be investigated and means to promote or enhance rooting with hormonal treatments or manipulation of environmental conditions will be studied.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-2

Contractor and Address General Electric Company The Controlled Environment Agriculture Operation Court Street Plant 2, Room 1 Syracuse, New York 13221	Title Energy Biomass Production Study
Principal Investigator Kenneth Foote (315) 456-7740	Contract No. ET-78-C-02-4909
	Period of Performance September 1978 to April 1980
	Obligated Fiscal Year 1978 Funding \$148,429
Work Location Syracuse, New York	Cumulative Funding thru Fiscal Year 1978 \$148,429

Project Summary

The objective of this project is to develop the technology for growing seedlings in controlled environments, at competitive prices, and in sufficient quantities to supply silviculture energy farms in the future. Emphasis will be placed on increasing the survival rate of these seedlings.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-3

Contractor and Address Hawaiiiana Investment Co., Inc.* Bioenergy Development Corporation P.O. Box 1826 Honolulu, Hawaii 96805	Title Eucalyptus Farms for Energy Production in Hawaii Contract No. ET-78-F-03-2159
Principal Investigator R.L. Herberg (805) 536-4461	Period of Performance September 30, 1978 to September 30, 1979 Obligated Fiscal Year 1978 Funding \$335,000
Work Location Hawaii County, Hawaii	Cumulative Funding thru Fiscal Year 1978 \$335,000

Project Summary

The objective of this project is to investigate a number of options to accomplish the following tasks:

- a. Increase the biomass production of eucalyptus.
- b. Determine the optimum cultural requirements to maximize yield.
- c. Assess planting, cultivation, harvesting, and transportation equipment requirements; modify existing equipment if necessary.
- d. Determine the optimal mixture of biomass (eucalyptus and bagasse) at the generator for the production of electricity.
- e. Evaluate a complete production/conversion system which utilizes optimum management conditions in relationship to costs.

*C. Brewer and Co.

Bibliographic Reference No.: 2

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-4

Contractor and Address Michigan Technological University Department of Forestry Houghton, Michigan 49931	Title Application of Sugar Maple and Black Locust to the Biomass Energy Farm Concept
	Contract No. ET-78-G-01-3071
Principal Investigator R.L. Sajdak (906) 487-1885	Period of Performance June 1, 1978 to May 31, 1981
	Obligated Fiscal Year 1978 Funding \$73,903
Work Location Houghton, Michigan	Cumulative Funding thru Fiscal Year 1978 \$73,903

Project Summary

This study involves the conversion of pole-sized maple stands to energy farms on sites of varying quality in the Upper Peninsula of Michigan. A detailed investigation will be conducted to determine the extent of sugar maple sprouting as an energy-efficient regeneration method. This will involve a detailed look at stump size, site quality, and additions of fertilizer as they affect sprouting. In addition, Btu content and pyrolysis products will be determined and compared to energy expended through harvest and fertilization to monitor energy input-output of the system. The potential of using black locust or other nitrogen-fixing species for increasing stand production and site fertility in mixtures with sugar maple or in pure stands will be investigated also.

The study area for the project has been established on state forest land. Three sites, representing high, medium, and low productivity levels, have been selected within the study area and plots have been established on each site. The data base for a characterization of site productivity has been collected; this includes complete volume and biomass estimates as well as stem analysis information. The soil has been described and characterized, and soil samples have been obtained. Selected plots have been fertilized. Foliage has been collected and will be analyzed to determine if fertilized uptake did occur in the trees. Roots will be analyzed for carbohydrate content. Samples of seedling and sprout material have been collected and will be evaluated in terms of biomass production, specific gravity, calorific value, and chemical composition.

Currently, black locust stands are being evaluated, and seed and root nodules are being collected. Differences in root nodulation have been observed. These nodules will be used to culture Rhizobium bacteria and, hopefully, selections of bacteria strains with improved nitrogen-fixing abilities can be obtained.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-5

Contractor and Address North Carolina State University Hardwood Research Cooperative School of Forestry Raleigh, North Carolina 27650	Title Species Selection and Silvicultural Systems for Producing Fuels from Woody Biomass in the Southeastern United States Contract No. ET-78-G-01-3038
Principal Investigator Douglas J. Frederick, Project Leader Robert C. Kellison, Co-project Leader William E. Gardner, Co-project Leader (919) 737-2891	Period of Performance June 1, 1978 to May 31, 1979 Obligated Fiscal Year 1978 Funding \$100,575
Work Location Raleigh, North Carolina	Cumulative Funding thru Fiscal Year 1978 \$100,575

Project Summary

The objectives of this project are to screen and identify three species and genetic sources most suitable for intensively managed, short-rotation biomass production; to identify optimum techniques for site preparation, stand establishment and stand management; and to use genetically improved plant materials best suited for fuel production.

To accomplish these objectives, use will be made of the extensive silvicultural information available through the N.C. State Hardwood Research Cooperative; sixteen southern and exotic species will be investigated. Additionally, the Cooperative members, who own or control over 15 million acres of land, will provide the study sites, technical support, and much of the equipment for this investigation. Proper species and source determination for maximum biomass and energy yields will be done by replicated species-site installations of both previously tested and untested species and sources; these species will be planted in a randomized block design for comparative performance analysis. About one-third of the 16 species will be planted each year for 3 consecutive years to complete this phase of the project.

Concurrently to species-site evaluation, the optimum silvicultural systems for maximizing energy yields will be determined through testing of spacing, cultivation, fertilization, and irrigation of both exotic and indigenous species on several site types. Species to be initially tested are sycamore, sweetgum, loblolly pine, eucalyptus, and European black alder. Some definitive results from these tests will be available at the end of the first 7 years; however, it is planned that the studies will be monitored over subsequent years by the Hardwood Research Cooperative. Additional species, as determined from the species-site studies, will be established for determination of optimum silvicultural systems as appropriate.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-5

Contractor and Address North Carolina State University Hardwood Research Cooperative School of Forestry Raleigh, North Carolina 27650	Title Species Selection and Silvicultural Systems for Producing Fuels from Woody Biomass in the Southeastern United States
	Contract No. ET-78-G-01-3038
Principal Investigator Douglas J. Frederick, Project Leader Robert C. Kellison, Co-project Leader William E. Gardner, Co-project Leader (919) 737-2891	Period of Performance June 1, 1978 to May 31, 1979
	Obligated Fiscal Year 1978 Funding \$100,575
Work Location Raleigh, North Carolina	Cumulative Funding thru Fiscal Year 1978 \$100,575

Project Summary (continued)

Progress to date has included location of planting sites and selection of seed and seedlings in preparation for the first year winter planting. Genetic work has included the establishment of 100 families of sweetgum and 50 families of water-willow oak for the creation of seed orchards; evaluation of mother-tree studies of sycamore, sweetgum, green ash, and water-willow oak; and grafting experiments with these species plus several eucalyptus species. In addition, an outplanting of 44 European black alder sources has been established to identify those sources best suited to maximum biomass and energy production.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-6

Contractor and Address North Carolina State University School of Forest Resources Raleigh, North Carolina	Title Economics and Operating Characteristics of Various Materials Handling Systems and Wood Fuels in Small- to Medium-Sized Boiler Facilities
	Contract No. ET-78-G-01-3081
Principal Investigator Michael P. Levi (919) 737-2892	Period of Performance July 1, 1978 to June 30, 1979
	Obligated Fiscal Year 1978 Funding \$90,847
Work Location Raleigh, North Carolina	Cumulative Funding thru Fiscal Year 1978 \$90,847

Project Summary

This one-year study is intended to evaluate the economic and technical feasibility of burning wood as a fuel in nonwood product industries. The fuels of principal interest are whole tree chips, bark, sawdust, and wood pellets. These fuels are used to produce steam by direct combustion. Boiler sizes to be considered range from approximately 20,000 to 100,000 pounds of steam per hour.

An extensive review of literature and available technology is underway. From this, a bibliography, and directories of equipment suppliers and consultants are being developed. In addition, comparative test burns with several wood fuels are being planned at commercial installations. Results of these tests together with evaluations of various materials handling systems will be utilized in developing recommendations for selection of fuel and material handling systems.

At the conclusion of the project, publications will be developed to enable managers and engineers in industry and commerce to make objective decisions on the desirability of using wood as a fuel.

ELEMENT: Production Systems**SUB-ELEMENT: Silviculture**

D-7

Contractor and Address Alabama A & M University School of Agriculture and Environmental Science Dept. of Natural Resources and Environmental Studies Timber Harvesting Management Program Huntsville, Alabama 35762	Title Recovery of Above-Ground Woody Biomass (Logging Residue) Using Operational Modifications of Conventional Harvesting Systems
	Contract No. ET-78-G-01-3041
Principal Investigator John W. Herschelman (205) 859-7410	Period of Performance May 1978 to May 1979
	Obligated Fiscal Year 1978 Funding \$56,336
Work Location Paint Rock Valley, Jackson County and Green Mountain, Madison County, Alabama	Cumulative Funding thru Fiscal Year 1978 \$56,336

Project Summary

Under this study, harvesting systems will be created to determine if it is economically feasible to utilize presently unmerchantable woody-biomass. Two primary tasks are required:

- a. The modification of conventional harvesting systems in order to increase biomass recovery of logging residue and small diameter stems.
- b. The evaluation of existing stands to determine if it is economically feasible to use such modified systems.

Two logging systems will be assembled in the summer of 1979 to compare a conventional harvesting system with a harvesting system modified to utilize woody biomass for potential use as a fuel. Previous research at Alabama A & M University has shown that such a modified system can produce more biomass than a conventional system, but that energy consumption per ton of woody biomass produced remained the same. The 1979 comparison will attempt to develop a system that will not only produce more tonnage of biomass, but will also reduce energy consumption of fuel and oil through operational modifications.

In order to evaluate the amount of woody biomass available in a given stand of timber, prediction equations will be developed by measuring and weighing component parts of individual trees.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-8

Contractor and Address Virginia Polytechnic Institute and State University Department of Forestry & Forest Products Blacksburg, Virginia 24061	Title An Integrated Investigation of Procurement, Harvesting, Drying, Transportation, and Storage of Woody Biomass
	Contract No. ET-78-G-01-3069
Principal Investigator T.A. Walbridge, Jr. W.B. Stuart (703) 961-6000	Period of Performance June 1, 1978 to May 31, 1980
	Obligated Fiscal Year 1978 Funding \$281,658
Work Location Blacksburg, Virginia	Cumulative Funding thru Fiscal Year 1978 \$281,658

Project Summary

The objective of this work is to evaluate alternative methods of harvest, storage, transport, and preparation of woody materials as a source of energy for three plant types:

- Plants specifically designed to operate using woody material as a primary fuel on a full-time basis.
- Plants using woody material to augment other energy forms on a full-time basis.
- Plants using woody fuels as an alternative during shortages of their primary fuel.

The woody materials considered may originate from residues created from conventional harvesting operations, from silvicultural treatments on lands held for timber production, and from stands established specifically for energy production.

The research will be divided into four subparts:

- Severance and field drying.
- In-woods processing, transportation, and storage.
- Procurement, transportation, and storage between forest and plant site.
- Receiving facilities and preparation of material at the plant site.

Three major product forms will be considered: roundwood; full tree; and segmented stems, chips, and bales.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-9

Contractor and Address Washington State University Department of Forestry and Range Management Pullman, Washington 99164	Title Evaluating and Modelling Tree Biomass Yields from Small-Diameter Conifer Stands in the Inland Northwest
	Contract No. ET-78-G-01-3079
Principal Investigator Roger Chapman (Project Manager) V.C. Baldwin D. Burnell (509) 335-3564	Period of Performance May 15, 1978 to May 14, 1983
	Obligated Fiscal Year 1978 Funding \$224,006
Work Location Pullman, Washington	Cumulative Funding thru Fiscal Year 1978 \$124,006

Project Summary

The major objective of the project is to provide biological data and simulation models that are needed for an accurate assessment of energy potential in small-diameter conifer stands in the inland Northwest. A secondary objective is to provide statistical models describing the distribution of biomass within stands for a variety of utilization standards.

This 5-year cross-sectional study will provide detailed biomass information obtained from sample trees in selected stands. The study population is the small-diameter pure and mixed species stands of Douglas fir, ponderosa pine, western larch, and lodgepole pine found in eastern Washington, northeastern Oregon, and northern and central Idaho.

The study is limited to determination, modelling, and simulation of above-ground tree biomass. Field data will be collected in two overlapping phases. The first phase consists of identifying and locating stands with appropriate characteristics. In the second phase, sampling teams will establish four plots within a stand to assess stand condition and destructively sample representative trees to estimate biomass. Regression techniques will be utilized initially to develop models for individual tree boles, branches, and foliage. These models will form the basis for developing integrated biomass models. The Growth Prognosis Model, an existing volume simulator, will be investigated to determine if it can be modified to produce accurate biomass estimates. If this simulator cannot be satisfactorily modified, a new biomass simulator will be constructed.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-10

Contractor and Address University of Illinois Department of Forestry 211 Mumford Urbana, Illinois, 61801	Title Woody Biomass Production for Solar Energy Conversion
	Contract No. ET-78-G-01-3067
Principal Investigator Gary L. Rolfe (217) 333-1000	Period of Performance June 1, 1978 to May 31, 1979
	Obligated Fiscal Year 1978 Funding \$78,019
Work Location Urbana and Simpson, Illinois	Cumulative Funding thru Fiscal Year 1978 \$78,019

Project Summary

This study will assess the feasibility of continual solar energy conversion through the production of woody plant biomass over 2- to 3-year rotations on marginal lands in central and southern Illinois. Lands incorporating a variety of site factors have been selected as test sites. These areas will be planted with at least four woody species including sycamore, autumn olive, alder, and eastern cottonwood in a range of spacings from 9 to 24 inches to determine the effects of site quality, species, and spacing on biomass production. Stand establishment, maintenance, and harvesting techniques will also be developed. Net energy budgets and the nutrient budget will be developed for each site for further evaluation of the intensive short-rotation biomass production system.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-11

Contractor and Address Kansas State University Department of Forestry Call Hall Manhattan, Kansas 66506	Title Great Plains Energy Forest Study
	Contract No. ET-78-G-01-3042
Principal Investigator Wayne Allan Geyer (913) 532-6932	Period of Performance April 3, 1978 to September 30, 1983
	Obligated Fiscal Year 1978 Funding \$76,066
Work Location Manhattan, Kansas	Cumulative Funding thru Fiscal Year 1978 \$76,066

Project Summary

Experiments have been initiated under this 5-year study to determine the woody plant biomass yield on several sites in Kansas. The objective of the project has been to find the best tree species, the optimum planting density, cultural techniques, and harvest age for fast growing hardwoods using the short-rotation concept. Plant adaptability, longevity, biomass yield, and production costs in terms of dollars and energy inputs will be evaluated.

Numerous soil/site locations in central Kansas are being utilized to test fast growing coppicing hardwood trees (cottonwood, black locust, and catalpa) at seven planting densities, ranging from 3 1/2 to 11 feet apart. Competing vegetation is being mechanically controlled in 1/3 of the study plots and compared to Casoron and Ronstar herbicide treatments in the other plots. A randomized block field design with three replications has been established at each site. Species differences in height, diameter, growth (volume, weight, and Btu yield), weed control success, and herbicide toxicity to trees will be evaluated annually.

Silvicultural Energy Farms were established at three locations and treated with herbicide or cultivated to control weed competition. Over-spraying planted trees with Ronstar at 3 lbs. acid ingredient (a.i.) per acre or Casoron at 10 lbs. a.i. per acre showed no toxicity symptoms on black locust, cottonwood, or catalpa. Both herbicides gave at least 80 percent control of both broadleaf and grassy weeds.

Contractor and Address University of Kentucky Department of Forestry Lexington, Kentucky 40506	Title Production of Black Locust Biomass on Surface-Mined Sites in the Southern Appalachians
	Contract No. ET-78-G-01-3039
Principal Investigator Stanley B. Carpenter (606) 258-9000	Period of Performance April 17, 1978 to April 17, 1983
	Obligated Fiscal Year 1978 Funding \$70,130
Work Location Southern Appalachian Region: Kentucky, West Virginia, Tennessee	Cumulative Funding thru Fiscal Year 1978 \$70,130

Project Summary

The principal purpose of this project is to determine the amount of black locust biomass that can be produced on surface-mined sites in the southern Appalachian region (Kentucky, Tennessee, and West Virginia). This study is being accomplished in two phases. First, the biomass produced in previously established stands of black locust across this region is being sampled. Second, energy farms involving the intensive culture of black locust at two locations in Kentucky are being established.

The biomass production potential of black locust on surface-mined sites and the effects of various cultural treatments such as fertilization, manipulation of stand density, varying cutting cycles, mulching, and irrigation is being evaluated. The economic efficiencies based on costs and yields associated with the various production system combinations is being evaluated, also.

Preliminary analysis of data collected in the summer of 1978 on 72 previously established stands of black locust show dry weight yields ranging from an average of 4.5 metric tons/hectare (mT/ha) for 2-year-old stands to 63.0 mT/ha for 13-year-old stands. Average annual growth for all sites (ranging in age from 2 to 13 years) was approximately 3 mT/ha. Average stand densities ranged from over 31,000 stems/ha for 2-year-old stands to 2000 stems/ha for 13-year-old stands.

Bibliographic Reference No.: 3

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-13

Contractor and Address The Pennsylvania State University Institute for Research on Land and Water Resources University Park, Pennsylvania 16802	Title Feasibility of Using Municipal Wastewater and Waste Heat to Maximize Biomass Production on Silvicultural Energy Farms
	Contract No. ET-78-G-01-3066
Principal Investigator William E. Sopper (814) 865-4700	Period of Performance May 15, 1978 to May 14, 1980
	Obligated Fiscal Year 1978 Funding \$83,349
Work Location State College, Pennsylvania	Cumulative Funding thru Fiscal Year 1978 \$83,349

Project Summary

A hybrid poplar energy farm was established in May 1978. The cuttings were planted at spacings of 0.4, 0.8, and 1.6 feet in rows 2.5 feet apart, thus providing the equivalent of 1, 2, and 4 square feet of growing space per tree.

Six replications were established also. Three of the replications are being irrigated with secondary treated municipal sewage effluent at the rate of 2 inches (54,000 gallons per acre) per week. Effects of the wastewater irrigation on survival, growth, and biomass production are being evaluated. Suction lysimeters have also been installed to collect soil percolate water at the 4-foot depth in each spacing plot to evaluate the efficiency of each plantation in renovating the wastewater. Foliar and soil samples have been taken to evaluate nutrient uptake and depletion.

A similar energy farm was established at a soil-warming facility. The soil-warming facility consists of a buried pipe network and a hot water heating system. Pipes are buried at a depth of 1 foot at a 2-foot spacing. Hot water is being circulated through the pipes with average monthly water temperatures of approximately 100°F. A portion of the energy farm is also being irrigated with sewage effluent at the rate of 2 inches per week. A similar monitoring system has been established to evaluate the effects of wastewater irrigation only and wastewater plus waste heat.

In 1973, a hybrid poplar energy plantation was established at the site with a similar experimental design. During the past 5 years, it was irrigated each growing season with sewage effluent at the rate of 2 inches per week. In March 1978, six sample trees were harvested from each spacing plot and are currently being analyzed to evaluate the effect of the wastewater irrigation on annual tree growth and biomass production.

Contractor and Address The Pennsylvania State University 807 Old Main University Park, Pennsylvania 16802	Title Energy Sensitivity and Variability Analysis of <u>Populus</u> Hybrid Short-Rotation Silvicultural Energy Farms in the Northeastern United States
Principal Investigator T.W. Bowersox P.R. Blankenhorn (814) 865-4700	Contract No. ET-78-G-01-3070
Work Location University Park, Pennsylvania	Period of Performance September 1, 1978 to August 30, 1979
	Obligated Fiscal Year 1978 Funding \$47,852
	Cumulative Funding thru Fiscal Year 1978 \$47,852

Project Summary

The overall objective of this project is to complete a net energy analysis for various management strategies with the ultimate goal of recommending a management strategy. Emphasis will be placed on energy farms of Populus hybrids that are applicable to the Northeastern United States.

This project will deal mainly with investigating and establishing the energy inputs for the various management strategies. The variability of each energy input will be established and the sensitivity of the energy input to the net input energy analysis will be investigated. Energy values will have to be assigned to every area for each management strategy.

Various management strategies have advantages and disadvantages. Some strategies may be very site specific, such as the use of irrigation or municipal sewage treatment plant effluent. Since each management strategy requires a different energy input, it becomes extremely important to establish baseline energy data per-year per-hectare for each treatment and level of treatment. Establishing baseline data will allow easy expansion of the data to various treatment levels. The method used in the analysis will be to establish these data using literature values and research team experience, and then to analyze different treatment levels.

Contractor and Address University of Washington College of Forest Resources Seattle, Washington 98195 and Washington State University Pullman, Washington 99163	Title Evaluation and Genetic Improvement of Black Cottonwood for Short-Rotation Coppice Culture Contract No. ET-78-G-01-3065
Principal Investigator Reinhard F. Stettler Paul Heilman (206) 543-2723	Period of Performance June 1, 1978 to May 31, 1984 Obligated Fiscal Year 1978 Funding
Work Location Seattle, Washington	\$77,445 Cumulative Funding thru Fiscal Year 1978 \$77,445

Project Summary

This study addresses two major objectives: (1) genetic improvement and (2) evaluation of quality criteria for fuel and/or chemical use of black cottonwood (Populus trichocarpa) and its hybrids with P. deltoides.

Related to genetic improvement, a six-year research program is proposed to identify superior clones derived from natural populations of black cottonwood and from hybrids produced with P. deltoides plus trees. Both clonal and seedling selection will be used to evaluate performance. Field trials will be conducted on two contrasting but common soil types and will compare early productivity of pure cottonwood energy farms and 1:1 mixtures of cottonwood with red alder (Alnus rubra). From an initial number of 340 to 430 clones to be tested, a selection of the best 10 to 20 will be included in a second set of energy farms to provide a more realistic assessment of the production potential of the species. A clone bank, preserving all 340 to 430 clones, will serve as a repository of germ plasm for subsequent field trials and research in the region.

To satisfy the second major objective, an eight-year-old spacing trial of black cottonwood will be harvested during the first year and analyzed relative to biomass and several wood properties pertinent to fuel production.

This study is a continuation of a sustained research effort on black cottonwood at both the University of Washington and Washington State University.

Contractor and Address U.S. Department of Agriculture Forest Service North Central Forest Experiment Station 1992 Folwell Avenue St. Paul, Minnesota 55108	Title Establishment of <u>Populus</u> Silvicultural Energy Farms Contract No. EG-77-A-29-1094
Principal Investigator David H. Dawson (715) 362-7474	Period of Performance June 13, 1977 to June 12, 1979 Obligated Fiscal Year 1978 Funding \$250,000
Work Location Rhineland, Wisconsin	Cumulative Funding thru Fiscal Year 1978 \$493,000

Project Summary

The U.S. Department of Agriculture Forest Service is establishing 40 acres of the genus Populus (Poplars) as test energy farms, plus several thousand acres of pilot-sized cooperative energy farms on industrial lands.

The objective of this effort is threefold:

- a. To develop propagation material and production systems for genetically improved Populus for energy plantations.
- b. To develop production methods and modified planting machinery.
- c. To determine feasible means for controlling weeds and plant pests.

Those biological factors which limit the attainment of the objectives are being researched. Five variables are being tested:

- a. Planting stock preparation (cutting storage, collection, treatment, and containers).
- b. Planting mechanics.
- c. Competition control (herbicide, cultivation, and cover crops).
- d. Fertilization.
- e. Irrigation.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-17

Contractor and Address U.S. Department of Agriculture Forest Service Southern Forest Experiment Station 2500 Shreveport Highway Pineville, Louisiana 71360	Title Construction and Field Trials of a Prototype Forestland Residue Machine (Mobile Hog) to Harvest Fuel from Forest Residues or from Energy Farms
	Contract No. EX-76-A-29-1045
Principal Investigator Peter Koch (318) 445-6511	Period of Performance October 14, 1976 to January 31, 1980
	Obligated Fiscal Year 1978 Funding \$35,000
Work Location Pineville, Louisiana	Cumulative Funding thru Fiscal Year 1978 \$235,000

Project Summary

The USDA Forest Service, Southern Forest Experiment Station, has developed a prototype machine to harvest forest residues for fuel. The objective of this project has been to manage a cooperative effort involving five forest product companies and Nicholson Equipment, a logging equipment manufacturer.

The project's principal task involved constructing the "mobile hog" forest residue machine and evaluating it at sites provided by the forest product companies.

In a typical Southern woodland, about 20 tons per acre (dry basis) of forest residue might be harvested for fuel during a 25- to 30-year rotation for pulp or saw timber. Such equipment could reduce the reliance of large segments of the forest products industry on fossil fuels. The machine could also harvest silviculture energy farms which might yield up to 6 dry tons per acre per year.

Bibliographic Reference No.: 4

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-18

Contractor and Address Emory University Biology Department Atlanta, Georgia 30322	Title Screening of Non-commercial Woody Plants as Biomass Fuel Producers
	Contract No. ET-78-G-01-3185
Principal Investigator H.L. Ragsdale J.N. Skeen (404) 329-6262	Period of Performance June 1, 1978 to March 1, 1979
	Obligated Fiscal Year 1978 Funding \$81,760
Work Location Atlanta, Georgia	Cumulative Funding thru Fiscal Year 1978 \$81,760

Project Summary

The objectives of this project are to identify and field-test woody plant species suitable for biomass fuel production on marginal Piedmont and Upper Coastal Plain soils of the Southeastern U.S.

Potential woody biomass fuel species have been identified from literature analysis by species adapted to marginal soil habitats and by species which colonize urban habitats. A list of the most promising woody biomass fuel species has been prepared from the larger list of possible species. An intensive literature analysis focusing on physiological, ecological, and other pertinent characteristics of the most promising species is in preparation. This analysis will be used to select woody species for field trials.

Field screening of woody biomass species will be conducted at a favorable Piedmont site, and at marginal sites in the Piedmont and Upper Coastal Plain. At each site, the species selected for screening will be statistically compared to species of known potential (Cottonwood and Sycamore) for growth and fuel yield to reveal the most promising woody biomass fuel species.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-19

Contractor and Address Michigan State University Department of Forestry East Lansing, Michigan 48823	Title Tree Species for Biomass Production in Northern Michigan
	Contract No. ET-78-G-01-3078
Principal Investigator James W. Hanover (517) 355-1855	Period of Performance June 1, 1978 to May 31, 1980
	Obligated Fiscal Year 1978 Funding \$75,645
Work Location East Lansing, Michigan	Cumulative Funding thru Fiscal Year 1978 \$75,645

Project Summary

The purpose of this project is to study approximately 30 tree species which may have potential for use in silvicultural energy farms in Michigan. Native and introduced species and hybrids which fit a set of criteria for rapid growth and site adaptability are included, with both conifer and hardwood species represented. Planting stock is being raised from seed or, if appropriate, cuttings. Where possible, seed has been collected from field selections of above-average phenotypes. If not available in the field, seeds have been obtained through cooperative research agreements or through commercial seed dealers.

Seedlings are being grown in greenhouse facilities under accelerated conditions to produce large planting stock within a few months. Growth is being programmed so that various species are ready for outplanting in either spring or fall of 1979. These seedlings are being grown in square containers 5 cm x 5 cm x 27 cm deep.

Trees will be planted at 10 locations in Michigan which have been or will be prepared for planting using proven mechanical and chemical techniques. Each silvicultural energy farm will consist of approximately 42 plots (replicated four times in the species trial) and a small-scale spacing study, altogether requiring approximately 2 hectares.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-20

Contractor and Address	Title
Garrett Energy Research and Engineering Co. 911 Bryant Place Ojai, California 93023	Investigation of Woody Biomass Species for Fuel Production in Warm-Climate, Non- agricultural Land Irrigated by Brackish or Saline Water
Principal Investigator	Contract No. ET-78-C-01-3077
D.E. Garrett (805) 646-0159	Period of Performance
Work Location	April 24, 1978 to April 23, 1979
Hanford, California	Obligated Fiscal Year 1978 Funding
	\$75,000
	Cumulative Funding thru Fiscal Year 1978
	\$75,000

Project Summary

Tamarisk plants (Athel Tree, Salt Cedar, etc.) are species which thrive under conditions of poor soil fertility and exposure to brackish or saline water. These species grow from clones and will coppice.

Work on this project has determined growth and production rates of four Tamarisk species under various conditions of planting, watering, fertilization, water salinity, and harvesting schedules. Results have included evaluation of best species, optimum fertilization schemes, influence of saline water, optimum growth/harvest cycles, and net energy recovery. Harvested yields have averaged 14 dry tons per acre for the first year's crop.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-21

Contractor and Address Utah State University Institute for Land Rehabilitation Logan, Utah 84322	Title Selection of High-Producing Shrubs of the Western United States for Energy Biomass Production
	Contract No. ET-78-G-01-3076
Principal Investigator Cyrus M. McKell (801) 752-4100	Period of Performance April 1, 1978 to September 30, 1982
	Obligated Fiscal Year 1978 Funding \$84,673
Work Location Logan, Utah and Nephi Field Station (outside Nephi, Utah)	Cumulative Funding thru Fiscal Year 1978 \$84,673

Project Summary

The objectives of this contract are to select large biotypes from shrub populations in the arid intermontane West, measure their productivity under natural conditions, propagate the selected biotypes, and plant their progeny on a dryland research station for growth and yield comparison as biomass for energy under low-cost cultural treatments.

Indigenous locations of these shrubs are being determined. Actual plant measurements and ecological data are being obtained at each site along with plant samples for laboratory analysis. Propagation material such as wildlings, cuttings, and seeds are being/will be obtained depending on availability and season. Two visits to some sites may be necessary to obtain the necessary propagation material. Wildlings, cuttings, or germinated seeds will be grown during winter in a greenhouse prior to field planting in early spring of 1979.

Adaptation and growth comparisons of the various species and biotypes will be made following field planting; necessary cultural and management practices will be carried out.

Desired results will be dependent upon plant growth of the various biotypes and how they respond when removed from their natural habitat and planted in a uniform comparison nursery.

ELEMENT: Production Sysms

SUB-ELEMENT: Silviculture

D-22

Contractor and Address University of Massachusetts Amherst, Massachusetts 01003	Title Assessment of Tree-Harvesting Machinery for Non-commercial Timber
	Contract No. ET-78-S-01-3143
Principal Investigator F.R. Erskine Crossley (413) 545-0111	Period of Performance July 27, 1978 to July 26, 1980
	Obligated Fiscal Year 1978 Funding \$62,168
Work Location Amherst, Massachusetts	Cumulative Funding thru Fiscal Year 1978 \$62,168

Project Summary

The objective of this project is to make a comparative evaluation of current commercially available harvesting systems, both U.S. and foreign. Special consideration is being given to their suitability for thinning dense unmanaged hardwoods on hilly terrain such as in central New England.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-23

Contractor and Address University of Houston 4800 Calhoun Blvd. Houston, Texas 77004	Title Cultural and Management Practices for the Chinese Tallow Tree as a Biomass Fuel Source
	Contract No. ET-78-G-01-3037
Principal Investigator Joe R. Cowles H.W. Scheld (713) 749-3135	Period of Performance May 1, 1978 to April 30, 1979
	Obligated Fiscal Year 1978 Funding \$38,308
Work Location Hitchcock, Texas	Cumulative Funding thru Fiscal Year 1978 \$38,308

Project Summary

The objectives of this project are to assess the biomass accumulation potential of the Chinese tallow tree and to determine the cultural and management practices required to optimize biomass production.

Experimental plots have been established at the University of Houston Coastal Center to determine the growth response of the Chinese tallow tree (Sapium sebiferum) to different cultural and management practices. The tallow tree, an introduced species, grows vigorously in the Gulf Coastal Region where there is a long growing season and ample rainfall. The trees, in addition to having high growth rates, are easily maintained in pure stands, are resistant to pathogens and insects, and are tolerant of saline soils.

Basically, two types of experimental plots have been initiated: one within existing tallow stands and another within newly established stands in a seasonally wet prairie. Eighteen plots in existing stands are designed to study the effect of stand release and coppicing on biomass accumulation. Eighteen plots established in the open prairie are designed to study the effect of spacing, fertilization, and irrigation on biomass accumulation. Experimental plots also have been established to compare the growth rates of clonal plantings from individual trees selected from the Coastal Center population.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-24

Contractor and Address University of Vermont and State Agricultural College Burlington, Vermont 05405	Title The Production of Biomass for Energy on Abandoned Farmlands in the Northeast
	Contract No. ET-78-G-01-3075
Principal Investigator Frederick M. Laing (802) 656-2930	Period of Performance May 1, 1978 to April 30, 1979
	Obligated Fiscal Year 1978 Funding \$67,578
Work Location Burlington, Vermont	Cumulative Funding thru Fiscal Year 1978 \$67,578

Project Summary

The potential of native, and introduced, successional tree and shrub species for the production of biomass for energy will be evaluated. Abandoned agricultural lands presently reverting to woodlands will be used for mini-rotation management of coppices. Energy- and cost-efficient methods of harvesting, transporting, and storing the wood fiber product will be analyzed. Pelletizing and similar pretreatment of the product to provide better handling, storage, and fuel characteristics will be evaluated. Economic analyses of each of the possible combinations of methods will be made.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-25

Contractor and Address The MITRE Corporation Metrek Division 1820 Dolley Madison Boulevard McLean, Virginia 22101	Title Structuring Pilot Silvicultural Biomass Farm Development
	Contract No. EG-77-C-01-4101
Principal Investigator Martin M. Scholl Jean Henry (Consultant) David Salo (deceased 3/4/79) (703) 827-7192	Period of Performance August 8, 1977 to September 8, 1978
	Obligated Fiscal Year 1978 Funding \$141,830
Work Location McLean, Virginia	Cumulative Funding thru Fiscal Year 1978 \$141,830

Project Summary

DOE is planning to establish a Pilot Silvicultural Biomass Farm (PSBF) at the Savannah River Plant (SRP) near Aiken, South Carolina. The PSBF will enable DOE to estimate the potential of silvicultural energy farms, develop and refine energy crop management practices, evaluate and test specialized equipment, and conduct associated research studies to improve energy farming practices. The plan developed by MITRE includes discussions of site selection, layout and design, and capital and operating costs for two sites on the tract.

The target date for the first planting is February 1, 1981. At that time one module (about one-sixth of the farm) will be planted. The other modules will be planted in succession at one year intervals. Trees will be planted at a density of 2,725 trees per acre, in a 2 ft. by 8 ft. pattern. Tree species selected for planting include sycamore (Plantanus occidentalis), European alder (Alnus glutinosa), and slash pine (Pinus elliottii).

It is expected that yields will approach 8 oven-dry tons per year and that trees will be harvested in 6-year rotations. Harvesting will be performed by a new machine expected to be developed by DOE. The PSBF, therefore, will provide the opportunity to field test this equipment on a significant scale.

Bibliographic Reference No.: 32

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-26

Contractor and Address The MITRE Corporation Metrek Division 1820 Dolley Madison Boulevard McLean, Virginia 22101	Title Near-Term Use of Wood as a Fuel Contract No. EG-77-C-01-4101
Principal Investigator David Salo (deceased 3/4/79) Abu Talib (703) 827-7192	Period of Performance June 1, 1978 to May 31, 1979 Obligated Fiscal Year 1978 Funding
Work Location McLean, Virginia	\$70,500 Cumulative Funding thru Fiscal Year 1978 \$70,500

Project Summary

Two studies are to be conducted to compare commercially available technologies for converting wood into usable forms of energy. The processes being compared include direct combustion, gasification, pyrolysis, and densification.

The first study describes the technologies and estimated costs which can expand the use of wood residues and standing forests. Regional availability of wood supplies is compared and the costs of conversion products are computed. Possible near-term incentives to encourage the use of wood for energy are evaluated, including retirements and investment tax credits. A list of industries selling industrial wood energy equipment is included in the report, "Near-Term Potential of Wood as a Fuel," which resulted from this study.

A subsequent study will elaborate on the market readiness of gasification, pyrolysis, and densification technologies. A report, expected to be published in June 1979, will include a review of low- and medium-Btu gas-producing systems which are operating. These systems range from bench-scale to commercial-scale units with background, process descriptions, schematics, and economic data. The study will address the status of wood densification and will describe a pellet mill manufacturer, a wood pellet producer, and a pellet fuel user. The report will present conclusions and make recommendations regarding technological status, generic process comparisons, and issues associated with further evaluation and development efforts.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-27

Contractor and Address U.S. Department of Agriculture Forest Service Southeastern Forest Experiment Station P.O. Box 2570 Asheville, North Carolina 28802	Title Fuel Farm Research (Chemically Induced Oleoresin as a Petrochemical Substitute) Contract No. EY-76-A-09-0903
Principal Investigator Jack Stubbs (803) 450-3628	Period of Performance October 10, 1975 to September 30, 1979
Work Location Aiken, South Carolina	Obligated Fiscal Year 1978 Funding Solar Energy : \$216,000 DBER* : \$ 75,000 Cumulative Funding thru Fiscal Year 1978 Solar Energy : \$336,000 DBER* : \$548,100

Project Summary

The objective of this project is to develop optimum treatment techniques for lightwood production (resin-soaking) in southern pines in order to increase oleoresin yields and Btu content, reduce costs and insect hazards, and enable induced lightwood technology to come into commercial use as rapidly and efficiently as possible.

A research program consisting of two elements is being conducted at DOE's Savannah River Plant in Aiken, South Carolina. Program element I involves Proof-of-Concept Experimentation. By using current research information, the feasibility of producing and processing chemically induced lightwood on a commercial scale is being ascertained. For these large-scale studies, data is gathered both from woodlands operations and actual production runs in pulp mills. Goals include (1) the determination of oleoresin yield, degree of insect pest protection required, and costs in dollars and energy; and (2) the solving of technical problems both in woodland and plant operations. It is expected that this approach will stimulate industry toward rapid application of existing lightwood technology.

Program element II is concerned with (1) exploratory research to test new ideas in lightwood technology and (2) studies covering a range of biological and environmental factors that complement the work of program element I.

* Division of Biological and Environmental Research

Bibliographic Reference No.: 6

ELEMENT: Production Systems

UB-ELEMENT: Silviculture

D-28

Contractor and Address University of Georgia School of Forest Resources Athens, Georgia 30602	Title Biomass Production of Short- Rotation Coppice Forests
	Contract No. EG-77-S-09-1015
Principal Investigator Klaus Steinbeck Claud Brown (404) 542-1376	Period of Performance October 1, 1977 to September 30, 1978
	Obligated Fiscal Year 1978 Funding \$314,630
Work Location Piedmont and Coastal Plains Province	Cumulative Funding thru Fiscal Year 1978 \$314,630

Project Summary

The objective of this study has been to evaluate the potential of sycamore, sweetgum, alder, and other hardwoods for high-yield renewable energy sources. To achieve this objective the following approaches have been undertaken:

- a. Two 50-acre plantations have been established to test pure and mixed plots of the above species using appropriate cultural techniques, fertilizer, and irrigation.
- b. Cloning techniques have been developed whereby superior sycamore and other hardwood strains can be mass-produced rapidly in the laboratory through pure cultures derived from single or multiple cells on solid or in liquid media; the ultimate aim is to obtain better strains for forest plantings.
- c. Efforts have been made (1) to develop techniques to identify hardwoods with the potentials for superior growth from nursery, plantation, and natural populations; and (2) to concentrate these in areas for future evaluation and multiplication.

Additional benefits can be expected from information on the advantages of mixed hardwood cultures as opposed to monocultures in the maintenance of soil productivity, better wildlife habitat, and the possible opportunities for economic returns that short rotation hardwood culture offers to farmers and landowners.

Bibliographic Reference No.: 1

Contractor and Address University of Minnesota Soil Science Department Minneapolis, Minnesota	Title Use of Wetlands for Production of Woody Plants for Fuels and Petrochemical Substitutes Contract No. ET-78-G-01-3082
Principal Investigator Rouse S. Farnham (612) 373-2851	Period of Performance June 1, 1978 to May 31, 1983
Work Location St. Paul, Minnesota	Obligated Fiscal Year 1978 Funding \$64,343 Cumulative Funding thru Fiscal Year 1978 \$64,343

Project Summary

The primary concern of this project is the selection of suitable woody plant species on wetland soils, especially underdeveloped peat lands.

An inventory of potential wetland sites in Minnesota for locating research plots containing native non-commercial woody plant species was the first task completed for this study.

Criteria were established for stand selection, including a minimum area requirement, accessibility of the stand, dominant vegetation types, and location on public (state or county) lands if possible. To date, 37 stands (plots) were selected for biomass analyses. These are located in 15 Minnesota counties on both organic and mineral wetland soils.

Vegetation sampling of woody species was conducted:

- a. Wetland areas containing suitable stands of alder (*Alnus rugosa*), willows (*Salix* species), bog birch (*Betula pumila*), dogwood (*Cornus stolonifera*), and *Spirea* species were selected.
- b. A plant count and diameter measurements were made on 10 randomly selected milacre plots for quantifying standing crop biomass. Species (composition), diameter at 15 cm height, and amount of living and dead vegetation were recorded.
- c. Plants were clipped at ground level according to several size classes.
- d. A basal disc was cut from each stem within each plot and dried. (These are to be used for age determinations and measuring annual growth rate.)

Eventually growth and statistical yield data will be correlated with site conditions such as soil chemistry, hydrology, and nutrient status.

Contractor and Address University of Florida School of Forest Resources and Conservation Institute of Food and Agricultural Sciences Gainesville, Florida 32611	Title Energy from Woody Species in Florida Contract No. ET-78-G-01-3040
Principal Investigator W.H. Smith (904) 392-1792	Period of Performance April 17, 1978 to April 16, 1979 Obligated Fiscal Year 1978 Funding \$98,082
Work Location Gainesville, Florida	Cumulative Funding thru Fiscal Year 1978 \$98,082

Project Summary

The purpose of this project is to assess the potential for sustained production of biomass by several woody species in Florida. Land availability and productivity are being assessed. Field trials are being designed to evaluate effects of site preparation, fertilization, and cropping components of cultural treatments. Site effects of biomass farming on water use and nutrient conservation will be evaluated. Rotation age and energy input/output efficiencies will also be evaluated.

Computer software packages have been developed to (1) digitize and store the U.S. Geological Survey map data on land use, forest soil potential, soil associations, Federal lands, and State lands; (2) interface the stored data with the Northeast Regional Data Center's main computing facilities to generate tape files by counties; and (3) display stored data in map format.

Genetic selection activities have concentrated on sand pine, slash pine, and Melaleuca. Sixty Chocawhatchee sand pine progenies have been sampled for biomass production, and comparative results will be used for progeny selection. Intensive culture studies with slash pine have been reviewed to identify progenies suitable for biomass farms.

Determinations of moisture content, specific gravity, and higher heat values (Btu/lb) of various above-ground components have been made for Melaleuca quinquenervia and Eucalyptus grandis. The 400 or more calorimetric burns made to date indicate that the wood heat values of these species are similar (8,200 to 8,700 Btu/lb) and typical of domestic hardwoods. Heat values for Melaleuca bark were much higher (11,500 Btu/lb), while Eucalyptus bark was distinctly lower in heat value (700 Btu/lb). Foliage heat values were relatively high: 8,900 Btu/lb for Melaleuca and 9,300 Btu/lb for Eucalyptus.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-30

Contractor and Address University of Florida School of Forest Resources and Conservation Institute of Food and Agricultural Sciences Gainesville, Florida 32611	Title Energy from Woody Species in Florida
	Contract No. ET-78-G-01-3040
Principal Investigator W.H. Smith (904) 392-1792	Period of Performance April 17, 1978 to April 16, 1979
	Obligated Fiscal Year 1978 Funding \$98,082
Work Location Gainesville, Florida	Cumulative Funding thru Fiscal Year 1978 \$98,082

Project Summary (continued)

Stands of sand pine and Melaleuca have been sampled in an attempt to establish preliminary regression equation for small trees at close spacing. Three planted sand pine stands have been sampled. Preliminary analysis indicates that total above-ground dry weight yield ranges from 12.8 metric tons/hectare/year (mT/ha/yr) to 8.8 mT/ha/yr.

Since there are no young plantations of closely spaced Melaleuca, an attempt has been made to locate stands which approximate plantations. Preliminary data indicate a total above-ground dry weight yield of 13.9 mT/ha/yr to 17 mT/ha/yr.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-31

Contractor and Address SRI International 333 Ravenswood Avenue Menlo Park, California 94025	Title Land and Water Availability for Energy Farming
	Contract No. ET-78-C-01-3142
Principal Investigator Fred A. Schooley (415) 326-6200	Period of Performance October 1978 to October 1979
	Obligated Fiscal Year 1978 Funding \$163,120
Work Location Menlo Park, California and 10 selected U.S. areas	Cumulative Funding thru Fiscal Year 1978 \$163,120

Project Summary

The purpose of this study is to assist DOE in determining the physical and economic availability of land and water resources for energy farming. The overall objective will be to rank selected water areas possessing favorable land and water availabilities according to their overall potential for biomass production. To accomplish this objective, SRI International (formerly Stanford Research Institute) will perform the following tasks:

- Evaluate the current water availability in each of the 99 continental U.S. water sub-basins.
- Project water demands in each sub-basin and determine how water use competition may affect the amount of water available for energy farms.
- Determine the availability of U.S. land resources for biomass farming based upon the regional cost of crop production and the projected return to the farmer.
- Rank selected areas (within sub-basins of favorable land and water availability) according to their overall potential for biomass production.

The result of this work will be a consistent and comprehensive analysis of water resources as well as a systematic comparison of the potential and economic viability of alternative energy farm sub-basin locations. The final report will include appropriate research and development program recommendations for DOE's Biomass Energy Systems Program.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-32

Contractor and Address Oak Ridge National Laboratory P.O. Box X Oak Ridge, Tennessee 37830	Title Management Support to the Fuels from Woody Biomass Program
	Contract No. W-7405-ENG-26
Principal Investigator R.I. Van Hook (615) 483-8611 x1414	Period of Performance October 1, 1977 to September 30, 1978
	Obligated Fiscal Year 1978 Funding \$150,000
Work Location Oak Ridge, Tennessee	Cumulative Funding thru Fiscal Year 1978 \$150,000

Project Summary

The objective of this project has been to assist and advise DOE's Biomass Energy Systems Branch in the development, management, and program administration of a comprehensive research effort to improve the productivity and cost efficiency of growing and harvesting woody plants for fuels. Included in this effort has been the development of a data base necessary to evaluate the future contribution of wood to the U.S. energy supply.

Contractor and Address Mathtech Inc. P.O. Box 2392 Princeton, New Jersey 08540	Title Harvesting of Close-Spaced Short-Rotation Woody Biomass
Principal Investigator William J. Barr (606) 966-2600	Contract No. ET-78-C-01-3068
Work Location Princeton, New Jersey	Period of Performance April 21, 1978 to April 20, 1979
	Obligated Fiscal Year 1978 Funding \$78,551
	Cumulative Funding thru Fiscal Year 1978 \$78,551

Project Summary

The major purpose of this study is to evaluate alternative strategies and techniques of harvesting, collecting, transporting, and storing which appear to be commercially viable for use on closely spaced, short-rotation woody biomass energy farms where coppicing is used. Factors being evaluated include products and processes, farm sites, species of woody biomass selected, treatment and management of the stand, and equipment available for harvesting, collecting, and transporting the wood.

Conventional and innovative methods of harvesting, collecting, transporting, and storing young hardwoods are being considered; particular emphasis is being placed on evaluating their energy-consumption characteristics. Modeling of alternate harvesting techniques will be applied to determine the effectiveness of various harvesting systems.

Data has been obtained on some existing stands of young close-spaced sycamores which have been fertilized and cultivated in southeastern Virginia. Information relative to growth, coppicing, type of terrain, and soil characteristics has been secured. Performance data and machine characteristics are being obtained on forest products equipment and agricultural harvesting equipment as well as on some modified machines that were constructed for tests conducted by early investigators in this field. Preliminary results indicate that agricultural harvesting equipment, rather than those designed for forest applications, appears to be more applicable for stands of diameters less than 10 centimeters.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-34

Contractor and Address Seattle City Light Office of Environmental Affairs 1015 Third Avenue Seattle, Washington 98104	Title Cultural Treatment of Selected Species for Woody Biomass Production in the Pacific Northwest
	Contract No. ET-78-G-01-4126
Principal Investigator Carol S. Harlow - Project Manager Chadwick Oliver - Principal Investigator (206) 625-3109	Period of Performance August 1, 1978 to July 31, 1979
	Obligated Fiscal Year 1978 Funding \$149,949
Work Location Seattle, Washington	Cumulative Funding thru Fiscal Year 1978 \$149,949

Project Summary

This project covers the first year of a proposed 5-year effort. During the 5-year period, three tasks will be required:

- a. Evaluating the performance of red alder and black cottonwood in short-rotation (1- to 4-year) energy farms with different cultural treatments and on different soils. (The cultural treatments will involve variations in spacing, rotation length, species mixture, irrigation, fertilization, and cultivation.)
- b. Evaluating the woody biomass obtainable in total and in component parts for these variations and combinations of cultural treatments to enable later analysis of the commercial feasibility of biomass farming for energy production.
- c. Suggesting modifications of cultural techniques and areas for further refinement of cultural practices.

Study plots have been established beneath electric powerlines in the municipal Cedar River Watershed. The area will be fenced to eliminate deer and elk browse. Red alder seedlings and black cottonwood cuttings will be planted in the spring of 1979 after stumps have been removed.

ELEMENT: Production Systems

SUB-ELEMENT: Silviculture

D-35

Instructor and Address University of California Department of Soil and Environmental Sciences Riverside, California 92521	Title Collection, Propagation, and Evaluation of <u>Prosopis</u> Species for Growth Rate Under Controlled Moisture and Nitrogen Treatments
	Contract No. ET-78-G-01-3074
Principal Investigator Peter Felker (714) 787-1012	Period of Performance April 1, 1978 to March 30, 1980
	Obligated Fiscal Year 1978 Funding \$90,053
Work Location Riverside, California	Cumulative Funding thru Fiscal Year 1978 \$90,053

Project Summary

Mesquite (Prosopis) occurs naturally on 72 million acres in the Southwestern U.S.A. Because of the poor soil fertility and lack of rainfall in the Southwest, mesquite is a good candidate for biomass production: it is heat and drought tolerant and it fixes its own nitrogen.

A mesquite germ plasm acquisition program is underway which has obtained over 300 Prosopis selections representing genetic material from North America, South America, and Africa. Thirty-two of these acquisitions are being field tested for growth rate under three moisture stress treatments at the University of California, Riverside, Agricultural Experiment Station.

Vegetative propagation techniques for mesquite are also being worked out to overcome the threefold to fourfold differences in growth rates from the same seed tree and to enable propagation of promising selections prior to fruiting.

Thus far several mesquite cuttings have been successfully rooted, and an estimated tenfold difference in biomass productivity between acquisitions has been observed.

ELEMENT: Production Systems

SUB-ELEMENT: Herbaceous

E-1

Contractor and Address University of Puerto Rico G.P.O. Box 4984-G San Juan, Puerto Rico 00936	Title Production of Sugarcane and Tropical Grasses as a Renewable Energy Source
	Contract No. ET-78-S-05-5912
Principal Investigator Alex G. Alexander (809) 472-6620	Period of Performance June 1, 1977 to May 31, 1979
	Obligated Fiscal Year 1978 Funding \$166,568
Work Location Rio Piedras, Puerto Rico	Cumulative Funding thru Fiscal Year 1978 \$463,488

Project Summary

The primary objective of this program is twofold:

- a. To determine the agronomic and economic feasibility of mechanized, year-round production of solar-dried biomass through the intensive production of sugarcane and napier grass as tropical forages.
- b. To examine alternate tropical grasses as potential sources for intensive biomass production.

The secondary objective consists of engaging in the selection and breeding of new Saccharum progeny having superior biomass productivity as their principal attribute.

Greenhouse experiments designed to screen candidate clones and to evaluate growth curves were the first to be conducted. Chemical growth control tests have also been initiated. Field studies on test plots are evaluating the variables of row spacing, fertilization, and irrigation, as well as the effect of harvest frequency on yield. Candidate grasses include short-, intermediate-, and long-rotation species for co-production with food crops. Minimum-tillage candidates are also being sought for extensive production on marginal lands. Production targets for intensively propagated species are 40 dry tons per acre per year at a cost of \$22 per ton. Field-scale studies on mechanized production and harvest operations began during fiscal 1978.

Bibliographic Reference No.: 9

ELEMENT: Production Systems

SUB-ELEMENT: Herbaceous

E-2

Contractor and Address Arthur D. Little, Inc. Acorn Park Cambridge, Massachusetts 02174	Title Herbaceous Species Screening Program (Phase I)
	Contract No. ET-78-C-02-5035
Principal Investigator Ms. Kathryn Saterson Dr. Robert E. Lee (617) 864-5770	Period of Performance October 1978 to April 1979
	Obligated Fiscal Year 1978 Funding \$123,531
Work Location Cambridge, Massachusetts	Cumulative Funding thru Fiscal Year 1978 \$123,531

Project Summary

The objective of this program is to screen previously unexploited, terrestrial annual and perennial herbaceous plants in order to identify those with the greatest potential for use on energy farms. The six-month Phase I screening will recommend approximately 15 species in each of the six regions in the U.S. where field screening should be conducted in the three- to five-year Phase II effort.

Specific Phase I tasks include a literature review and the delineation of approximately six regions where field screening should be conducted. Recommended species will be evaluated on the basis of potential yield, growth requirements, sensitivity to environmental factors, pathogen susceptibility, Btu content, and economic feasibility. Species will be considered for whole-plant productivity.

Phase II will entail the screening of approximately 15 to 20 species and/or varieties in each region (five sites per region) for two to five growing seasons. Field screening will include regular measurements for survival, height, green and dry weights, and Btu content. The objective of Phase II will be to recommend the most promising species for future research and development.

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CONVERSION SYSTEMS

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ELEMENT: Conversion Systems

SUB-ELEMENT: Anaerobic Digestion

F-1

Contractor and Address University of Illinois Department of Civil Engineering Urbana, Illinois 61801	Title Biological Conversion of Biomass to Methane
	Contract No. EY-76-S-02-2917
Principal Investigator John T. Pfeffer (217) 333-1000	Period of Performance August 1, 1977 to July 31, 1979
	Obligated Fiscal Year 1978 Funding \$235,000
Work Location Urbana, Illinois	Cumulative Funding thru Fiscal Year 1978 \$710,000

Project Summary

Research has shown that the biological conversion of organic refuse to methane is a technically feasible process. The objective of this project is to obtain experimental data on conversion efficiency to predict the cost of gas production.

An experimental system consisting of four completely mixed heated fermentation tanks was constructed and began operating in 1976. Beef feedlot manure was selected as the initial substrate. This work has been completed and a report issued. Corn stover has been evaluated as a feed stock for this system also. Additional studies are currently underway using wheat straw as a substrate.

Current project tasks include evaluating the methane yield as a function of the following factors:

- a. Plant species and fiber composition.
- b. Thermochemical pretreatment.
- c. Mesophilic and thermophilic temperature.
- d. Liquid recycle.
- e. Residence time.

Residues from the fermenter will also be evaluated to determine fiber composition, plant nutrient content, and slurry dewatering characteristics. A simple simulation model of the fermentation, residue processing, and disposal systems will be constructed to help determine optimum operating and design parameters for the substrate being tested.

Bibliographic Reference No.: 18

ELEMENT: Conversion Systems

SUB-ELEMENT: Anaerobic Digestion

F-2

Contractor and Address Dynatech R/D Company Division of Dynatech Corporation 99 Erie St. Cambridge, Massachusetts 02139	Title Engineering Evaluation of Programs in the Area of Methane from Residues/ Biomass
	Contract No. ET-78-C-02-5099
Principal Investigator Donald L. Wise R.L. Wentworth (617) 868-8050	Period of Performance May 17, 1978 to June 30, 1979
	Obligated Fiscal Year 1978 Funding \$155,266
Work Location Cambridge, Massachusetts	Cumulative Funding thru Fiscal Year 1978 \$155,266

Project Summary

The objective of this program is to perform technical engineering evaluation and coordination for DOE's Biomass Energy Systems Program in the areas of methane from residues/biomass.

To achieve this goal, the following tasks are required:

- a. Arrange quarterly meetings for review of progress and exchange of information by contractors active in this area.
- b. Hold meetings at contractors' sites in order to permit inspection of experimental facilities.
- c. Prepare summaries of contract status in bound report form following these meetings.
- d. Monitor overall program progress through visits to contractors and review of their formal reports.
- e. Prepare a comprehensive report dealing with the design and economics of facilities for generation of fuel gas from animal residues.

ELEMENT: Conversion Systems

SUB-ELEMENT: Fermentation

G-1

Contractor and Address Purdue University West Lafayette, Indiana 47907	Title Selective Solvent Extraction in Utilization of Stored Solar Energy in Cellulosic Biomass
	Contract No. ET-78-S-02-4658
Principal Investigator George T. Tsao (317) 749-2591	Period of Performance January 1, 1978 to December 31, 1978
	Obligated Fiscal Year 1978 Funding \$218,877
Work Location West Lafayette, Indiana	Cumulative Funding thru Fiscal Year 1978 \$218,877

Project Summary

The dissolution, re-precipitation, and hydrolysis of cellulose are major research subjects of this project. Work involves the use of selective solvent extraction in the fractionation of three major components (i.e., cellulose, hemicellulose, and lignin) from cellulosic wastes. Once cellulose is dissolved in a solution, it is no longer protected by its lignin seal nor its highly ordered crystalline structure against hydrolysis. Re-precipitated cellulose, from the solution before recrystallization takes place, can be easily hydrolyzed with acids or enzymes to give quantitative yields of glucose.

The economics of this method of cellulose hydrolysis depend upon the success in developing an efficient method of solvent recycle. Thus, an extensive research program is proposed for investigating techniques of solvent recovery. At this point, there is no foreseen insurmountable difficulty in recycling the solvent. A complete process of fractionation and utilization of cellulosic wastes will be ready for large-scale demonstration at the end of this two-year project.

ELEMENT: Conversion Systems

SUB-ELEMENT: Fermentation

G-2

Contractor and Address Dartmouth College Thayer School of Engineering Hanover, New Hampshire 03755	Title Acid Hydrolysis of Concentrated Slurries of Cellulosic Biomass
	Contract No. EG-77-S-01-4061
Principal Investigator Hans E. Grethlein (603) 646-2239	Period of Performance September 26, 1977 to September 30, 1979
	Obligated Fiscal Year 1978 Funding \$109,243
Work Location Hanover, New Hampshire	Cumulative Funding thru Fiscal Year 1978 \$207,400

Project Summary

The objective of this investigation is to obtain the kinetic and engineering design data in the economic region of the design space to evaluate the potential of acid hydrolysis of cellulosic biomass.

A bench-scale continuous plug flow reactor has been constructed which is operated at isothermal conditions over a range of 200° to 240°C, at residence times of about 0.2 minutes, and at acid concentrations of 0 to 2.0 percent. The kinetic information on various substrates will be fit to a model which will be used to find the optimum process conditions.

The results to date show that wood-derived products such as Solka Floc and newsprint have the same kinetic parameters over a slurry concentration from 5 percent to 13.5 percent. Demonstrated glucose yields of 52 percent have been obtained on repeated experiments. The hydrolysis of corn stover shows a different set of kinetic parameters, but can achieve a 50 percent yield also. Process economic calculations show that for a 50 percent yield or greater, the process comes into economic range at 10 percent slurry concentration or higher. Thus, some of the results are in the region of economic interest. Work is underway to obtain data at slurry concentrations in the range of 10 to 20 percent on a number of substrates and particle sizes. By-product formation and hemicellulose hydrolysis are being determined also.

ELEMENT: Conversion Systems

SUB-ELEMENT: Fermentation

G-3

Contractor and Address University of California Lawrence Berkeley Laboratory Building 38 Berkeley, California 94720	Title Process Development Studies on the Bioconversion of Cellulose and Production of Ethanol
	Contract No. W-7405-ENG-48
Principal Investigator Charles R. Wilke Harvey W. Blanch (415) 642-1387	Period of Performance 1974 to September 30, 1978
	Obligated Fiscal Year 1978 Funding \$160,000
Work Location Berkeley, California	Cumulative Funding thru Fiscal Year 1978 \$838,000

Project Summary

This research program is directed toward the conversion of the carbohydrate content of cellulosic materials to ethanol and other energy-bearing products. As the product of photosynthesis, carbohydrates may be viewed as a form of stored solar energy. Vast quantities of cellulose are available in the form of whole trees, and agricultural and domestic wastes. Additional supplies could be specifically grown to provide biomass for conversion. DOE's Biomass Energy Systems Program has concentrated on the hydrolysis of cellulose to sugars and the subsequent fermentation of these sugars to ethanol, a potential liquid transportation fuel.

This project's process development studies and pilot plant studies have been concerned with various processing schemes for the optimal economic production of ethanol. These studies will result in the continued refinement of the overall Lawrence Berkeley Laboratory processing concept.

Bibliographic Reference No.: 22

ELEMENT: Conversion Systems

SUB-ELEMENT: Fermentation

G-4

Contractor and Address Rensselaer Polytechnic Institute Department of Chemical and Environmental Engineering Troy, New York 12181	Title Coordination of Fermentation Contractors
	Contract No. ET-78-G-01-3018 (Formerly EG-77-G-01-4001)
Principal Investigator Henry R. Bungay III (518) 270-6376	Period of Performance December 28, 1978 to February 28, 1979
	Obligated Fiscal Year 1978 Funding \$103,300
Work Location Troy, New York	Cumulative Funding thru Fiscal Year 1978 \$179,800

Project Summary

This project deals with coordination, analysis, reporting, and planning of research on fermentation of biomass to produce fuels and petrochemical substitutes.

Bibliographic Reference No.: 25

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Gasification

H-1

Contractor and Address Catalytica Associates, Inc. 3255 Scott Boulevard Suite 7-E Santa Clara, California 95051	Title Catalytic Conversion of Biomass to Fuels and Chemicals Contract No. ET-78-C-03-1883
Principal Investigator Robert L. Carten (408) 243-9243	Period of Performance September 15, 1978 to September 14, 1979
Work Location Santa Clara, California	Obligated Fiscal Year 1978 Funding \$124,850
	Cumulative Funding thru Fiscal Year 1978 \$124,850

Project Summary

The objective of this study is to determine the most cost-effective biomass-to-fuels thermochemical conversion technologies which should be developed in future R&D efforts. Of the possible thermochemical conversion routes — direct combustion, gasification, and liquefaction — only the latter two will be considered.

To achieve the objective, the following activities will be conducted:

- a. Chemical and engineering aspects of existing and emerging technologies for thermochemical production of synthetic fuels from biomass and from coal will be reviewed.
- b. Key technical limitations in the various technologies will be identified.
- c. The practicality of applying synthetic fuels technology for coal to biomass will be discussed, drawing on a comparison of the physical and chemical properties of biomass relative to coal. This discussion will include an assessment of the advantages and disadvantages of biomass in coal conversion technologies and identification of the technical limitations in utilizing biomass as a feedstock in the coal processes.
- d. New developments in catalysis and reactor engineering which could impact on future R&D efforts in converting biomass to fuels will be assessed.
- e. Recommendations regarding the most promising technologies for reducing production costs will be presented.

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Gasification

H-2

Contractor and Address Texas Tech University Lubbock, Texas 79409	Title Application of SGFM Technology to Other Feedstocks (Phase II)
	Contract No. EY-76-S-04-3779
Principal Investigator Steven R. Beck (806) 742-3553	Period of Performance September 1, 1977 to August 31, 1979
	Obligated Fiscal Year 1978 Funding \$160,000
Work Location Lubbock, Texas	Cumulative Funding thru Fiscal Year 1978 \$296,000

Project Summary

A counter-current pyrolysis reactor for producing synthesis gas from manure (SGFM) has been invented which allows volatile organic compounds to escape from the heating zone very rapidly. This results in a different product mix than has been observed in other pyrolysis research, containing unusually high concentrations of ethylene. Fuel values of gases plus the sparing of petroleum needs by ethylene, if economically feasible, would supplement petroleum supplies.

This project entails conducting studies in an existing 1/2 ton/day test reactor, utilizing animal manures and other biomass materials as feedstocks, to determine the influence of temperature, residence time, pressure, and feedstock materials on the yield and quality of the process. These studies include the effects of reactor geometry and solid/gas contact in cold models. Relationships for the design of a staged reactor will be developed.

Bibliographic Reference No.: 29

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Gasification

H-3

Contractor and Address Battelle Pacific Northwest Laboratories P.O. Box 999 Richland, Washington 99352	Title Investigation of Gasification of Biomass in the Presence of Catalysts
	Contract No. EY-76-C-06-1830
Principal Investigator Lyle K. Mudge L. John Sealock, Jr. Robert J. Robertus (509) 946-2432	Period of Performance December 1, 1977 to November 30, 1979
	Obligated Fiscal Year 1978 Funding \$490,000
Work Location Richland, Washington	Cumulative Funding thru Fiscal Year 1978 \$490,000

Project Summary

This project entails conducting studies to determine the technical and economic feasibility of catalyzed biomass gasification to produce specific products: (1) methane; (2) hydrogen; (3) carbon monoxide; and (4) synthesis gas for generation of ammonia, methanol, or hydrocarbons. The biomass materials being studied consist of wood chips and bark.

Three project tasks have been initiated to accomplish program objectives: (1) laboratory studies; (2) process development unit (PDU) design, procurement, and installation; and (3) PDU operation. Laboratory studies have evaluated gasification catalyst contacting methods, gasification catalyst activities, and the effect of biomass composition. A 0.6 dry tons per day wood gasification system has been designed, procured, and installed. Equipment checkout is underway, and initial gasification runs will follow.

Future work areas include operation of the PDU and determination of technical and economic feasibility. Two types of studies are being conducted:

- a. Studies of combined catalyst systems for the production of CH₄, H₂, CO, ammonia, and hydrocarbon synthesis gas.
- b. Studies to evaluate catalyst recovery, regeneration, and recycling of both gasification and secondary catalysts.

Bibliographic Reference No.: 27

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Gasification

H-4

Contractor and Address Battelle Columbus Laboratories 505 King Avenue Columbus, Ohio 43201	Title Conversion of Forest Residues to a Methane-Rich Gas
	Contract No. W-7405-ENG-92
Principal Investigator Herman F. Feldmann (614) 424-4734	Period of Performance August 1, 1977 to September 30, 1978
	Obligated Fiscal Year 1978 Funding \$416,000
Work Location Columbus, Ohio	Cumulative Funding thru Fiscal Year 1978 \$611,260

Project Summary

The purpose of this project was to evaluate several potential catalytic systems for wood gasification in the bench-scale reactor systems. Of all the catalytic materials tested, wood ash was found to be the best candidate for further evaluation.

A multisolid gasification reactor concept was successfully applied to wood residues. This concept was tested by injecting wood chips into a fluidized bed of coarse alumina particles (eight mesh). This method provided a major contacting improvement over the method which utilized the wood chips alone. The addition of an entrained sand phase improved contacting even more. Thus, the concept proposed is to use this technique with the entrained sand providing the heat for gasification. In addition, this so-called multisolid gasifier can operate at the high gas velocities required to take advantage of the high gasification reactivity of even uncatalyzed wood.

The economic feasibility study indicated that an intermediate-Btu gas can be produced in reasonably sized (1,000 dry tons per day) gasification plants at a price competitive with other supplemental energy, such as No. 2 fuel oil or synthetic natural gas.

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Gasification

H-5

Contractor and Address Gilbert Associates, Inc. Industrial/Energy Research Division P.O. Box 1498 Reading, Pennsylvania 19603	Title Research and Evaluation of Biomass Resources Conversion-Utilization Systems (Market/Experimental Analysis for Development of a Data Base for a Fuels from Biomass Model) Contract No. ET-78-C-02-5022
Principal Investigator Richard P. Stringer (215) 775-2600	Period of Performance September 1, 1978 to October 31, 1980
Work Location Reading, Pennsylvania	Obligated Fiscal Year 1978 Funding \$851,004 Cumulative Funding thru Fiscal Year 1978 \$851,004

Project Summary

This two-year contract is designed to develop a linear programming model which will assist in determining the most economical mix of biomass resources and conversion processes to produce the desired biomass-based fuels on a regional basis. This is the first biomass study which includes all elements of a commercial biomass scenario, i.e., resources, conversion, and utilization.

To accomplish this study, the following tasks are required:

- a. A market analysis of the need for biomass-derived fuels, and the national and regional availability of biomass resources on seasonal bases will be conducted.
- b. Biomass conversion profiles will be developed for about 100 biomass materials which have been selected as viable biomass candidates, e.g., wood, bagasse, sugar cane, wheat and rice straw, and corn stover. These profiles will be developed from Thermo Gravimetric Analysis runs under various conditions of temperature and pressure, and in the presence of catalysts. Gasification, pyrolysis, and direct combustion shall be the modes of conversion.
- c. An attempt will be made to develop biomass-to-fuels process models and to verify them using Process Development Unit runs. The data banks of market conditions, biomass conversion profiles, and commercial-scale process economics will be used as input to the model.
- d. A linear programming model will be developed for selecting the most economical combination of biomass feedstocks and the conversion processes required to supply a given volume of fuel for a given user in a specific region.

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Gasification

H-5

Contractor and Address Gilbert Associates, Inc. Industrial/Energy Research Division P.O. Box 1498 Reading, Pennsylvania 19603	Title Research and Evaluation of Biomass Resources Conversion-Utilization Systems (Market/Experimental Analysis for Development of a Data Base for a Fuels from Biomass Model) Contract No. ET-78-C-02-5022
Principal Investigator Richard P. Stringer (215) 775-2600	Period of Performance September 1, 1978 to October 31, 1980 Obligated Fiscal Year 1978 Funding \$851,004
Work Location Reading, Pennsylvania	Cumulative Funding thru Fiscal Year 1978 \$851,004

Project Summary (continued)

Dr. Richard Bailie will supervise the Thermo Gravimetric Analysis work at West Virginia University and the Process Development Unit Work at Environmental Energy Engineering, Inc. in Morgantown, WV. Gilbert Associates will perform the project management, market analysis, process modelling, and linear programming portions of the project.

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Gasification

H-6

Contractor and Address Garrett Energy Research & Engineering Co. 911 Bryant Place Ojai, California 93023	Title Conversion of Biomass Materials into Gaseous Products
	Contract No. EY-76-C-03-1241
Principal Investigator D.E. Garrett R.D. Mikesell D.C. Hoang (805) 646-0159	Period of Performance May 1976 to June 1979
	Obligated Fiscal Year 1978 Funding Funding obligated prior to FY 1978
Work Location Hanford, California	Cumulative Funding thru Fiscal Year 1978 \$585,000

Project Summary

The objective of this work is to demonstrate the feasibility of gasifying difficult-to-handle biomass materials in a specially designed multiple-hearth furnace.

Drying, pyrolysis, combustion, and steam/char gasification all occur on separate hearths of the multiple-hearth furnace. Because solids pass from one hearth to the next through rotary solid valves which leak very little gas, the conditions on each hearth can be adjusted to suit each function. The solids are swept across each hearth by rotating rabble teeth; therefore, this multiple-hearth furnace is capable of handling materials that are moist, fibrous, sticky, or susceptible to ash fusion. Heat is transferred to the pyrolysis hearth indirectly; thus, this reactor produces pyrolysis gas that is not diluted in nitrogen (a medium-Btu gas).

A bench-scale single hearth furnace was used to obtain experimental drying, pyrolysis, combustion, and water/gas reaction data. On the basis of these data, a 4-foot-diameter, four-hearth pilot plant unit was designed and constructed; it is now in its shake-down phase.

Bibliographic Reference No.: 28

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Gasification

H-7

Contractor and Address Gorham International, Inc. P.O. Box 8 Gorham, Maine 04038	Title Assessment of Technical and Economic Feasibility of Converting Wood to Fuels Using Coal Conversion Technology
	Contract No. ET-78-C-02-4862
Principal Investigator Andrew C. Nyce (207) 892-6761	Period of Performance June 1, 1978 to July 31, 1979
	Obligated Fiscal Year 1978 Funding \$126,428
Work Location Gorham, Maine	Cumulative Funding thru Fiscal Year 1978 \$126,428

Project Summary

This project will pursue two objectives:

- a. To determine which state-of-the-art and advanced coal gasifiers are technically and economically suitable for gasification of wood residues to produce low-, medium-, and high-Btu gas and synthesis gas.
- b. To specify the various modifications necessary to convert these gasifiers for use with wood residues.

The project's primary tasks are (1) to critically review patents and published literature; (2) to conduct 40 to 50 in-depth on-site interviews with gasifier developers, users, and manufacturers; (3) to gather information regarding gasification technology; (4) to collect prior art and operating data on wood gasification; (5) to estimate operating cost, capital equipment costs, gas costs, and gasification rates for coal gasifiers operating on wood residues; (6) to identify advantages and disadvantages of using wood residues; (7) to evaluate the sensitivity of capital costs and product costs to plant size; (8) to determine wood type, size, shape, and moisture content for various gasifiers; and (9) to identify barriers to implementation of wood gasification plants.

At the end of this 14-month study the contractor will deliver a final report presenting information obtained as a result of performing the above-stated tasks.

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Gasification

H-8

Contractor and Address Wright-Malta Corporation Ballston Spa, New York 12020	Title Catalyzed Water/Steam Gasification of Biomass
	Contract No. ET-78-C-02-4736 (Formerly EY-76-C-02-4124)
Principal Investigator John A. Coffman (518) 899-2227	Period of Performance September 22, 1976 to December 31, 1978
	Obligated Fiscal Year 1978 Funding \$303,000
Work Location Ballston Spa, New York	Cumulative Funding thru Fiscal Year 1978 \$371,000

Project Summary

The purpose of this contract has been to develop a process and equipment for efficient and economical conversion of wood chips and other biomass feedstocks into medium-Btu fuel gas.

Contractor effort has resulted in six major accomplishments:

- Process chemistry has been proven on bench-scale (10 lbs/hour) in batch and continuous equipment.
- The overall process has been shown to be sufficiently exothermic so that, with recuperative feedback, no external heat will be required.
- Gasification is essentially complete; overall efficiency may be about 87 percent.
- Heat transfer coefficients have been shown to be sufficiently high so that indirectly heated, rotary kiln reactors are feasible.
- Design work has identified practical means for the various mechanical steps.
- Preliminary economic analysis indicates a 20-year gas selling price of \$2.00 to \$2.50/10⁶ Btu.

Further project tasks include quantifying the process parameters; designing a 3 ton/day process development unit, and making an economic assessment of the process on production scale.

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Liquefaction

I-1

Contractor and Address	Title
University of Arizona Department of Chemical Engineering Tucson, Arizona 85721	Modified Extruder for Feeding Fine-Ground Cellulosic Slurries to Pressure Systems
Principal Investigator	Contract No. EW-78-S-05-5679
Don H. White (602) 626-1224	Period of Performance January 1, 1978 to December 31, 1979
Work Location	Obligated Fiscal Year 1978 Funding \$109,540
Tucson, Arizona	Cumulative Funding thru Fiscal Year 1978 \$109,540

Project Summary

The objective of this contract is to evaluate through experimental tests whether a modified screw extruder (as used in the food and plastics industries) could be used to feed a finely ground slurry (ground sawdust in heavy oils or water) into a pressure reactor system. Results of this evaluation will be of direct interest to those involved in both the DOE waste-to-oil pilot plant in Albany, Oregon, and the DOE-sponsored cellulosic gasification facility at Ballston Spa, New York.

This project entails the following tasks:

- a. Determine rheological and related properties of concentrated cellulosic slurries in oils and water.
- b. Evaluate pumping and pressure heads developed in single screw extruders.
- c. Evaluate stiff cellulosic slurry masterbatching and pelletizing.
- d. Evaluate alternative types of extruders in outside field tests.
- e. Analyze and correlate extruder feeding performance data.

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Liquefaction

I-1

Contractor and Address University of Arizona Department of Chemical Engineering Tucson, Arizona 85721	Title Modified Extruder for Feeding Fine-Ground Cellulosic Slurries to Pressure Systems
	Contract No. EW-78-S-05-5679
Principal Investigator Don H. White (602) 626-1224	Period of Performance January 1, 1978 to December 31, 1979
	Obligated Fiscal Year 1978 Funding \$109,540
Work Location Tucson, Arizona	Cumulative Funding thru Fiscal Year 1978 \$109,540

Project Summary (continued)

The basic overall goal of feeding sawdust/oil slurries of greater than 30 weight percent sawdust against a pressure head of 3,000 psi was achieved during the first year of the project using model liquids. The results showed:

	<u>Feeder Pressure</u>	<u>Sawdust Feed Concentration</u>
Key Project Goals	>3,000 psi	>30 wt.%
First Success (9/7/78)	3,200 psi	33 wt.%
Best to Date (9/11/78)	8,500 psi	67 wt.%
Highest Slurry to Date	*	70 wt.%

Formal reports on the work to date are in progress and will be available between April and June 1979.

* Not measured

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Liquefaction

I-2

Contractor and Address Battelle Pacific Northwest Laboratories P.O. Box 999 Richland, Washington 99352	Title Bench-Scale Research in Thermochemical Conversion of Biomass to Liquids in Support of the Albany, Oregon, Experimental Facility
	Contract No. EY-76-C-06-1830
Principal Investigator Douglas C. Elliott (509) 946-2432	Period of Performance October 1, 1976 to September 30, 1981
	Obligated Fiscal Year 1978 Funding
Work Location Richland, Washington	\$120,000
	Cumulative Funding thru Fiscal Year 1978 \$220,000

Project Summary

The objective of this project is twofold:

- a. To determine process changes required to facilitate fuel oil production at the Albany, Oregon, Biomass Liquefaction Experimental Facility through bench-scale investigation.
- b. To provide routine and specialized analytical support for the facility operators as needed.

During the past two years, work has entailed two types of activities: the use of a quick heat-up/cool-down autoclave to investigate process parameters and the use of an array of analytical techniques. In earlier work, various process parameter effects were examined, including temperature, pressure, cover gas composition, and time at temperature. During FY 1978, autoclave studies have focused on catalyst-related parameters, including catalyst application techniques, agitation rates, concentration effects, and use of substitute catalysts.

Much process analytical chemical support was provided to the Albany facility operator due to the lack of analytical facilities on site originally. As these facilities were developed and continue to develop on site, the Battelle Pacific role in analytical support has shifted/is shifting from that of process monitoring to specialized analysis and product characterization.

Bibliographic Reference No.: 37

Contractor and Address Wheelabrator Cleanfuel Corporation 2550 M Street, NW Suite 600 Washington, D.C. 20037	Title Operations of the Biomass Liquefaction Facility at Albany, Oregon Contract No. ET-78-C-06-1092
Principal Investigator W.L. Berry, Jr., Project Manager (205) 254-4101 David R. Hart, Resident Manager (503) 926-0940	Period of Performance July 1, 1978 to December 31, 1978 Obligated Fiscal Year 1978 Funding \$633,000
Work Location Albany, Oregon	Cumulative Funding thru Fiscal Year 1978 \$633,000

Project Summary

The objective of the project has been to obtain definitive process information, sufficient for commercial design and economic evaluation purposes, for the conversion of biomass to syncrude. This objective has been accomplished through the execution of experimental and developmental programs in the U.S. process development unit (PDU) located adjacent to the Bureau of Mines Metallurgical Research Center at Albany, Oregon.

As the on-site operating contractor, The Rust Engineering Company, on behalf of Wheelabrator Cleanfuel Corporation, accepted responsibility for the facility on October 1, 1978. A period of pre-start-up personnel familiarization and organization followed. An Environmental, Health, and Safety Assessment of the facility was conducted, per Department of Energy directive, prior to plant start-up. Repairs and/or modifications suggested by the assessment were accomplished.

An analytical laboratory to provide on-site test capabilities during operating periods was installed. Laboratory personnel familiarization and checkout was begun. Several operating runs were conducted utilizing locally available wood chips. Further confirmation of the laboratory work performed by the Pittsburgh Energy Research Center was obtained. The additional operating data generated was used to develop testing plans for the facility.

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Liquefaction

I-4

Contractor and Address	Title
Bechtel National, Inc. Research and Engineering 50 Beale Street San Francisco, California 94119	Experimental Program for the Albany, Oregon, Wood-to-Oil Experimental Facility
Principal Investigator	Contract No. EG-77-C-03-1338
Tom Lindemuth 415 (768-1135)	Period of Performance October 1, 1976 to September 30, 1978
Work Location	Obligated Fiscal Year 1978 Funding \$66,572
Albany, Oregon	Cumulative Funding thru Fiscal Year 1978 \$1,932,621

Project Summary

The Albany Pilot Plant was designed to test and further develop the Pittsburgh Energy Research Center (PERC) biomass-to-oil process. The primary objective of DOE's program in this facility had been to develop sufficient data to design a commercial plant and to evaluate process costs. A secondary objective of this program had been to conduct exploratory experiments to develop technologies essential to biomass processing.

Initial operations emphasized wood chips as the biomass feedstock, but agricultural crop residues were tested to a limited degree. The PERC process was investigated under a wide range of operating conditions. Flow rates, oil recycle rates, heating rates, temperatures, and pressures and proportions of hydrogen and carbon monoxide were varied.

Through the DOE program, the initial oil production was accomplished and data for the process evaluation was collected. The plant was modified to minimize problems with pressure containment on some of the process equipment.

A conceptual design for commercial process was prepared. The projected cost of product oil was calculated for plant capacity between 500 and 2,500 oven-dried tons per day. In addition, the proportional cost of product for capital recovery, raw materials, utilities, and operation was prepared. The results of the conceptual design can be used as a guide to future development work. As of September 1978, the responsibility of operating the Albany facility was transferred from Bechtel to another contractor. Funds were provided in FY 1978 to effect an orderly phase-in/phase-out of contractors from July through September of 1978.

ELEMENT: Conversion Systems

SUB-ELEMENT: Thermochemical: Liquefaction

I-5

Contractor and Address University of California Lawrence Berkeley Laboratory Berkeley, California 94720	Title Albany, Oregon, Process Developmental Unit/Biomass Conversion into Oil
	Contract No. W-7405-ENG-48
Principal Investigator Sabri Ergun (415) 486-6666	Period of Performance October 1, 1977 to September 30, 1982
	Obligated Fiscal Year 1978 Funding \$210,000
Work Location Berkeley, California	Cumulative Funding thru Fiscal Year 1978 \$210,000

Project Summary

The objective of this project is threefold:

- To provide DOE's Biomass Energy Systems Branch with an evaluation of the technical progress of DOE-funded biomass liquefaction projects.
- To monitor the operations of the Biomass Liquefaction Facility at Albany, Oregon, and to provide technical operating directives for test runs conducted there.
- To undertake engineering and bench-scale experimental studies to enhance the progress of DOE's biomass-to-oil program.

To achieve these objectives, the following tasks are required:

- Develop a program for the liquefaction of biomass.
- Evaluate experimental results.
- Modify the program on the basis of experimental results.
- Technically direct the program.

Bibliographic Reference No.: 30

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ELEMENT: Research and Development

SUB-ELEMENT: Innovative Conversion

J-1

Contractor and Address General Electric Company Corporate Research and Development P.O. Box 8; Building K-1, Room 3B12 Schenectady, New York 12301	Title Bioconversion of Plant Biomass to Ethanol
	Contract No. EG-77-C-02-4147
Principal Investigator T.M. Su W.D. Bellamy (518) 385-8640	Period of Performance December 1976 to December 1978
	Obligated Fiscal Year 1978 Funding \$181,000
Work Location Schenectady, New York	Cumulative Funding thru Fiscal Year 1978 \$352,000

Project Summary

The goal of this research is to demonstrate the technical and economic feasibility of the General Electric/Corporate Research and Development process for producing ethanol from hardwood and agricultural residues.

In the proposed thermophilic wood fermentation process, relatively coarse hardwood (and/or softwood, if amenable) chips are steamed at low pressure in the presence of supplemental amounts of sulfur dioxide (or equivalent reagent) for a brief time and are rapidly decompressed. The partially defibrated wood is neutralized with ammonia gas and fed directly into a fermenter which operates at a temperature of approximately 60°C. A mixed culture of Clostridium thermocellum and thermosaccharolyticum is employed to ferment the readily digestible substrate to ethanol. C. thermocellum is used primarily to solubilize cellulose and secondarily to convert cellobiose to ethanol. C. thermosaccharolyticum is employed to ferment the pentose sugars, produced during pretreatment but not utilized by C. thermocellum, to ethanol. Product recovery and cell recycle are accomplished by continuous withdrawal of the broth to a vacuum distillation chamber (modified vacuform) and subsequent distillation to produce 95 percent ethanol. After ethanol separation, cell mass is returned to the fermenter to maintain cell density while lignin is discharged, partially dried, and used to fuel the pretreatment steam boiler. If practical, spent silage is recovered and used as a fertilizer.

Considerable progress has been demonstrated in overcoming the technical barriers to ethanol production from wood; however, additional development work is required before technical feasibility can be established.

Bibliographic Reference No.: 35

ELEMENT: Research and Development

SUB-ELEMENT: Innovative Conversion

J-2

Contractor and Address Massachusetts Institute of Technology 77 Massachusetts Avenue Cambridge, Massachusetts 02139	Title Degradation of Cellulosic Biomass and Its Subsequent Utilization for the Production of Chemical Feedstocks.
	Contract No. EG-77-S-02-4198
Principal Investigator Daniel I.C. Wang (617) 253-2126	Period of Performance December 1, 1976 to January 31, 1979
	Obligated Fiscal Year 1978 Funding \$450,150
Work Location Cambridge, Massachusetts	Cumulative Funding thru Fiscal Year 1978 \$900,029

Project Summary

The objective of this project is the microbial degradation of cellulosic biomass and the subsequent utilization of the degradation products for the production of chemicals.

To achieve the degradation, the use of an anaerobic and thermophilic bacterium, Clostridium thermocellum, has been under investigation. In addition, mutation and selection programs to increase the tolerance of this organism to ethanol, as well as to direct the catabolism to a single end product, ethanol, are also being pursued. Different types of biomasses such as corn stover, wheat straws, and poplar have been tested. Process and engineering analyses are performed to assess the overall economics.

Chemical feedstock production is this project's second area of development. Three important fermentation products are being examined: (1) acrylic acid, (2) acetone/butanol, and (3) acetic acid. Acrylic acid production is achieved through the use of the microorganism Clostridium propionicum; acetone/butanol production, through Clostridium acetobutylicum; and acetic acid production, through Clostridium thermoaceticum. All of these studies have the objective of increasing the rate and conversion efficiency to minimize overall cost.

Bibliographic Reference No.: 23

ELEMENT: Research and Development

SUB-ELEMENT: Innovative Conversion

J-3

Contractor and Address	Title
Exxon Research and Engineering Company Government Research Laboratories Linden, New Jersey 07036	Sensitized Photoelectrolysis of Water with Sunlight
	Contract No. EG-77-C-02-4271
Principal Investigator	Period of Performance
Amal K. Ghosh H. Paul Maruska (201) 474-3465	June 1, 1977 to December 31, 1978
Work Location	Obligated Fiscal Year 1978 Funding
Linden, New Jersey	Funding obligated prior to FY 1978
	Cumulative Funding thru Fiscal Year 1978
	\$76,384

Project Summary

This project entailed conducting a study of solar-driven water photoelectrolysis cells employing semiconductor electrodes. An extensive review of the literature was undertaken, and three major problem areas for these devices were identified: corrosion, poor sunlight absorption, and external bias requirement.

Although many semiconductors had been tested, none had proven free of all three defects. Thus, two approaches were followed for the experimental studies: (1) impurity sensitization of wide band gap stable oxides and (2) heterostructure formation between unstable sunlight absorbers and corrosion-resistant oxides.

Water decomposition was achieved with visible light excitation of Cr-doped TiO_2 . Transport properties were studied for TiO_2 and SrTiO_3 electrodes doped with V, Cr, Mn, Fe, Co, and Ni. The correlation between bias requirement and electron affinity of oxides was identified. Performance of heterostructure electrodes was shown to be limited either by pinhole problems or by potential barriers between the valence bands.

Bibliographic Reference No.: 31

ELEMENT: Research and Development

SUB-ELEMENT: Innovative Conversion

J-4

Contractor and Address University of Pennsylvania Department of Biochemistry and Biophysics Medical School Philadelphia, Pennsylvania 19104	Title The Biological Production of Liquid Fuels from Cellulosic Residues
	Contract No. EY-76-S-02-4070
Principal Investigator E.K. Pye A.E. Humphrey (215) 243-8038	Period of Performance September 15, 1976 to December 14, 1979
	Obligated Fiscal Year 1978 Funding \$278,787
Work Location Philadelphia, Pennsylvania	Cumulative Funding thru Fiscal Year 1978 \$575,248

Project Summary

The objective of this project is to investigate the technical and economic constraints on a modular process designed for the conversion of cellulosic biomass into liquid fuels and oil-sparing chemicals and solvents. Examples of convertible cellulosic biomass are wood chips from fast-growing poplar trees, agricultural residues, and urban residues.

The process is designed to produce ethanol (a gasoline extender) and a lignin/butanol slurry (a pumpable heating or diesel fuel) as major products. The process emphasizes total biomass utilization, maximizes high-value by-products (e.g., polymer-grade lignin), operates at elevated temperatures to reduce capital and operating costs, and uses novel low-energy technology for recovery of both ethanol and butanol. The process employs (1) pretreatment of the biomass with hot butanol, (2) combined high-temperature saccharification and vacuum fermentation for ethanol production, and (3) combined saccharification and extractive fermentation for butanol production.

Economic and technical optimization studies are in progress. Recent results confirm the feasibility of the overall concept of the process. Excellent stabilities of Thermoactinomyces cellulase have been demonstrated making high-temperature operations possible. Several good, cheap extractants for butanol have been identified and tested. Economic analysis of this process indicates that ethanol production costs range between \$.70 to \$.80/gallon; these costs depend on by-product credits, operating yields, and original biomass costs.

Bibliographic Reference No.: 24

ELEMENT: Research and Development

SUB-ELEMENT: Innovative Conversion

J-5

Contractor and Address Dynatech R/D Company 99 Erie Street Cambridge, Massachusetts 02139	Title Liquid Fuels from Biomass
Principal Investigator D.L. Wise (617) 868-8050	Contract No. EG-77-C-02-4388
Work Location Cambridge, Massachusetts	Period of Performance July 1, 1977 to June 30, 1979
	Obligated Fiscal Year 1978 Funding \$244,000
	Cumulative Funding thru Fiscal Year 1978 \$469,000

Project Summary

This is a continuation of a Dynatech project formerly titled "Acetic Acid Production from Marine Algae." Anaerobic fermentation of biomass is being carried out in a fixed packed bed fermenter, followed by recovery of organic acids from the fermenter broth. The acids are converted by Kolbe electrolysis to liquid fuels such as octane.

This project includes optimization and definition of all engineering process parameters needed for scale-up, including design data for the packed bed fermenter, a liquid-liquid extraction unit, and Kolbe electrolysis of organic acids to liquid fuels. Process modeling, sensitivity, and economic analysis also are an integral part of the project.

Bibliographic Reference No.: 36

ELEMENT: Research and Development

SUB-ELEMENT: Innovative Conversion

J-6

Contractor and Address	Title
Rutgers University Cook College Department of Biochemistry and Microbiology New Brunswick, New Jersey 08903	Producing Mutants of Trichoderma
	Contract No. ET-78-S-02-4591 (Formerly EY-76-G-01-2539)
Principal Investigator	Period of Performance
Douglas E. Eveleigh (201) 932-9829	September 1, 1976 to October 1, 1979
Work Location	Obligated Fiscal Year 1978 Funding
New Brunswick, New Jersey	\$109,000
	Cumulative Funding thru Fiscal Year 1978
	\$146,000

Project Summary

The objective of this project is to develop mutant strains of Trichoderma to produce higher yields of the enzyme cellulose.

Economical production of glucose from cellulosic biomass can provide the basis for industrial fermentation products which substitute for petrochemicals. This project devised a method to obtain catabolite repression-resistant mutants that hydrolyze cellulose in the presence of glycerol. Twenty-five mutants have been selected for characterization. In order to characterize potential hypercellulase-producing mutants, the project is evaluating individual and synergistic contributions of cellobiohydrolases, endoglucanases, and cellobiases.

Bibliographic Reference No.: 26

ELEMENT: Research and Development

SUB-ELEMENT: Innovative Conversion

J-7

Contractor and Address Stanford University Stanford, California 94305	Title Heat Treatment of Organics for Increasing Anaerobic Biodegradability
	Contract No. EY-76-S-03-0326
Principal Investigator Perry L. McCarty (415) 497-2300	Period of Performance April 29, 1976 to April 30, 1979
	Obligated Fiscal Year 1978 Funding \$108,000
Work Location Palo Alto, California.	Cumulative Funding thru Fiscal Year 1978 \$274,000

Project Summary

The purpose of this study has been to develop a means for increasing methane production and reducing the cost of methane gas, which can be used as an energy source. The procedures evaluated were heat treatments at temperatures up to 300°C, generally under alkaline conditions (300 to 400 meq/l NaOH).

The components of lignocellulose (e.g., lignin and cellulose) were separately treated and evaluated for their biodegradability and potential for methane production.

The Biochemical Methane Potential (BMP) assay was developed which can be used for assessing the biodegradability of complex organics, such as products from the heat treatment of lignocellulose.

Waste-activated sludge (WAS) was selected as a representative residual organic with high nitrogen content. Heat treatment led to substantial increases in the anaerobic biodegradability of WAS. A maximum of 85 percent of the organics was biodegradable compared to 53 percent for the nontreated controls.

Microbiological studies examined biodegradation of the model lignin derivative, ferulic acid, which had previously been shown to undergo anaerobic decomposition and ring cleavage with the production of methane. Examination with the light microscope and the electron microscope indicate that a consortium of three predominant organisms appear to be primarily responsible for the bioconversion.

ELEMENT: Research and Development

SUB-ELEMENT: Innovative Conversion

J-8

Contractor and Address	Title
University of California College of Engineering Sanitary Engineering Research Lab 301 South 46th Street Richmond, California 94804	Solar Energy Conversion Through Biophotolysis
	Contract No. EY-76-S-03-0034
Principal Investigator	Period of Performance
John R. Benemann (415) 231-9516	February 1, 1976 to June 30, 1979
	Obligated Fiscal Year 1978 Funding
Work Location	\$104,950
Richmond, California	Cumulative Funding thru Fiscal Year 1978
	\$238,258

Project Summary

The objective of this project is to explore the feasibility of using nitrogen-fixing heterocystous blue-green algae in solar energy converters to produce hydrogen by biophotolysis of water.

To achieve this objective, the following tasks are required:

- a. Continue previous work which established the fact that these algae produce hydrogen and stoichiometric oxygen from water and light energy.
- b. Conduct tests which will focus on (1) improvement of hydrogen production, (2) outdoor cultures, and (3) comparison of in vivo and in vitro interacting hydrogenases.
- c. Perform an engineering analysis to determine economic feasibility of the process.

Thus far, four different heterocystous blue-green algae strains have been tested. Increased hydrogen production and stability were found to result from inclusion of one percent nitrogen in the gaseous phase.

ELEMENT: Research and Development

SUB-ELEMENT: Advanced Feedstocks

K-1.

Contractor and Address University of California Lawrence Berkeley Laboratory Chemical Biodynamics Division Berkeley, California 94720	Title Hydrocarbons from Plants
	Contract No. W-7405-ENG-48
Principal Investigator Melvin Calvin J.W. Otvos (415) 486-4311	Period of Performance February 1, 1977 to September 30, 1978
	Obligated Fiscal Year 1978 Funding \$30,000
Work Location Berkeley, California	Cumulative Funding thru Fiscal Year 1978 \$65,000

Project Summary

The objective of this project is to cultivate hydrocarbon-producing crops, such as certain Euphorbias, to determine the feasibility of producing hydrocarbons and related materials for fuel or chemical feedstocks. Since these and many other latex-producing plants have never before been cultivated or studied for commercialization of their chemical content, various basic information is needed.

To achieve the objective, the following tasks are required:

- The yields of hydrocarbon as well as total caloric yield must be determined along with the effects of fertilizer, irrigation, and dates of planting and harvest on the growth rate. Early results based on very small plots indicate an annual biomass yield for Euphorbia lathyris of 11 dry tons per acre.
- The possibility of increasing oil yield for E. lathyris above the present 90 percent yield (by altering the metabolism of the plant with hormonal technique) must be investigated.
- In addition to screening tests for hydrocarbons, resin, oils, etc., the analytical methods must be improved and expanded in scope to include molecular weight distribution as well as chemical composition.
- Optimum methods of extracting the useful components (waxes, oils, polyisoprenes, terpenoids, etc.) must be found and exploratory process chemistry must be conducted to see how the product can be modified into a more convenient form for use as a fuel or chemical feedstock.

ELEMENT: Research and Development

SUB-ELEMENT: Advanced Feedstocks

K-1

Contractor and Address University of California Lawrence Berkeley Laboratory Chemical Biodynamics Division Berkeley, California 94720	Title Hydrocarbons from Plants
Principal Investigator Melvin Calvin J.W. Otvos (415) 486-4311	Contract No. W-7405-ENG-48 Period of Performance February 1, 1977 to September 30, 1978
Work Location Berkeley, California	Obligated Fiscal Year 1978 Funding \$30,000 Cumulative Funding thru Fiscal Year 1978 \$65,000

Project Summary (continued)

- e. As experimental results become available, evaluations of (1) the agricultural production costs of a Euphorbia crop and (2) the processing costs of producing the extractable product must be made.

Bibliographic Reference No.: 15

ELEMENT: Research and Development

SUB-ELEMENT: Aquatic Systems

L-1

Instructor and Address Woods Hole Oceanographic Institution Woods Hole, Massachusetts 02543	Title Cultivation of Macroscopic Marine Algae and Freshwater Aquatic Weeds
	Contract No. EY-76-S-02-2948
Principal Investigator John H. Ryther (617) 548-1400	Period of Performance May 1, 1977 to April 30, 1979
	Obligated Fiscal Year 1978 Funding \$222,486
Work Location Ft. Pierce, Florida	Cumulative Funding thru Fiscal Year 1978 \$623,193

Project Summary

The objective of this project is fivefold:

- Determine maximum rates of biomass production throughout the year for selected species of seaweeds and freshwater plants living in the latitude and climate of central Florida.
- Compare maximum growth rates of these plants in culture, under optimal conditions, with their natural growth rates in their normal environment.
- Determine evapo-transpiration losses and the annual water budget of selected freshwater plants.
- Determine environmental factors that control and limit the growth of the plants in culture.
- Develop economical, nonenergy-intensive culture methods.
- Investigate the feasibility of recycling the nutrients in the residues from anaerobic digestion of the plant biomass for new plant production.

Bibliographic Reference No.: 14

ELEMENT: Research and Development

SUB-ELEMENT: Aquatic Systems

L-2

Contractor and Address	Title
Woods Hole Oceanographic Institution Woods Hole, Massachusetts 02543	Bioengineering Aspects of Inorganic Carbon Supply to Mass Algal Cultures
	Contract No. ET-78-S-02-4812
Principal Investigator	Period of Performance
Joel C. Goldman (617) 548-1400	June 1, 1978 to May 31, 1979
	Obligated Fiscal Year 1978 Funding \$78,967
Work Location	Cumulative Funding thru Fiscal Year 1978 \$78,967
Woods Hole, Massachusetts	

Project Summary

The study involves a thorough investigation of the inorganic carbon requirements of algae (both micro and macro species) under mass culture conditions. The major research topics include (1) growth kinetics of various freshwater and marine algae under inorganic limitation at different pH levels, (2) comparisons of growth with bubbled CO₂ and HCO₃ alkalinity as inorganic carbon sources at varying pH levels, (3) effects of pH on algal growth under noncarbon-limiting conditions, and (4) effects of mixing in inorganic carbon-limiting and nonlimiting situations on algal growth.

Studies are being carried out under laboratory conditions with continuous algal cultures and controlled temperature and light intensity. Algae are grown in defined mediums with pH control using noncarbon buffers. A variety of algal species that typically have been identified as being dominant in outdoor mass cultures are being examined under the above conditions.

The major goal is to isolate the effects of inorganic carbon limitation, pH, and mixing on algal growth under mass culture conditions. With this knowledge it may be possible to estimate the actual quantities of inorganic carbon necessary to force light to be limiting under mass culture conditions; this will allow rational decisions to be made regarding the engineering design and economics of supplying carbon for very large algal bioconversion schemes.

Bibliographic Reference No.: 13

ELEMENT: Research and Development

SUB-ELEMENT: Aquatic Systems

L-3

Contractor and Address California Institute of Technology Division of Engineering and Applied Science 1201 E. California Blvd. Pasadena, California 91125	Title Biological Investigation of Marine Farms
	Contract No. EY-76-C-03-1275
Principal Investigator James J. Morgan Wheeler J. North (213) 795-6811	Period of Performance July 1, 1977 to September 30, 1979
	Obligated Fiscal Year 1978 Funding
Work Location Corona del Mar, California	\$200,000
	Cumulative Funding thru Fiscal Year 1978 \$1,103,000

Project Summary

The project objectives include determining elemental requirements of Macrocystis (Giant Kelp), developing an optimal strategy for fertilizing plants in an oceanic setting, and determining harvest yields from a group of continually fertilized adult test plants.

The laboratory approach utilizes juvenile kelp sporophytes, weighing from 1 to 10 grams, grown under batch culturing either in seawater or in an artificial, defined medium (Aquil). Most experiments have employed seawater pumped up from depths of 300 meters or more because waters of this depth will probably be used to fertilize plants on oceanic farms. Work has emphasized the roles of trace metals in kelp nutrition. Selected trace metals have been added in known concentrations to seawater or to Aquil, and growth rate effects have been measured. Effects of omitting suspected nutrient elements from Aquil also have been studied. The project has also involved the planning and design of a large-scale field experiment wherein 100 adult Macrocystis transplants will be constantly exposed to nutrient-rich water pumped up from depths of about 450 meters. Canopies will be harvested periodically to determine yields. Nutrients in the surrounding water and in plant tissues will be monitored as well as growth rates, recruitment success, and general condition of the transplants and associated organisms.

Laboratory results indicate that growth-stimulating properties of deep water have been variable. In some cases, changes in availability of trace metals such as iron and manganese in deep water correlate with changes in ability of the medium to stimulate growth. Manganese is clearly a required nutrient. Surface water usually contains adequate supplies of those trace metals lacking in deep water and vice versa. Hence, mixtures of the two can complement each other as growth media. The test farm experiment is in the initial stages with transplanting in progress.

Bibliographic Reference No.: 10

ELEMENT: Research and Development

SUB-ELEMENT: Aquatic Systems

L-4

Contractor and Address CSO International, Inc. 2450 Stanwell Drive Concord, California 94520	Title Cost Analysis of Aquatic Biomass Systems (Fresh Water Micro-Algae)
	Contract No. ET-78-X-01-1605
Principal Investigator L.E. Swanson (415) 798-1711	Period of Performance December 14, 1977 to January 15, 1978
	Obligated Fiscal Year 1978 Funding \$5,700
Work Location Concord, California	Cumulative Funding thru Fiscal Year 1978 \$5,700

Project Summary

The objective of this project was to develop conceptual engineering drawings, supportive cost estimates, and the necessary explanatory text outlining the concept of a 100 square-mile freshwater system for growing and harvesting microscopic algae.

The results indicate that the cost of micro-algae produced in such systems would be on the order of \$40 per dry weight ton (based on 1978 dollars), neglecting possible future improvements in the systems.

ELEMENT: Research and Development

SUB-ELEMENT: Aquatic Systems

L-5

Contractor and Address Dynatech R/D Company 99 Erie Street Cambridge, Massachusetts 02139	Title Cost Analysis of Algal Biomass Systems
	Contract No. EG-77-C-01-4000
Principal Investigator D.L. Wise (617) 686-8050	Period of Performance June 27, 1977 to December 31, 1978
	Obligated Fiscal Year 1978 Funding \$43,000
Work Location Cambridge, Massachusetts	Cumulative Funding thru Fiscal Year 1978 \$192,000

Project Summary

A cost analysis of aquatic biomass systems was conducted to provide DOE with engineering cost information on which to base decisions in the area of planning and executing R&D programs dealing with aquatic biomass as an alternative energy resource. It was found that the projections of costs for harvested open-ocean biomass, utilizing optimistic assumptions of scientific and engineering design parameters, appear to be above any practical costs to be considered for energy. One of the major limitations was the need to provide upwelled subsurface water containing needed nutrients, for which pumping energy was required.

Results indicate that for lower yields of biomass, the energy in ocean waves may marginally provide energy to pump suitable amounts of upwelled water for nutrient supply; however, costs of harvested biomass are very high at lower yields. For projections of biomass growth at increasingly higher yields, so much nutrient-containing water is required that environmental wave energy is insufficient and fuel or electric power is required for pumping; thus, with high yields, obtaining a net positive energy balance from the open-ocean farm becomes tenuous. Further, there are very substantial environmental and legal aspects of aquatic biomass farming that appear especially ponderous for an open-ocean system.

It is concluded from this analysis that large-scale land-based aquatic biomass farms may merit development, but perhaps within a much narrower range than heretofore investigated. For example, land-based aquatic biomass systems based on biomass which require a carbon source other than carbon dioxide from the air appear to have higher costs than may be acceptable as an energy resource. Aquatic plants which appear to have potential for development as an energy resource are the so-called emersed plants, or angiosperms, including many types of freshwater weeds such as duckweed, Hydrilla, and water hyacinths. It is recommended that substantially greater basic and applied knowledge of these aquatic biomass be obtained, especially of growth rates and nutrient requirements.

Bibliographic Reference No.: 12

ELEMENT: Research and Development

SUB-ELEMENT: Aquatic Systems

L-6

Contractor and Address Columbia University School of Engineering and Applied Science New York, New York 10027	Title Algal Concentration by Ultrafiltration Contract No. EY-76-S-02-4076
Principal Investigator Harry P. Gregor (212) 280-4716	Period of Performance September 1, 1976 to July 31, 1979 Obligated Fiscal Year 1978 Funding \$66,410
Work Location New York, New York	Cumulative Funding thru Fiscal Year 1978 \$269,371

Project Summary

Laboratory studies using new nonfouling ultrafiltration membranes of sulfonic acid fixed-charged character shows that these membranes are capable of harvesting a wide variety of fresh water and marine algae at high flux rates without any membrane fouling. A number of different organisms grown under laboratory conditions were concentrated from the usual 100 to 200 milligrams/liter levels up to as high as 14 percent total solids with virtually no loss of organisms. A variety of Nannochlorus grown in a field laboratory on a mixture of New York City sewage and East River water can also be harvested effectively by these membranes. Work is continuing on the preparation of small pilot plants, each having membrane areas five feet square. Each pilot plant is designed for site use.

It has been estimated that given large field installations, the cost of harvesting algae by ultrafiltration could be as low as \$.05/thousand gallons of suspension treated; this rate corresponds to a total harvesting cost which is allowable for a fuel source.

Bibliographic Reference No.: 34

ELEMENT: Research and Development

SUB-ELEMENT: Aquatic Systems

L-7

Contractor and Address Columbia University School of Engineering and Applied Science New York, New York 10027	Title Permselective Membrane Control of Algal and Wood Digesters for Increased Production and Chemical Recovery
	Contract No. EG-77-S-02-4292
Principal Investigator Harry P. Gregor (212) 280-4716	Period of Performance June 15, 1977 to June 14, 1978
	Obligated Fiscal Year 1978 Funding \$82,682
Work Location New York, New York	Cumulative Funding thru Fiscal Year 1978 \$82,682

Project Summary

Membrane-controlled fermentation involves the continuous or semi-continuous ultrafiltration of the contents of a fermenter to remove low (less than 1,000) molecular-weight substances present with complete recycling of cells. The permeate is then treated by a combination of membrane processes involving electrodialysis, water splitting, and water extraction. Thus, chemical by-products are removed and subsequently concentrated. Toxic elements are removed also, and nutrients and substrate are recycled as needed.

Studies have shown that the anaerobic fermentation of glucose to methane and organic acids (principally acetic) can be increased several-fold over the levels usually allowed for in conventional fermentation/digestion processes of this kind. It has also been determined that organic acids can be separated and concentrated by a combination of water splitting, solvent extraction, and electrodialytic processes.

A contract extension has been approved and will be funded in 1979. The use of membranes in fermentation processes will be extended to studies on membranes capable of separating hydrochloric acids/sugar solutions. These studies are intended to lead to the rapid and potentially inexpensive hydrolysis of cellulose by concentrated hydrochloric acid. In addition, these membrane processes will then be used to accelerate the fermentation of sugars to alcohol. New membrane permeation systems for the removal of alcohol from fermentation mixtures at a low concentration will then be evaluated. Similarly, other membrane permeation processes to dewater concentrated alcohol/water mixtures in order to reach levels required by gasohol will be reviewed. The membrane-facilitated dewatering of stillage will be studied also.

ELEMENT: Research and Development

SUB-ELEMENT: Aquatic Systems

L-8

Contractor and Address University of California Sanitary Engineering Research Laboratory Berkeley, California 94720	Title Large-Scale Freshwater Microalgae Biomass Production for Fuel
	Contract No. EY-76-S-03-0034
Principal Investigator William J. Oswald (415) 642-6000	Period of Performance October 1, 1977 to September 30, 1978
	Obligated Fiscal Year 1978 Funding \$153,928
Work Location Richmond, California	Cumulative Funding thru Fiscal Year 1978 \$153,928

Project Summary

The cultivation technology of microalgal biomass for conversion to fuels was investigated. The key limiting factors were the maintenance of a stable, high-productivity culture and the development of a low-cost harvesting technology. A simple bioflocculation-settling process was investigated as the most cost-effective method of algal harvesting. Settled municipal sewage was used as the algal growth medium.

Experiments were carried out in both 12-square-meter experimental ponds and 1,000-square-meter pilot ponds. These were operated at a depth of 20 to 30 cm, mixing speeds of 5 to 15 cm/second (using paddle wheels for mixing) and a variable hydraulic detention time. Detention time was a key factor in promoting algal cultures which exhibit rapid (24 hour) bioflocculation and settling. Flocculation-settling experiments were carried out in both small cones and a 32,000-liter separation pond. Removal efficiencies exceeded 90 percent in 48 hours; however, maintenance of such high removal rates is not yet possible.

Additional experiments carried out under this project involved cultivation of nitrogen-fixing blue-green algae, the anaerobic digestion of microalgal biomass, and the study of zooplankton predation in the algal ponds. An engineering feasibility analysis indicated that fuels from microalgal biomass produced during wastewater treatment is of near-term potential.

Bibliographic Reference No.: 11

SUPPORT

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ELEMENT: Support

SUB-ELEMENT: Analyses

M-1

Contractor and Address InterTechnology/Solar Corporation 100 Main Street Warrenton, Virginia 22186	Title Follow-on Studies of the Photosynthesis Energy Factory
	Contract No. ET-78-C-01-3024 (Formerly EX-76-C-01-2548)
Principal Investigator Malcolm D. Fraser (703) 347-7900	Period of Performance July 7, 1978 to October 6, 1979
	Obligated Fiscal Year 1978 Funding \$208,796
Work Location Warrenton, Virginia	Cumulative Funding thru Fiscal Year 1978 \$208,796

Project Summary

A Photosynthesis Energy Factory (PEF) is an integrated bioconversion system consisting of a dryland energy farm, a wood-fired power plant, and a wetlands biological wastewater treatment system. Products of a PEF are electricity from the power plant, synthetic natural gas from digestion of the wetlands biomass, and reclaimed wastewater. The possible advantages of a PEF are that effluents and by-products from one part of the system can be beneficially used by other parts, leading to increased energy conversion and resource recovery at lower costs.

In the initial study of this type of system, a general technoeconomic model of a PEF was developed. This model was used to investigate possible interactions between the various subsystems in a PEF. Cost-effectiveness studies showed that electricity could be produced at prices competitive with coal-derived electricity. These results showed that the primary benefit of the algae pond in the system is to obtain a cost credit for treating municipal wastewater, and that the methane cannot be produced from the algae at reasonable costs with near-term technology.

The three main objectives of this follow-on program are (1) to expand and generalize the PEF model to make it applicable to a wider variety of site situations, (2) to investigate potential improvements in the PEF to make it more cost-effective, and (3) to evaluate the PEF concept for possible demonstrations at a wider variety of sites displaying widely different local climatic and site-specific constraints. The PEF model will be expanded and generalized by analyzing possible model improvements in the areas of materials transportation, water and nutrient balances, other types of wetland biological systems for wastewater treatment, and improvements in wood-fired combustion systems. Direct application of municipal wastewater to a dryland energy farm will be analyzed, also.

ELEMENT: Support

SUB-ELEMENT: Analyses

M-2

Contractor and Address SRI International 333 Ravenswood Avenue Menlo Park, California 94025	Title Mission Analysis for the Federal Fuels from Biomass Energy Program Contract No. EY-76-C-03-0115
Principal Investigator Fred A. Schooley (415) 326-6200	Period of Performance January 1, 1978 to January 30, 1979 Obligated Fiscal Year 1978 Funding
Work Location Menlo Park, California and 10 U.S. areas	\$250,000 Cumulative Funding thru Fiscal Year 1978 \$250,000

Project Summary

SRI International (formerly Stanford Research Institute) has been assisting the DOE in determining which fuels from biomass missions (conversion routes) are most likely to lead to economically viable market penetration within the competitive fuels environment. The overall objective of this study is to perform a mission analysis of the Federal Biomass Energy Systems Program and, based on the results, develop program recommendations.

To accomplish this objective, SRI has undertaken the following activities:

- a. Energy flow diagrams showing all possible paths of the biomass production/resource base, potential conversion technologies, alternative products, and end-use consumption markets have been developed.
- b. Forecasts of biomass availability as a function of price through the year 2020 for alternatives including organic residues, terrestrial energy crops, and marine energy crops have been developed.
- c. Potential biomass conversion technologies including current status of development have been described. Considered in the evaluation of selected options were feed-stock requirements, storage and preparation requirements, process efficiency (detailed schematic flow diagrams including energy and material balances), and process economics (including capital and operating costs, and required selling prices of products).
- d. Program recommendations for the Federal Biomass Energy Systems Program have been developed.

Bibliographic Reference No.: 38

ELEMENT: Support

SUB-ELEMENT: Analyses

M-3

Contractor and Address SRI International 333 Ravenswood Ave. Menlo Park, California 94025	Title Preparation of a Cost Data Bank for DOE/Biomass Energy Systems Branch Contract No. EY-76-C-03-0115
Principal Investigator A.Y. Kam-Principal Investigator Ron Dickenson-Supervisor (415) 326-6200 X5560	Period of Performance September 29, 1978 to December 31, 1979 Obligated Fiscal Year 1978 Funding \$340,000
Work Location Menlo Park, California	Cumulative Funding thru Fiscal Year 1978 \$340,000

Project Summary

This study deals with the preparation of a broad-based biomass energy systems technology and cost data bank for the Biomass Energy Systems Branch of DOE.

The major effort involves a critical and technical analysis of 19 promising technology options for processing various biomass materials into energy products. The options cover the production of electric power, steam, gases, liquids, and solid fuels from biomass. The majority of these options are believed to be available now or in the near term.

Upon completion, the data bank will be used as the basis for studies on the likely future market penetration of biomass energy products and the probable influence of available Federal options on the commercialization of biomass energy system technologies.

ELEMENT: Support

SUB-ELEMENT: Assessments

N-1

Contractor and Address	Title
University of Arkansas Fayetteville, Arkansas 72701	Evaluation of a Cellulose Waste Converter and Pyrolytic Process
Principal Investigator	Contract No. EG-77-S-04-4096
Henry Hicks (501) 575-3153	Period of Performance September 26, 1977 to April 30, 1979
Work Location	Obligated Fiscal Year 1978 Funding \$290,000
Fayetteville and Jonesboro, Arkansas	Cumulative Funding thru Fiscal Year 1978 \$440,000

Project Summary

This research project involves three main objectives:

- a. To obtain pyrolytic conversion data for the biomass materials available in the Ozark plateau region.
- b. To develop engineering design data for the general class of rotary kiln converters.
- c. To make an engineering evaluation of the recently patented rotary kiln pyrolytic converter developed by the project's subcontractor, Angelo Industries of Jonesboro, Arkansas.

A fourth, but secondary, objective is the preliminary design of a demonstration plant utilizing the Angelo Industries' converter to produce charcoal as a generally valuable solid fuel along with steam as a source of heat in the processing of precooked rice.

BIBLIOGRAPHY

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BIBLIOGRAPHY

The bibliography consists of two sections. The first section lists reports, technical papers, articles which have resulted from or are related to various research projects described in the program summary. Most of the projects described in the program summary are covered in this section. The second section lists general bibliographic references related to Biomass Technology.

Most of these publications can be obtained through technical libraries or sometimes as a complimentary copy from the authors, whose addresses have been included with each citation. Unless otherwise specified, all of the reports can be obtained from:

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, Virginia 22161
(703) 557-4650

To facilitate receipt of a report from NTIS, provide as much relevant information as possible (title, author, report number, date of publication, etc.). The NTIS is required by its enabling legislation to recover the costs incurred for printing and distributing copies of reports to the public. To comply with this legislation, NTIS imposes a cost for each service provided.

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The materials will be ready for pick-up approximately two weeks after the order is placed and must be paid for either by check, money order, or American Express Card. One day pick-up rush service can be obtained for an extra cost of \$6.00 per volume or book.

- o Establish an NTIS deposit account. Information can be obtained directly from NTIS at the Springfield, Virginia, address.

BIBLIOGRAPHIC REFERENCES FOR SPECIFIC FISCAL YEAR 1978

BIOMASS PROJECTS

The following publications are related to the project described in summary A-2.

"Development of Wood as an Alternative for Large Power Generating Systems".
August 1978

Authors: J.T. Hamrick, Aerospace Research Corp.,
4 Jae Valley Road S E Roanoke, Virginia
Published by: Oak Ridge National Laboratory,
Oak Ridge, Tennessee,
Report No.: ORO5682-8 (NTIS)

The following publications are related to the project described in summary A-3.

"Study of Wood Fired Electric Power Generating Plants"
(answers of 74 respondents to Questionnaires)

Authors: D.W. Pingrey and N.E. Waggoner
Published by: Northwest Pacific Corporation,
Suite 600, Plaza 600 Building,
Seattle, Washington 98101
Available from the authors

The following publications are related to the project described in summary B-1.

"Anaerobic Attached Film Expanded Bed Reactor Treatment of Dilute Organics"
(October 3, 1978)

Authors: M. Switzenbaum and W. Jewell,
Department of Agricultural Engineering,
Cornell University, Cornell, New York 14853
Publication: Journal of Water Pollution Control Federation,
42 pages, (NTIS)

"Anaerobic Fermentation of Agricultural Residue: Potential for Improvement
and Implementation" Progress Reports

Authors: W. Jewell et al., Dept of Agri. Engineering,
Cornell University, Cornell, New York 14853
Report No.: HCP/T2981-07, February 1978, 427 pages
(\$14.50 printed; \$3.00 microfiche)(NTIS)
C00-2981-7, December 16, 1977 to March 15, 1978
TID-28736, March 16-June 15, 1978
(\$4.50 printed; \$3.00 microfiche)(NTIS)

"Bioconversion of Agricultural Wastes for Pollution Control and Energy Conservation"
(September 1976)

Authors: W. Jewell et al., Dept. of Agricultural Engineering,
Cornell University, Cornell, New York 14853
Report No.: TID-27164, 321 (NTIS)

"Biomass Fuels - Past, Present and Future"

Authors: W. Jewell et al., Dept. of Agri Engineering,

"Biomass Fuels - Past, Present and Future"

Authors: W. Jewell et al., Dept. of Agri Engineering,
Cornell University, Cornell, New York 14853
Publication: Proceedings of the 1978 Annual Meeting of the American
Section of the International Solar Energy Society,
August 1978, pages 42-53
Available from the author

"Small Farm Methane Generation Potential"

Author: W. Jewell et. al., Dept. of Agri. Engineering,
Cornell University, Cornell, New York 14853
Publication: Proceedings of the Second Annual
Symposium on Fuels from Biomass,
Troy, New York
June 20-22, 1978, pages 701-736 (NTIS)

"Energy, Agriculture and Waste Management"

Author: William J. Jewell et al., Dept. of Agri. Engineering,
Cornell University, Cornell, New York 14853
Publication: Ann Arbor Science Publishers Inc.,
P.O. Box 1425, Ann Arbor,
Michigan 48106

The following publications are related to the project described in summary B-2.

"A Review of International Biomass Programs"

Author: Tracey and Brunstrom Co.
1214 John Street, Seattle, Washington 98109
Presented at: The Second Annual Fuels from
Biomass Symposium, Rensselaer
Polytechnic Institute
Troy, New York
June 20-22, 1978
(\$15.50 printed, \$3.00 microfiche)(NTIS)

"Biomass Energy Technology"

Author: Tracey and Brunstrom Co.,
1214 John Street, Seattle, Washington 98109
Presented at: The International Solar Energy Society
Congress, New Delhi, India
Available from the authors

"Engineering Feasibility of Fuels from Biomass Utilizing Dairy Farm Residue"

Author: Tracey and Brunstrom Co., 1214 John Street,
Seattle, Washington 98109
Publication: (NTIS)

The following publications are related to the project described in summary B-3.

"Design and Operation of a 50000 Gallon Anaerobic Digester at the State Honor Dairy Farm, Monroe, Washington."

Authors: Elizabeth Copinger et al.
Ecotope Group 747 - 16th East,
Seattle, Washington 98112
Publication: Solar Energy Research Institute
1536 Cole Boulevard, Golden,
Colorado 80401 (NTIS)

The following publications are related to the project described in summary B-5.

"Dirt Feedlot Residue Experiments" Quarterly Progress Report
(October 1977)

Author: M. Turk, Hamilton Standard Division
Windsor Locks, Connecticut 06096
Report No.: C00-2952-15, (NTIS)

"Monfort Dirt Lot Experiments" Status Report (March 31, 1978)

Author: Hamilton Standard, United Technologies Corp.,
Windsor Locks, Connecticut 06096
Report No.: C00-2952-17 (NTIS) (\$4.50 printed; \$3.00 microfiche)

"Monfort Waste Conversion Demonstration" Quarterly Progress
Report (July 1977)

Author: M. Turk, Hamilton Standard, United Technologies Corp.,
Windsor Locks, Connecticut 06096
Report No.: C00-2952-14 (\$5.25), (NTIS)

The following publications are related to the project described in summary B-6.

Anaerobic Digestion Technology" Progress Report (June 1977)

Authors: Dynatech R/D Company, 99 Erie Street,
Cambridge, Mass. 02139
Report No.: C00/2991-19 (\$7.25) (NTIS)

"Evaluation of Systems for Purification of Fuel Gas from Anaerobic
Digestion" (July 30, 1978)

Author: E. Ashare, D.C. Augenstein, J.C. Young, J. Hossan,
and L. Duret - Dynatech R/D Company
99 Erie Street, Cambridge, Mass. 02139
Report No.: C00-2991-19 (244 pages) (\$10.75) (NTIS)

"Fuel Gas Production from Animal and Agricultural Residues and Biomass,"
Coordination Meeting Report, Seattle (January 27 1978)

Authors: L. Wise and R.L. Wentworth
99 Erie Street, Cambridge, Mass. 02139
Report No.: C00-2991-28 (154 pages) (\$8.00) (NTIS)

"Fuel Gas Production from Animal and Agricultural Residues and Biomass,"
Coordination Meeting Report, Fort Lauderdale (May 30, 1978)

Authors: L. Wise and R.L. Wentworth
99 Erie Street, Cambridge Mass. 02139
Report No.: C00-2991-34-(208 pages) (\$9.25) (NTIS)

"Fuel Gas Production from Animal Residue" (November 15, 1976)

Authors: E. Ashare, L. Wise, and R.L. Wentworth
99 Erie Street, Cambridge, Mass. 02139
Report No.: C00-2991-10 (141 pages) (\$7.25) (NTIS)

"Fuel Gas Production from Animal Waste" (February 1, 1977)
Authors: E. Ashare, R.L. Wentworth, D.L. Wise -
Dynatech R/D Company, 99 Erie Street,
Cambridge, Mass. 02129
Report No.: C00-2991-11 (\$4.50) (NTIS)

"Fuel Gas Production from Residues and Biomass," Coordination Meeting
Report, Hastings (October 28, 1977)
Authors: R.L. Wentworth and D.L. Wise,
Dynatech R/D Company, 99 Erie Street,
Cambridge, Mass. 02139
Report No.: C00-2991-25 (91 pages) (\$6.00) (NTIS)

The following publications are related to the project described in B-7.

"A Generalized Model for Substrate Utilization Kinetics" (1978)
Authors: Y.R. Chen and A.G. Hashimoto,
P.O. Box 166, USDA, Clay Centre,
Nebraska 68933
Published by: Environmental Engineering Division
American Society of Civil Engineers
345 E 47th Street
New York, NY 10017

"Chemical Composition and Nutritional Value of Anaerobically
Fermented Beef Cattle Residues" (Abstracts)
Authors: R.L. Prior, R.V. Mlejnek, and A.G. Hashimoto,
P.O. Box 166, USDA, Clay Centre, Nebraska 68933
Presented at: Joint Meeting of American Dairy Science
Association
113 N Neil Street
Champaign, Ill 61820; and
American Society of Animal Science
c/o David C. England
Department of Animal Science
Oregon State University
Corvallis, Oregon 97331
Michigan State University, East Lansing,
MI, July 9-13, 1978

"Methane and Biomass Production Systems for Beef Cattle Manure"
Authors: A.G. Hashimoto, R.L. Prior, and Y.R. Chen,
P.O. Box 166, USDA, Clay Centre, Nebraska 68933
Publication: Proceedings, Great Plains Extension Seminar on
Methane Production from Livestock Manure, 1978.
Available from the authors

"Methane Fermentation Kinetics" (Abstracts)
Authors: Y.R. Chen and A.G. Hashimoto, P.O. Box 166,
USDA, Clay Centre, Nebraska 68933
Publication: Symposium No. 8 of Biotechnology in Energy Production and
Conservation, Gatlinburg, TN, May 10-12, 1978
Published by John Wiley & Sons, Inc.
605 Third Avenue
New York, NY 10016

"Methane Fermentation Kinetics (1978)

Authors: Y.R. Chen and A.G. Hashimoto, P.O. Box 166,
USDA, Clay Centre, Nebraska 68933
Accepted by: Biotechnology and Bioengineering
John Wiley & Sons, Inc.
605 Third Avenue
New York, NY 10016

Anaerobic Fermentation of Animal Manure

Authors: A.G. Hashimoto, R.A. Rhodes, Y.R. Chen,
P.O. Box 166, USDA, Clay Centre, Nebraska 68933
Publication: Transactions of American Society of Agricultural Engineers (ASAE)
2950 Niles Road
St. Joseph, MI 49085
ASAE Paper No. 79-4066

"Methane and Protein Production from Animal Feedlot Wastes"

Authors: A.G. Hashimoto, Y.R. Chen, and R.L. Prior
P.O. Box 166, USDA, Clay Centre,
Nebraska 68933
Presented at: 33rd Annual Meeting of the Soil Conservation
Society of America
7515 NE Ankeny Road
Ankeny, IA 50021
Denver, CO
July 30 - August 2, 1978

"Thermophilic, Anaerobic Fermentation of Beef Cattle Residue"

Authors: A.G. Hashimoto, Y.R. Chen, and R.L. Prior
P.O. Box 166, USDA, Clay Centre, Nebraska 68933
Publication: Proceedings, Institute of Gas Technology's Conference
on Energy from Wastes and Biomass
Washington, D.C., August 1978
Institute of Gas Technology
3423 S. State Street
Chicago, Ill 60610

The following articles/publications are related to the project described in summary C-2.

"Evaluation of the State of the Art of Biomass Based Methanol Process."

Progress Report No.: 1, August 14, 1978
Author: Edward Wan
Published by: Science Applications, Inc.,
McLean, Virginia 22101 (NTIS)

The following articles/publications are related to the project described in summary C-5.

"Biomass Conversion: Recent Developments"

Author: E.S. Lipinsky
Presented to: the Interiencia Association, Guarujá,
Brazil, March 15, 1978
Available from the author

"What Roles for Fuels from Biomass"

Author: E.S. Lipinsky
Publication: Energy Digest, 2 (12), June 15, 1977, page 4
Published by Technical Insights, Inc.
158 Linwood Plaza
P.O. Box 1304
Ft. Lee, New Jersey 07024

"Can Sucrose Compete with Hydrocarbons as a Chemical Feedstock?"

Authors: E.S. Lipinsky and W. Sheppard
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201
Publication: Sucrochemistry, American Chemical Society (ACS) Symposium Series
No. 41,
1977, pages 336-350
ACS
1155 16th Street, NW
Washington, D.C. 20036

"Conversion of Sugar Cane Products into Fuels and Chemicals Feedstock"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201
Publication: Sugar Journal, 39, August 1976, pages 27-30.
Available from the author

"Energy: New Crop Sources"

Authors: T.A. McClure and D.A. Scantland
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201
Publication: Agricultural Engineering, September 1977

"Field Crops as a Future Source of Fuels and Chemicals Feedstocks"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201
Publication: Agricultural, Biomass, Wind, New Developments,
7, August 1976, pages 105-107
Available from the author

"Fuels from Biomass: Integration with Food and Materials Systems"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus Ohio 43201
Publication: Science, 199 (4329), February 10, 1978, pages 644-651
American Association for the Advancement of Science
1515 Massachusetts Avenue
Washington, D.C. 2005

"Fuels from Biomass Systems for Arid Land Environments"

Authors: E.S. Lipinsky and S. Kresovich
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201

Presented at: The International Arid Lands Conference on Plant Resource,
October 19, 1978
Proceedings of the Aridland Plant Resources Conference
Aridland Plant Resources
Texas Tech. University
Lubbock, TX 79409

"Fuels from Sugarcane and Corn"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201

Presented at: Power Engineering Society, January 30, 1978
Institute of Electrical and Electronics Engineers
345 E 47th Street
New York, NY 10017

"Fuels from Sugar Crops" First Quarterly Report, (July 29, 1977)

Authors: E.S. Lipinsky et al.
Battelle Columbus Laboratories,
505 King Avenue, Columbus, Ohio 43201

Report No.: TID-27834 (\$8.00), (NTIS)

"Fuels from Sugar Crops: Status and Prospects"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201

Presented at: The American Society of Sugarcane Technologists
P.O. Box 1546
Fort Collins, Colorado 80522
Conference at Orlando, FL., June 22, 1978

"Growing Sugar Crops for Fuel"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201

Presented at: The Second Annual Fuels from Biomass Symposium,
Troy, NY, June 20-22, 1978.

"Perspectives on Preparation of Cellulose for Hydrolysis"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio, 43201

Publication: American Chemical Society Monograph, October 1978
American Chemical Society (ACS)
1155 16th Street, N.W.
Washington, D.C. 20036

"Sugarcane Versus Corn Versus Ethylene as Sources of Ethanol for Motor Fuels and Chemicals"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201
Presented at: The American Society of Sugarcane Technologists (ASSCT)
P.O. Box 1546
Fort Collins, Colorado 80522
Meeting in Fort Walton Beach, FL, June 23, 1977

"Sugar Crops as a Source of Fuel"

Authors: E.S. Lipinsky, S. Kresovich, T. McClure, and W. Lawhon
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201 (NTIS)
Volume I - Agricultural Research, June 31, 1978
Volume II - Processing and Conversion Research, August 31, 1978

"Systems Analysis of Fuels from Biomass"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201
Presented at: The American Physical Society (APS) Conference,
Washington, D.C. March 29, 1978.
APS
335 E 4th Street
New York, NY 10017

"Systems Study for Fuels from Sugarcane, Sweet Sorghum, and Sugar Beets"
(Multi-volume report). Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201. Available from NTIS.

Authors: E.S. Lipinsky et al.
Report No.: Volume I - Comprehensive Evaluation, 1976
BMI-1957-V1/LL (\$8.00)
Report No.: Volume II - Agricultural Consideration, 1976
BMI-1957-V2/LL (\$10.75)
Report No.: Volume III - Conversion of Fuels and Chemical Feedstocks, 1976
BMI-1957-V3/LL (\$9.25)
Report No.: Volume IV - Corn Agriculture, 1977
BMI-1957 A-V4/LL (\$9.25)
Report No.: Volume V - Comprehensive Evaluation of Corn, 1977
BMI-1957 A-V5/LL (\$9.00)

"Systems Study of Sugarcane, Sweet Sorghum, Sugar Beets and Corn for Fuels and Chemical Feedstocks"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201
Publication: Proceedings of Fuels from Biomass Symposium,
University of Illinois, April 18-19, 1977
Available from the author

"The Prospects for Fuels from Biomass"

Author: E.S. Lipinsky
Battelle Columbus Laboratories, 505 King Avenue,
Columbus, Ohio 43201
Publication: Proceedings of the 12th Intersociety Energy Conversion
Engineering Conference, Volume I, Washington, D.C.
August 28 to September 2, 1977.
Available from the author

"Using Sugar Crops to Capture Solar Energy"

Author: E.S. Lipinsky
Battelle Columbus Laboratories
Columbus, Ohio 43201
Publication: Biological Solar Energy Conversion, Academic Press
111 5th Avenue
New York, NY 10003
1977, pages 397-410

The following publications are related to the project described in C-11.

"Biomass Based Alcohol Fuels"

Authors: W. Park, G. Price and D. Salo
Mitre Corporation, Mclean, Virginia 22101
Publication: NTIS

"Comparative Economic Assessment of Ethanol from Biomass"

Author: D. Medville, J. Rosenberg, D. Salo and M. Schauffler,
Mitre Corporation, Mclean, Virginia 22101
Publication: NTIS

The following publications are related to the project described in C-12.

**"Preliminary Engineering and Cost Analysis of Purdue/TSAO
Cellulose Hydrolysis Process"**

Authors: E.A. Kirchner, September 1978,
Publication: Arthur G. McKee Co., 10 S Riverside
Plaza, Chicago, Illinois 60606 (NTIS)

The following publications are related to the project described in D-12.

"Reclaiming Surface Mines with Black Locust Energy Plantations"

Authors: S.B. Carpenter, D.H. Groves, and R.A. Eigel,
University of Kentucky, Lexington, Kentucky 40506
Publication: Kentucky Farmer, January 1979
Kentucky Farmer
P.O. Box 645
Bowling Green, KY 42101

"UK Foresters Study Black Locust on Strip-mining Land"

Author: S.B. Carpenter, University of Kentucky
Lexington, Kentucky 40506
Publication: Cooperative Extension Service News
University of Kentucky
Lexington, Kentucky 40506
July 28, 1978, page 7

The following publications are related to the project described in D-16.

"A Study of Forest Plantations for Timber Production on the Island of Hawaii"

Authors: G.D. Pickford and R.K. LeBarron, Bioenergy Development Corporation, P.O. Box 1826, Honolulu, Hawaii 96805
Publication: USDA Forest Service Technical Paper PSW-52, 1960, 17 pages
Available from: The Pacific SW Forest and Range Experiment Station, Berkeley, CA 94720

"Forest Irrigation: A Review"

Author: E.A. Hansen, North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, Minnesota 55108
Publication: Proceedings, Soil Moisture...Site Productivity Symposium Myrtle Beach, SC, 1977, pages 126-137
Available from the author

"Harvesting and Benefication of Whole Tree Chips from Three Short Rotation, Intensively Cultured Species" (Abstracts)

Authors: J.A. Sturos, J.B. Crist, J.G. Isebrands, and N.D. Nelson North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, Minnesota 55108
Publication: Proceedings, Annual Meeting for Prod. Res. Doc., Atlanta, Georgia, June 25-29, 1978, page 5
Available from the authors

"Intensively Cultured Plantations. Structure and Biomass Production of 1- to 7-Year Old Tamarack in Wisconsin"

Authors: J. Zavitkovski and D.H. Dawson, North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, Minnesota 55108
Publication: Technical Association of Pulp & Paper Industry (TAPPI) 61(6):68-70, 1978
TAPPI
1 Dunwoody Park
Atlanta, Georgia 30338

"Propagating Cuttings of Some Populus Clones for Tree Plantations"

Authors: H.M. Phipps, D. Benton, and D. Netzer North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, Minnesota 55108
Publication: Plant Propagator 24(2):11-13, 1977
International Plant Propagator
P.O. Box 3131
Boulder, Colorado 80307
Available from the author

"Rooting Populus Cuttings in Various Media Bound with a Liquid Polymer"

Author: H.M. Phipps, North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, Minnesota 55108
Publication: Plant Propagator 24(2):11-13, 1978
Available from the author

"Short Rotation Silviculture as an Energy Source (Abstract)"

Author: J.G. Isebrands, North Central Forest Experiment Station,
1992 Folwell Avenue, St. Paul, Minnesota 55108
Publication: Proceedings, National Conference on Forest Product
Utilization Research, Madison, WI,
October 25-27, 1977, page 18
Available from the author

**"Structure and Biomass Production of 1- to 7- year-old Intensively Cultured
Jack Pine Plantations in Wisconsin"**

Authors: J. Zavitkovski and D.H. Dawson
North Central Forest Experiment Station,
1992 Folwell Avenue,
St. Paul, Minnesota 55108
Publication: USDA, Forest Service Research Paper, NC-157, page 15
Available from the authors

**"Structure and Biomass Production of 1- to 7-year-old Intensively Cultured
Tamarack Plantations in Wisconsin"**

Authors: J. Zavitovski and D.H. Dawson
North Central Forest Experiment Station,
1992 Folwell Avenue,
St. Paul, Minnesota 55108
Publication: 1978 Technical Association of Pulp & Paper Industry (TAPPI) Annual
Meeting
Proceedings presented at
Chicago, Illinois, 1978, pages 29-35

"Vegetative Propagation of Populus for Intensively Cultured Plantations"

Authors: D.H. Dawson and H.M. Phipps
North Central Forest Experiment Station,
1992 Folwell Avenue,
St. Paul, Minnesota 55108
Publication: Proceedings, Fourth North American for Biological Workshop,
August 9-11, 1976
State University of New York, Syracuse, NY, pages 8-22
Available from the author

The following publications are related to the project in summary D-17.

"Machine for Row-Mulching Logging Slash to Enhance Site--A Concept"

Authors: P. Koch and D.W. McKenzie, U.S. Forest Service,
2500 Shreveport Highway, Pineville, Louisiana
Publication: Transactions of the American Society of Agricultural Engineers
(ASAE)
2950 Niles Road
St. Joseph, MI 49085
20(1), 1977, pages 13 to 17

"Machine to Harvest Slash, Brush, and Thinnings for Fuel and Fiber--A Concept"

Authors: P. Koch and D.W. McKenzie, U.S. Forest Service,
2500 Shreveport Highway, Pineville, Louisiana
Publication: Journal of Forestry, 74, 1976, pages 809-812

"Utilization of Southern Hardwoods"

Author: P. Koch, U.S. Forest Service,
2500 Shreveport Highway, Pineville, Louisiana
Publication: Proceedings, Second Symposium on Southeastern Hardwoods,
Dothan, AL, 1977, pages 17 to 39
Available from the authors

The following publications are related to the project described in D-18.

"Non-Commercial Woody Plants as Potential Biomass Fuel Producers-
An Ecological Rationale for their Selection"

Authors: H.L. Ragsdale et al, Emory University,
Biology Department, Atlanta, Georgia 30322
Publication: Presented at the 3rd Annual Biomass Energy Systems
Proceedings at Golden, Colorado. October 1979. (NTIS)

The following publications are related to the project described in D-27.

Note: All publications listed below are available from Southeastern Forest Experiment
Station, P.O. Box 2570, Asheville, N.C. 28802

"Attempt to Induce Lightwood in Balsam Fir and Tamarack by Treating
with Paraquat"

Authors: P. Kiatgrajai et al
Publication: Wood Science 9(1), 1976, pages 31-36

"Attempt to Induce Lightwood in Eastern Hemlock by Treating with Paraquat"

Authors: P. Kiatgrajai et al.
Publication: Wood Science 8(3), 1976, pages 170-173

"Capturing Solar Energy in Pine Oleoresin"

Author: D. Roberts
Publication: Capturing the Sun through Bioconversion, Washington Center
for Metropolitan Studies Proceedings, Workshop No. 9,
Long Range Concepts, 1976, pages 673-674

"Chemical Stimulation of Wood Oleoresin Production in Pine Trees"

Author: D. Roberts
Publication: The 1977 McGraw-Hill Yearbook of Science and Technology,
pages 230-231
McGraw-Hill, Inc.
1221 Avenue of America
New York, NY 10018

"Chemically Inducing Lightwood Formation in Southern Pines"

Authors: D. Roberts and W. Peters
Publication: Forest Products Journal 27(6), 1977, pages 28-30

"Lightwood Formation in Red Pine Treated with Paraquat"

Authors: H. Wroblewska, A. Conner, and J. Rowe
Publication: Wood Science 10(1), 1977, pages 1-5

"Lightwood Research Coordinating Council, Proceedings of Annual Meeting, 1975"
"Lightwood Research Coordinating Council, Proceedings of Annual Meeting, 1976"
"Lightwood Research Coordinating Council, Proceedings of Annual Meeting, 1977"
"Lightwood Research Coordinating Council, Proceedings of Annual Meeting, 1978"
"Paraquat-Induced Lightwood in Two European Conifers--Scotch Pine and Norway Spruce"
Authors: H. Wroblewska, A. Conner, J. Rowe, W. Peters, and D. Roberts
Publication: Wood Science 10(4), 1978, pages 181-186

"Status of Lightwood Induction Technology"
Authors: D. Roberts and W. Peters
Publication: Naval Stores Review, January - February 1978, pages 4-5

The following publications are related to the project in D-25

"Silvicultural Biomass Farms, Volume I Summary" (1977)
Authors: R.E. Inman - Mitre Corporation, McLean, Virginia 22102
Report No.: MITRE-TR-7347-VI/LL (\$5.25) (NTIS)

"Silvicultural Biomass Farms, Volume II. The Biomass Potential of Short-rotation Farms" (1977)
Authors: K. Howlett and A. Gamache - Mitre Corporation
McLean, Virginia 22102
Report No.: MITRE-TR-7347-V2/LL (\$8.00) (NTIS)

"Silvicultural Biomass Farms, Volume III-Land Suitability and Availability" (1977)
Authors: K. Howlett and A. Gamache - Mitre Corporation
McLean, Virginia 22102
Report No.: MITRE-TR-7347-V3/LL (\$9.25) (NTIS)

"Silvicultural Biomass Farms, Volume IV. Site-specific Production Studies and Cost Analyses" (1977)
Authors: R.E. Inman, D.J. Salo, and B.J. McGurk - Mitre Corporation
McLean, Virginia 22102
Report No.: MITRE-TR-7347-V4/LL (\$9.00) (NTIS)

"Silvicultural Biomass Farms, Volume V. Conversion Processes and Cost" (1977)
Authors: C. Bliss and D.O. Blake - Mitre Corporation,
McLean, Virginia 22102
Report No.: MITRE-TR-7347-V5/LL (\$11.00) (NTIS)

"Silvicultural Biomass Farms, Volume VI. Forest and Mill Residues as Potential Sources of Biomass" (1977)
Authors: K. Howlett and A. Gamache - Mitre Corporation
Georgia Pacific Corporation
Report No.: MITRE-TR-7347-V6/LL (\$7.25) (NTIS)

"Design of a Pilot Silvicultural Biomass Farm at the Savannah River Plant". March 1977
Authors: D.J. Salo, J.F. Henry, R.E. Inman
Mitre Corporation, McLean, Virginia 22102
Published by: (NTIS)

The following publication are related to the project described in D-28.

"Energy Potential of Intensively Managed Short Rotation Hardwoods"

Author: K. Steinbeck, University of Georgia, Athens, Georgia 30602
Presented at: Forest Products Research Society Meeting, Tuscaloosa, AL,
October 1977

"Energy Values for Young Sprouts of Nine Hardwood Species"

Author: M. Neenan and K. Steinbeck, University of Georgia,
Athens, Georgia 30602

Note: These publications are available from the authors

The following publications are related to the project described in D-35.

"Row Spacing Effects on Biomass and Composition of Sugar Cane in Florida"

Authors: G.J. Gascho and S.F. Shih, University of California,
Department of Soil and Environmental Sciences,
Riverside, California 92521

Publication: Sugar Y Azucar (73(6):36), 1978
Available from the author

"Sugar Cane Biomass Production Related to Climate in Florida"

Authors: G.J. Gascho and S.F. Shih, University of California,
Department of Soil Environmental Sciences,
Riverside, California 92521

Publication: Sugar Y Azucar (73(6):46), 1978
Available from the authors

"Sugar Crops as a Source of Food"

Authors: S. Kresovich, W.T. Lawhorn, E.S. Lipinsky, and T.A. McClure
Publication: Agriculture Research, 1968
Available from: Battelle Columbus Laboratories, Columbus, Ohio 43201

The following publication are related to the project described in E-1.

All are available, free of charge, from:

The American Experiment Station
P.O. Box H
University of Puerto Rico
Rio Piedras, PR 00928

**"Agricultural and Wild Plants as Renewable Energy Sources for Puerto Rico"
(Abstract)**

Author: A.G. Alexander
Publication: Proceedings SOPCA (October 1978)

"Biomass as a Renewable Energy Source"

Author: A.G. Alexander
Presented at: Biomass Workshop, INTERCIENCA/SBPC Symposium, "Energy
and Development in the Americas," Santos, Brazil, March
1978.

**"Production of Sugar Cane as an Alternate Source of Fuels and Chemical
Feedstocks of Puerto Rico"**

Author: A.G. Alexander
Publication: Proceedings of the Puerto Rico Sugar Technology Association,
November 1977

"Production of Sugar Cane and Tropical Grasses as a Renewable Energy Source"
(Technical Quarterly Reports I, II, and III, June I, 1977 to February 28, 1978)

Authors: A.G. Alexander, C. Gonzalez-Molina, J. Ortiz-Velez

"Sugar Cane as a Source of Fiber, Fuels, and Chemical Feedstocks for Puerto Rico"

Author: A.G. Alexander

Publication: Proceedings, Puerto Rico Sugar Technology Association,
November 1978

"Solar Energy Storage by Tropical Grasses and Their Potential as Sources
of Biomass"

Author: A.G. Alexander

Publication: Proceedings, Caribbean Studies Association, January 1978

The following publications are related to the project described in E-2.

"Herbaceous Species Screening Program - Phase I"

Authors: K.A. Saterson, M.K. Luppold, K.M. Scow,
R.E. Lee, Arthur D. Little, ADL Cage No. 82412,
Cambridge, Massachusetts. Available from the authors & NTIS

The following publications are related to the project described in F-1.

"Biological Conversion of Organic Refuse to Methane, Annual Progress Report"
(July 1974)

Authors: C. Liebman and J.T. Pfeffer, Department of Civil Engineering,
University of Illinois, Urbana, Illinois 61801

Report No.: PB-235 468/6GI (184 pages) (NTIS)

"Biological Conversion of Organic Refuse to Methane, Annual Progress Report"
(August 1975)

Authors: J.C. Liebman and J.T. Pfeffer, Department of Civil Engineering,
University of Illinois, Urbana, Illinois 61801

Report No.: PB-247 751/IGI (160 Pages)(NTIS)

"Biological Conversion of Biomass to Methane"
(September 1976)

Author: J.T. Pfeffer, Department of Civil Engineering,
University of Illinois, Urbana, Illinois 61801

Publication: (NTIS)

"Biological Conversion of Biomass to Methane--Quarterly Progress Report"
(December 1976)

Author: J.T. Pfeffer, Department of Civil Engineering,
University of Illinois, Urbana, Illinois 61801

Publication: Available from the authors

"Biological Conversion of Organic Refuse to Methane, Final Report, Volume I"
(1976)

Authors: J.T. Pfeffer, J.C. Liebman, J.W. Brown and G.E. Quindry
Department of Civil Engineering, University of Illinois,
Urbana, Illinois 61801

Report No.: C00-2917-3-VI (\$9.00) (NTIS)

"Biological Conversion of Organic Refuse to Methane, Final Report, Volume 2"
Authors: J.T. Pfeffer, J.C. Liebman, J.W. Brown, and G.E. Quindry,
Department of Civil Engineering, University of Illinois,
Urbana, Illinois 61801
Report No.: C00-2917-3-V2 (\$6.50), (NTIS)

"Biological Conversion of Biomass to Methane--Quarterly Progress Report"
(April 1977)
Author: J.T. Pfeffer, Department of Civil Engineering,
University of Illinois, Urbana, Illinois 61801
Report No.: C00-2917-5, (NTIS)

"Biological Conversion of Biomass to Methane, The Effect of Reactor Design
on Kinetics" (December 1977)
Authors: R.H. Geissers and J.T. Pfeffer, Department of Civil Engineering,
University of Illinois, Urbana, Illinois 61801
Report No.: C00/2917-8 (59 pages)(NTIS)

"Biological Conversion of Biomass to Methane" Quarterly Progress Report
(May 1978)
Author: J.T. Pfeffer, Department of Civil Engineering,
University of Illinois, Urbana, Illinois 61801
Report No.: C00-2917-10 (NTIS)

"Biological Conversion of Biomass to Methane, Beef Lot Manure Studies"
(July 1978)
Authors: J.T. Pfeffer and G.E. Quindry, Department of Civil
Engineering, University of Illinois, Urbana, Illinois 61801
Report No.: C00/2917-9 (708 pages), (NTIS)

"Production of Panel Board from Residue Left from the Fermentation of
Organic Wastes to Methane"
Authors: C.S. Walters, J.T. Pfeffer, and P. Chaw,
Department of Civil Engineering, University of
Illinois, Urbana, Illinois 61801
Publication: Forest Products Journal, Volume 27(9), 1977, pages 12-20
Available from the authors

"Reclamation of Energy from Organic Wastes" (1974)
Author: J.T. Pfeffer, Department of Civil Engineering,
University of Illinois, Urbana, Illinois 61801
Report No.: PB-231 196/9G1 (132 pages) (\$6.50), (NTIS)

The following articles are related to the project described in G-3.

"Computation of the Fraction of Induced Cells in Enzyme Induction Systems"
Authors: C.R. Wilke, U. Von Stockoi, and R.D. Yang,
University of California, Lawrence Berkeley Labs.,
Berkeley, California 94720
Publication: Biotechnology and Bioengineering 19, 1977,
pages 445-458
John Wiley & Sons, Inc.
605 Third Avenue
New York, NY 10016

"Continous Cellulase Production"

Authors: C.R. Wilke and G. Mitra, University of California,
Lawrence Berkeley Labs., Berkeley, California 94720
Publication: Biotechnology and Bioengineering 17, 1975, page 1
John Wiley & Sons, Inc.
605 Third Avenue
New York, NY 10016

"Ethanol Effects on the Kinetics of Continuous Fermentation with Saccharomyces cerevisiae"

Authors: C.R. Wilke and C.D. Bazua, University of California,
Lawrence Berkeley Labs., Berkeley California 94720
Publication: Biotechnology and Bioengineering 7, 1977, pages 105-118
John Wiley & Sons, Inc.
605 Third Avenue
New York, NY 10016

"Exponential Growth Kinetics for Polyporus versicolor and Pleurotus ostreatus in Submerged Culture"

Authors: C.R. Wilke and P.A. Carroad, University of California,
Lawrence Berkeley Labs., Berkeley, California 94720
Publication: Applied and Environmental Microbiology 33, 1977, page 871
Available from the author

"Rapid Ethanol Fermentation Using Vacuum and Cell Recycle"

Authors: C.R. Wilke and G.R. Cysewski, University of California,
Lawrence Berkeley Labs., Berkeley, California 94720
Publication: Biotechnology and Bioengineering 19, 1977, page 1125
John Wiley & Sons, Inc.
605 Third Avenue
New York, NY 10016

"Utilization of Cellulase Materials through Enzymatic Hydrolysis, I. Fermentation of Hydrolysate to Ethanol and Single Protein"

Authors: C.R. Wilke, G.R. Cysewski and R.D. Yang
University of California, Lawrence Berkeley Labs., Berkeley,
California 94720
Publication: Biotechnology and Bioengineering 18, 1976, pages 1315-1323.
John Wiley & Sons, Inc.
605 Third Avenue
New York, NY 10016

The following publication is related to the project described in G-4.

"Fuels from Biomass Newsletter"

Issues published prior to March 1979 available through:
Dr. Henry Bungay,
Rensselaer Polytechnic Institute
Dept. of Chemical and Environmental Engineering,
Troy, New York 12181
Issues published after March 1979 available through:
Dr. Larry Douglas
Solar Energy Research Institute
1536 Cole Boulevard
Golden, Colorado 80401

The following publications are related to the project described in H-2.

"A Review of Heat/Mass Balances and Product Data During Partial Oxidation of Cattle Feedlot Manure"

Authors: W.J. Huffman, S.R. Beck, J.E. Halligan, and B.C. Landeene,
Texas Tech University, Lubbock, Texas 79409
Presented at: The 84th National American Institute of Chemical Engineers (AIChE)
Meeting, Atlanta, GA
February 26- March 1, 1978
AIChE
345 E 47th Street
New York, NY 10017

"Ammonia Synthesis Gas from Manure"

Authors: W.J. Huffman, R.L. Peterson, and J.E. Halligan,
Texas Tech University, Lubbock, Texas 79409
Presented at: Centennial American Chemical Society (ACS) Meeting, New York,
NY,
April 6-7, 1976
ACS
1155 16th Street, SW
Washington, D.C. 20036

"Conversion of Cattle Feedlot Wastes to Ammonia Synthesis Gas"
(1974) 55 pages

Authors: J.E. Halligan, K.L. Herzog, and H.W. Parker,
Texas Tech University, Lubbock, Texas 79409
Available from: (NTIS)

"Fluidized Bed Gasification of Cattle Feedlot Manure"

Author: S.R. Beck, Texas Tech University, Lubbock, Texas 79409
Presented at: Second Annual Fuels from Biomass Symposium,
Troy, NY, June 20-22, 1978(NTIS)

"Kinetic Analysis of Manure Pyrolyzers"

Authors: W.J. Huffman, C. Lin, S.R. Beck, and J.E. Halligan
Texas Tech University, Lubbock, Texas 79409
Presented at: Seminar on Thermochemical Conversion of Biomass Residues,
Golden, CO, November 30 - December 1, 1977(NTIS)

"Partial Oxidation of Cattle Feedlot Manure"

Authors: W.J. Huffman, J.E. Halligan, R.L. Peterson,
and E.M. de la Garza
Texas Tech University, Lubbock, Texas 79409
Presented at: Institute of Gas Technology (IGT), 2nd Symposium,
Clean Fuels from Biomass and Waste, January 1977.
IGT
3424 State Street
Chicago, Ill 60616

"Synthesis Gas from Bovine Wastes"

Authors: J.E. Halligan, K.L. Herzog, and H.W. Parker
Texas Tech University, Lubbock, Texas 79409
Publication: Industrial Engineering Chemistry, Process Design Development,
14, 1975, pages 64-69
Available from the author

"Thermochemical Evaluation of Animal Waste Conversion Processes"

Authors: J.E. Halligan and R.M. Sweazy, Texas Tech University,
Lubbock, Texas 79409
Presented at: The 72nd National American Institute of Chemical Engineers (AIChE)
Meeting,
St. Louis, MO, May 21-24, 1972
AIChE
345 E 47th Street
New York, NY 10017

"Variable Velocity Fluidized Bed for Pyrolysis of Biomass"

Authors: S.R. Beck, W.J. Huffman, U. Mann, and H.D. Wong,
Texas Tech University, Lubbock, Texas 79409
Publication: American Chemical Society (ACS) Symposium Series, No. 76, 1978,
pages 307-322
ACS
1155 16th Street, SW
Washington, D.C. 20036

The following publication are related to the project described in H-3.

"Catalyzed Gasification of Biomass"

Authors: J.L. Cox, D.H. Mitchell, L.K. Mudge, R.J. Robertus,
L.J. Sealock, Jr., and P.C. Walkup, Battelle Pacific North
West Labs, Richland, Washington 99352
Presented at: First World Conference on Future Sources of Organic
Raw Materials, July 10-13, 1978
Toronto, Ontario
PNL-SA-6689, Available from the authors

"Investigation of the Gasification of Biomass in the Presence of Catalyst"

Authors: D.H. Mitchell, L.K. Mudge, R.J. Robertus, and L.J. Sealock, Jr.
Battelle Pacific North West Labs, Richland, Washington 99352
Presented at: Fourth Biomass Thermochemical Conversion Coordination
Meeting: Fuels From Biomass Program, April 26-27, 1978

"Investigation of the Gasification of Biomass in the Presence of Catalyst"

Authors: E.G. Baker, D.H. Mitchell, L.K. Mudge, R.J. Robertus,
L.J. Sealock, Jr., and P.C. Walkup, Battelle Pacific North West
Labs, Richland, Washington 99352
Presented at: Fifth Biomass Thermochemical Conversion Meeting
Fuels from Biomass Program, September 19-20, 1978

"Investigation of Gasification of Biomass in the Presence of Multiple Catalyst"

Authors: J.L. Cox, L.K. Mudge, R.J. Robertus, L.J. Sealock, Jr.,
and P.C. Walkup, Battelle Pacific North West Labs,
Richland, Washington 99352

Presented at: Second Annual Fuels from Biomass Symposium,
June 20-22, 1978
Rensselaer Polytechnic Institute
Troy, New York
(NTIS)

The following publication is related to the project described in I-2.

"Bench-Scale Research in Thermochemical Conversion of Biomass to Liquids in Support of the Albany, Oregon, Experimental Facility"
(October 26, 1977)

Authors: D.C. Elliott and P.C. Walkup - Battelle, Pacific Northwest
Laboratories, Richland, Washington 99352

Report No.: TID-28415 (NTIS)

The following publication is related to the project described in I-5

"Technical Evaluation of the Waste-to-Oil Process Development Facility at Albany, Oregon" (1974)

Authors: E.H. Houle, S.F. Ciriello, S. Ergun, D.J. Basuino,
W.M. Keck Lab., California Institute of Technology,
101 Dahlia Street, Corona del Mar, California 92625

Publication: Available from the authors

The following publications are related to the project described in J-2.

"A Novel Route to the Production of Acetic Acid by Fermentation"

Authors: D. Wang, R. Fleischaker, and G. Wang,
Massachusetts Institute of Technology,
Cambridge, Mass. 02139

Publication: Biochemical Engineering: Renewable Resources of Energy
and Chemical Feedstocks, American Institute of Chemical Engineers
(AIChE) Symposium Series 181,
Volume 74, 1978, page 105
AIChE
345 E 47th Street
New York, NY 10017

"Anaerobic Biomass Degradation to Produce Sugars, Fuels, and Chemicals"

Authors: D. Wang, C. Cooney, S. Wang, J. Gordon, and G. Wang,
Massachusetts Institute of Technology,
Cambridge Mass. 02139

Publication: Proceedings of the Second Annual Fuels from Biomass
Conference, Volume I, Troy, N.Y., 1978, page 537(NTIS)

"Degradation of Cellulosic Biomass and its Subsequent Utilization for the Production of Chemical Feedstocks" - Progress Reports

Authors: D. Wang, C. Cooney, A. Demain, R. Gomez, and A. Sinskey, Massachusetts Institute of Technology, Cambridge, Mass. 02139

Report No.: C00-4198-1 (May 1977) 96 pages
C00-4198-2 (June 1977) 80 pages
C00-4198-3 (September 1977) 112 pages
C00-4198-4 (November 1977) 231 pages
C00-4198-5 (February 1978) 163 pages
C00-4198-6 (May 1978) 202 pages
C00-4198-7 (August 1978) 205 pages
C00-4198-8 (November 1978) 139 pages
(NTIS)

"Sugar Accumulation During Enzyme Hydrolysis and Fermentation of Cellulose"

Authors: J. Gordon, M. Jimenez, C. Cooney, and D. Wang, Massachusetts Institute of Technology, Cambridge Mass. 02139

Publication: Biochemical Engineering: Renewable Resources of Energy and Chemical Feedstocks, American Institute of Chemical Engineering (AIChE) Symposium Series 181
Volume 74, 1978, page 91
AIChE
345 E 47th Street
New York, NY 10017

The following publication is related to the project described in J-3.

"Photocatalytic Decomposition of Water at Semiconductor Electrodes"

Authors: H.P. Maruska and A.K. Ghosh, Exxon Research and Engineering Co., Linden, New Jersey 07036

Publication: Journal of Solar Energy, Volume 20, 1978, pages 443-458

Available from: Authors, Exxon Research and Engineering Company, Linden, New Jersey 07036

"Sensitized Photoelectrolysis of Water by Sunlight"

Authors: A.K. Gosh and H.P. Maruska, Exxon Research and Engineering Co., Linden, New Jersey 07036

Report No.: C00-4271-1, September 1977, 64 pages
C00-4271-2, December 1977, 25 pages
C00-4271-3, March 1978, 16 pages
C00-4271-4, June 1978, 35 pages
C00-4271-5, September 1978, 22 pages
C00-4271-6, December 1978, 163 pages

Available from: Authors, Exxon Research and Engineering Company, Linden, New Jersey 07036

The following publications are related to the project described in L-3.

"Adverse Factors Affecting Giant Kelp and Associated Seaweeds"

Authors: W.J. North, California Institute of Technology, Pasadena, California 91125

Publication: Proc. Symp. Pathogens of Marine Algae, Experientia, Available from the author

"Algae Nutrition in the Sea-Some Thoughts about Management Possibilities"

Author: W.J. North, California Institute of Technology,
Pasadena, California 91125
Publication: The Marine Plant Biomass of the Pacific Northwest Coast,
Oregon State University (OSU) Press, Corvallis, Oregon, 1977,
Pages 215 to 230
Available from OSU

"Concerning the Selection of Seaweeds Suitable for Mass Cultivation in a Number of Large Open-ocean, Solar Energy Facilities (Marine Farms) in Order to Provide a Source of Organic Matter for Conversion to Food, Synthetic Fuels, and Electrical Energy"

Authors: G.A. Jackson and W.J. North,
California Institute of Technology,
Pasadena, California 91125
Contract No.: N60530-73-MV176 (135 pages)
Available from: U.S. Naval Weapons Center, China Lake, California

"Evaluating Oceanic Farming of Seedwoods" Semi-Annual Progress Report (June 1 to November 30, 1974)

Author: W.J. North,
California Institute of Technology,
Pasadena, California 91125
Report No.: NSF/RANN/SE/GI-43881/PR/74/2 (53 pages)
National Science Foundation (NSF)
1800 G Street, NW
Washington, D.C. 20550

"Evaluating Oceanic Farming of Seedweeds as Sources of Organics and Energy" Semi-Annual Progress Report (December 1, 1974 to December 31)

Authors: B.N. Anderson and W.J. North,
California Institute of Technology,
Pasadena, California 91125
Report No.: NSF/RANN/SE/GI-43881/PR/75/4/ (210 pages)
National Science Foundation (NSF)
1800 G Street, NW
Washington, D.C. 20550

"Growth Factors in the Production of Giant Kelp"

Author: W.J. North, California Institute of Technology,
Pasadena, California 91125
Publication: Symposium Papers, Clean Fuels from Biomass and Wastes,
1977, pages 128-140
Available from: Institute of Gas Technology, Chicago, IL 60616

"Nutritional Requirements of Macrocytistics"

Authors: W.J. North and P.A. Wheeler,
California Institute of Technology,
Pasadena, California 91125
Publication: Proceedings, 9th International Seaweed Symposium
Santa Barbara California
Available from the authors

"Possibilities of Biomass from the Ocean: the Marine Farm Project"
Author: W.J. North, California Institute of Technology,
Pasadena, California 91125
Publication: Biological Solar Energy Conversion, Academic Press
New York, NY 10003
November 1976, pages 347-361

"Ocean Food and Energy Farm Project, Subtasks 1 and 2: Biological Studies
of *Macrocystis Pyrifera* Growth in Upwelled Oceanic Water, Final
Report" (November 1976)

Authors: W.J. North et al., California Institute of Technology,
Pasadena, California 91125
Report No.: ERDA/USN/1027/76/4/ (259 pages)(NTIS)

"Progress in Studies of Oceanic Production of Biomass"

Author: W.J. North, California Institute of Technology,
Pasadena, California 91125
Publication: Proceedings, Second Annual Symposium on Fuels from Biomass
Rensselaer Polytechnic Institute
Troy, New York
(NTIS)

"The Oceanic Setting as a Site for Biomass Production"

Author: W.J. North, California Institute of Technology,
Pasadena, California 91125
Publication: Proceedings, Fuel from Biomass Symposium
April 18-19, 1977; pages 99-114
University of Illinois
Urbana, Ill
(NTIS)

The following publication is related to the project described in J-4.

"Background Information for the Economic Assessment of Solvent Fermentation
Processes" (January 1977)

Author: E.K. Pye,
University of Pennsylvania, Medical School,
Philadelphia, Pa 19104
Report No.: C00/4070-4
(NTIS)

"Studies on Cellulose Degradation by a *THERMOACTINOMYCES* Sp."
(April 1977)

Authors: E.K. Pye, A.E. Humphrey, and J.R. Forro,
University of Pennsylvania, Medical School,
Philadelphia, Pa 19104
Report No.: C00/4070-1, (NTIS)

The following publication is related to the project described in J-5.

"Acetic Acid Production from Marine Algae" (October 14, 1977)

Authors: J.E. Sanderson, D.C. Augenstein, and D.L. Wise -
Dynatech R/D Co. 99 Erie Street, Cambridge, Mass. 02139
Report No.: C00/4388-1, (NTIS)

The following publication is related to the project described in J-6.

"Semiquantitative Plate Assay for Determination of Cellulase Production
by Trichoderma viride"

Authors: B.S. Montencourt and D.E. Eveleigh,
Rutgers University, Cook College, New Brunswick,
New Jersey 08903
Publication: Applied Environmental Microbiology 33,
1977, pages 178-183

The following publications are related to the project described in K-1.

"Chemistry, Population and Resources"

Author: M. Calvin,
University of California, Lawrence Berkeley
Laboratory, Chemical Biodynamic Division,
Berkeley, California 94720
Publication: Pure and Applied Chemistry 50, 407 (1978)
Available from the author

"Fermentation and Hydrocarbons"

Author: M. Calvin,
University of California, Lawrence Berkeley Laboratory,
Chemical Biodynamic Division,
Berkeley, California 94720
Publication: Proceedings, International Conference on Bio-Energy:
Energy from Living Systems, Gottlieb - Duttweiler Institute,
Ruschlikon-Zurich, Switzerland, 1978, pages 89-117
Available from the author

"Green Factories"

Author: M. Calvin,
University of California, Lawrence Berkeley
Laboratory, Chemical Biodynamic Division,
Berkeley, California 94720
Publication: Chemical Engineering News, March 20, 1978, pages 30-36
American Chemical Society
1155 16th Street, NW
Washington, D.C. 20036

"Green Factories for Liquid Fuel"

Authors: G. Calvin and M. Calvin,
University of California, Lawrence Berkeley Laboratory,
Chemical Biodynamics Division,
Berkeley, California 94720
Publication: Lawrence Berkeley Laboratory Report 7584, April 1978.
Available from the authors

"Hydrocarbons via Photosynthesis"

Author: M. Calvin,
University of California, Lawrence Berkeley Laboratory,
Chemical Biodynamics Division,
Berkeley, California 94720
Publication: Energy Research I, 299 (1977)
Available from the author

"Petroleum Plantations"

Author: M. Calvin,
University of California, Lawrence Berkeley Laboratory,
Chemical Biodynamics Division,
Berkeley, California 94720
Publication: Lawrence Berkeley Laboratories Report 8236, April 1978
Available from the author

"Plant Crops as a Source of Fuel and Hydrocarbon-like Materials"

Authors: P. Nielsen, H. Nishimura, J. Otvos, and M. Calvin,
University of California, Lawrence Berkeley Laboratory
Chemical Biodynamics Division, Berkeley, California 94720
Publication: Science, 198, 942 (1977)
American Association for the Advancement of Science
1515 Massachusetts Avenue
Washington, D.C. 20025

"The Only Source of Energy"

Authors: G. Calvin and M. Calvin,
University of California, Lawrence Berkeley Laboratory,
Chemical Biodynamics Division, Berkeley, California 94720
Publication: Lawrence Berkeley Lab., Report 7548, March 1978
Available from the author

The following publications are related to the project described in L-1.

"Biomass Production by Some Marine and Freshwater Plants"

Authors: T.A. DeBask, M.D. Hanisak, J.H. Ryther, R.W. Stenberg,
and L.D. Williams, Woodhole, Oceanographic Institute,
Woodhole, Mass. 02543
Presented at: Second Annual Fuels from Biomass Conference,
Rensselaer Polytechnical Institute
Troy, N.Y.
June 20-22, 1978
(NTIS)

"Cultivation of Macroscopic Marine Algae and Freshwater Aquatic Weeds"
Progress Report (December 1976)

Author: J.H. Ryther,
Woodhole Oceanographic Institute,
Woodhole, Mass. 02543
Report No.: C00/2948-2
(NTIS)

"Growth Patterns of Codium Fragile Subsp. Tomentosoides in Response to Temperature, Irradiance, Salinity, and Nitrogen Source"

Author: M.D. Hanisak, Woodhole, Oceanographic Institute,
Woodhole, Mass. 02543
Publication: Marine Biology
Available from the author

"Some Aspects of the Growth and Yield of Gracilaria Foliifera in Culture"

Authors: B.E. Lapointe and J.H. Ryther,
Woodshole, Oceanographic Institute,
Woodshole, Mass. 02543
Publication: Aquaculture, 1978
Available from the author

"Uptake of Inorganic Nitrogen by Codium Fragile Subsp. Tormentosoides (Chlorophyta)

Authors: M.D. Hanisak and M.M. Harlin,
Woodshole Oceanographic Institute,
Woodshole, Mass. 02543
Publication: Journal of Psychology, May 1978
Journal Press
2 Commercial Street
Provincetown, MA 02657

The following publication is related to the project described in L-2.

"Mass Production of Algae-Bioengineering Aspects"

Authors: J.C. Goldman and J.H. Ryther,
Woodshole Oceanographic Institute,
Woodshole, Mass. 02543
Publication: Biological Solar Energy Conversion, 1977 Academic Press
New York, NY 10007
pages 367-378

The following publications are related to the project described in L-5.

"Cost Analysis of Aquatic Biomass Systems" Volume I or two volumes (July 25, 1978)

Authors: E. Ashare et al., Dynatech R/D, 99 Erie Street,
Cambridge, Mass. 02139
Report No.: HCP/ET-4000-78/1 (\$11.00 printed, \$3.00 microfiche)(NTIS)

"Reviewers Comments on Cost Analysis of Aquatic Biomass Systems" Volume II of two volumes (July 25, 1978)

Authors: E. Ashare et al.,
Dynatech R/D, 99 Erie Street,
Cambridge, Mass. 02139
Report No.: HCP/ET-4000-78/2 (\$6.50 printed; \$3.00 microfiche), (NTIS)

"Tropical Report on Sources and Systems for Aquatic Plant Biomass as Energy Resource" (October 21, 1977)

Authors: J.C. Goldman, J.H. Ryther, R. Waaland, E.H. Wilson
Dynatech R/D, 99 Erie Street,
Cambridge, Mass. 02139
Report No.: DST-4000-77/1, (NTIS)

The following publication is related to the project described in L-6.

"Algal Concentration by Ultrafiltration" (1976)

Author: H.P. Gregor;
Columbia University, School of Engineering and
Applied Science, New York, N.Y. 10027
Report No.: C00/4076-2, (NTIS)

The following publications are related to the project described in L-8.

"A Critical Analysis of Bioconversion with Microalgae"

Authors: W.J. Oswald and J.R. Benemann,
University of California, Berkeley, California 94720
Publication: Biological Solar Energy Conversion
Academic Press
New York, NY
1977, pages 379-396

"Cost Analysis of Microalgae Biomass Systems" Final Report

Authors: W.J. Oswald and J.R. Benemann,
University of California, Berkeley, California 94720
Report No.: HCP/T1605-01, (NTIS)

"Cultivation on Sewage of Microalgae Harvestable by Microstrainers"

Progress Report

Author: J.R. Benemann et al.,
University of California, Berkeley, California 94720
Report No.: TID-27702 (\$9.25), (NTIS)

"Energy Production with Microalgae"

Author: J.R. Benemann et al.,
University of California, Berkeley, California 94720
Publication: Nature, 268, 1977, pages 19-23
McMillan Journals Ltd
4 Little Essex Street
London WC2R32F, England

"Species Control in Large-Scale Algal Biomass Production" (November 1977)

Authors: J.R. Benemann et al.,
University of California, Berkeley, California 94720
Report No.: SAN/7405-77/1, (NTIS)

**"Cultivation on Sewage of Micro Algae Harvestable by Microstrainers--
Progress Report" (April 1977)**

Authors: J.R. Benemann, B.L. Loopman, J.C. Weissmann, D.M. Eisenberg,
and W.J. Oswald -
Lawrence Berkeley Laboratory, University of California 94720
Report No.: TID-27702 (\$9.25), (NTIS)

The following publications are related to the project described in H-6.

"Conversion of Biomass Materials into Gaseous Products"

Author: D.E. Garrett,
Garrett Energy Research and Engineering Co.,
Ojai, California 93023
Report No.: SAN/1241-71/1 (\$6.00), (NTIS)

"Environmental Considerations in Forest Residue Energy Production"

Author: D.E. Garrett,
Garrett Energy Research and Engineering Co.,
Ojai, California 93023
Publication: American Institute of Chemical Engineers (AIChE) Symposium
Series, 177, 74, 1978, pages 87-91
AIChE
345 E. 47th Street
New York, NY 10017

"Thermal Processing of Biomass Materials: Technological and Economic Considerations"

Authors: D.E. Garrett and S. Vatcha,
Garrett Energy Research and Engineering Co.,
Ojai, California 93023
Publication: Proceedings of the 5th National Conference:
Energy and the Environment
Available from U.S. Environmental Protection Agency
R&D Branch
Cincinnati, Ohio 45268

"The Garrett Energy Research Biomass Gasification Process"

Authors: R. Mikesell, Dinh Co Hang, and D.E. Garrett,
Garrett Energy Research and Engineering Co.,
Ojai, California 93023
Publication: Symposium: Energy from Biomass and Wastes, August 14,
1978, pages 749-768 (published by the Institute of Gas
Technology, Chicago, IL 60616)

The following publications are related to the project described in M-2.

"Mission Analyses for the Federal Fuels from Biomass Program"

Authors: F.A. Schooley et al. - SRI International,
Menlo Park, California 94025
Volume I - Summary and Conclusions, December 1978
Volume II - Mission Selection, Market Penetration Modelling,
and Economic Evaluation, December 1978
TID-29091, (NTIS)
Volume III - Feedstock Availability (NTIS)
Volume IV - Thermochemical Conversion of Biomass to Fuels
and Chemicals, January 1979 (NTIS)
Volume V - Biochemical Conversion of Biomass to Fuels and Chemi-
cals
Report No.: TID-29093 (NTIS)

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Volume 2: East North-Central Including: Illinois, Indiana, Michigan, Ohio, Wisconsin
Volume 3: West North-Central Including: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
Volume 4: South Atlantic Including: Delaware, Florida, Georgia, Maryland, North Carolina, Virginia, West Virginia
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Volume 7: Mountain Including Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming

Volume 8: Pacific Including: California, Oregon, Washington

Author: Stanford Research Institute

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Author: A.F. Jensen

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Available through: Anthony F. Jensen
University of Florida
118 Newins-Ziegler Hall
Gainesville, FL 32611
(no charge)

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Authors: J.C. Weissman and J.R. Benemann

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Author: Naval Undersea Center

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Authors: A.L. James and D.W. Murphy - Hawaii Laboratory, Naval Undersea Center

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Author: R.E. Desrosiers
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Author: R.C. Baillie - West Virginia University
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Authors: J.R. Forro and E.J. Nolan - General Electric Company
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Authors: E. Mariani et al. - Marelco, Inc.
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APPENDIX

APPENDIX

Fiscal Year 1978 Biomass Projects—A Comparison of Current and Past Program Categories

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Current Program Category as of January 1979 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Updates Published in September 1978 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Program Summary Published in January 1978 (Element/Sub-element)</u>
A-1	Wheelabrator Clean-fuel Corp.	Advanced System Demonstration for Utilization of Biomass as an Energy Source	Technology Support/Direct Combustion Systems	---	---
A-2	Aerospace Research Corp.	Development of Wood as an Alternative Fuel for Large Power Generation Systems	Technology Support/Direct Combustion Systems	---	Conversion of Biomass/ Thermochemical Conversion
A-3	Nor'West-Pacific Corp.	Study of Wood-Fired Electric Power Generating Plants	Technology Support/Direct Combustion Systems	Thermochemical Conversion/ Direct Combustion	---
B-1	Cornell University	Anaerobic Digestion of Agricultural Residues: Potential for Improvement and Implementation	Technology Support/On-Farm Systems	---	Conversion of Biomass/Anaerobic Digestion
B-2	Tracey & Brunstrom Co.	Engineering Feasibility of Fuels from Biomass Utilizing Dairy Farm Residue	Technology Support/On-Farm Systems	Biochemical Conversion/ Anaerobic Digestion	---
B-3	Ecotope Group	Monitor, Test, and Evaluate an Operational Digester for 350 Cattle Units	Technology Support/On-Farm Systems	---	Conversion of Biomass/Anaerobic Digestion
B-4	United Technologies Corp.	Experimental Anaerobic Digestion Facility	Technology Support/On-Farm Systems	---	Conversion of Biomass/Anaerobic Digestion
B-5	United Technologies Corp.	Dirt Lot Residue Experiments	Technology Support/On-Farm Systems	---	Conversion of Biomass/Anaerobic Digestion
B-6	Dynatech R/D Co.	Engineering Evaluation of the Recovery of the Energy Value of Animal Residues	Technology Support/On-Farm Systems	---	Conversion of Biomass/Anaerobic Digestion
B-7	U.S. Department of Agriculture	Anaerobic Digestion of Beef Cattle Manure and Crop Residues	Technology Support/On-Farm Systems	---	Conversion of Biomass/Anaerobic Digestion
B-8	SRI International	Evaluation of the Proposed Bio-gas Project at Lamar, Colorado	Technology Support/On-Farm Systems	Biochemical Conversion/ Anaerobic Digestion	---

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Current Program Category as of January 1979 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Updates Published in September 1978 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Program Summary Published in January 1978 (Element/Sub-element)</u>
B-9	Touche Ross & Co.	Economic Analysis of Proposed Bio-conversion Facility - Lamar, Colorado	Technology Support/On-Farm Systems	Biochemical Conversion/ Anaerobic Digestion	---
C-1	Louisiana State University	The Potential for Producing and Harvesting Sugarcane and Sweet Sorghum as a Renewable Biomass Energy Resource	Technology Support/Alcohol Production Systems	---	---
C-2	Science Applications, Inc.	Conversion of Biomass Resources to Methanol	Technology Support/Alcohol Production Systems	Thermochemical Conversion/ Gasification	---
C-3	U.S. Department of Agriculture	Sugarcane Spacing Study and High-Fiber Sugarcane Selection	Technology Support/Alcohol Production Systems	---	Production and Collection of Biomass/Agricultural Production
C-4	U.S. Department of Agriculture	Sweet Sorghum Energy Research	Technology Support/Alcohol Production Systems	Biochemical Conversion/ Fermentation	---
C-5	Battelle Columbus Laboratories	Carbohydrate Crops as a Renewable Resource for Fuel Production	Technology Support/Alcohol Production Systems	---	Production and Collection of Biomass/Agricultural Production
C-6	Battelle Columbus Laboratories	Feasibility of Integrating Corn Agriculture with the Manufacture of Fermentation Fuels	Technology Support/Alcohol Production Systems	---	---
C-7	Battelle Columbus Laboratories	Evaluation of Feasibility of Sequential Fermentation for the Production of Ethanol	Technology Support/Alcohol Production Systems	---	---
C-8	Battelle Columbus Laboratories	Economics of Manufacturing Liquid Fuels from Corn Stover	Technology Support/Alcohol Production Systems	---	---
C-9	Bernard Wolnak & Associates	Economics of Conversion of Cellulose (Wood) and Corn Starch to Sugars, Alcohol, and Yeast	Technology Support/Alcohol Production Systems	Biochemical Conversion/ Fermentation	---
C-10	University of Florida	Sugarcane Growth for Use as an Energy Crop	Technology Support/Alcohol Production Systems	---	---
C-11	The MITRE Corp.	Biomass-Based Alcohol Fuels	Technology Support/Alcohol Production Systems	---	---

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Current Program Category as of January 1979 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Updates Published in September 1978 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Program Summary Published in January 1978 (Element/Sub-element)</u>
C-12	Arthur G. McKee & Co.	Preliminary Engineering and Cost Analysis of Purdue/Tsao Cellulose Hydrolysis Process	Technology Support/Alcohol Production Systems	Biochemical Conversion/Fermentation	---
D-1	Purdue Research Foundation	Species Selection for Silvicultural Energy Farms on Reclaimed Mineland	Production Systems/Silviculture	Production and Harvest	---
D-2	General Electric Co.	Energy Biomass Production Study	Production Systems/Silviculture	Production and Harvest	---
D-3	Hawaiiana Investment Co., Inc. (C. Brewer)	Eucalyptus Farms for Energy Production in Hawaii	Production Systems/Silviculture	---	---
D-4	Michigan Technological University	Application of Sugar Maple and Black Locust to the Biomass Energy Farm Concept	Production Systems/Silviculture	Production and Harvest	---
D-5	North Carolina State University	Species Selection and Silvicultural Systems for Producing Fuels from Woody Biomass in the Southeastern United States	Production Systems/Silviculture	Production and Harvest	---
D-6	North Carolina State University	Economics and Operating Characteristics of Various Materials Handling Systems and Wood Fuels in Small- to Medium-Sized Boiler Facilities	Production Systems/Silviculture	Production and Harvest	---
D-7	Alabama A&M University	Recovery of Above-Ground Woody Biomass (Logging Residue) Using Operational Modifications of Conventional Harvesting Systems	Production Systems/Silviculture	Production and Harvest	---
D-8	Virginia Polytechnic Institute and State University	An Integrated Investigation of Procurement, Harvesting, Drying, Transportation, and Storage of Woody Biomass	Production Systems/Silviculture	Production and Harvest	---
D-9	Washington State University	Evaluating and Modelling Tree Biomass Yields From Small - Diameter Conifer Stands in the Inland Northwest	Production Systems/Silviculture	Production and Harvest	---
D-10	University of Illinois	Woody Biomass Production for Solar Energy Conversion	Production Systems/Silviculture	Production and Harvest	---

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D-11	Kansas State University	Great Plains Energy Forest Study	Production Systems/ Silviculture	Production and Harvest	---
D-12	University of Kentucky	Production of Black Locust Biomass on Surface-Mined Sites in the Southern Appalachians	Production Systems/ Silviculture	Production and Harvest	---
D-13	Pennsylvania State University	Feasibility of Using Municipal Wastewater and Waste Heat to Maximize Biomass Production on Silvicultural Energy Farms	Production Systems/ Silviculture	Production and Harvest	---
D-14	Pennsylvania State University	Energy Sensitivity and Variability Analysis of Populus Hybrid Short-Rotation Silvicultural Energy Farms in the Northeastern United States	Production Systems/ Silviculture	Production and Harvest	---
D-15	University of Washington and Washington State University	Evaluation and Genetic Improvement of Black Cottonwood for Short-Rotation Coppice Culture	Production Systems/ Silviculture	Production and Harvest	---
D-16	U.S. Department of Agriculture	Establishment of Populus Silvicultural Energy Farms	Production Systems/ Silviculture	---	Production and Collection of Biomass/Silviculture Production
D-17	U.S. Department of Agriculture	Construction and Field Trials of a Prototype Forestland Residue Machine (Mobile Hog) to Harvest Fuel from Forest Residues or from Energy Farms	Production Systems/ Silviculture	---	Production and Collection of Biomass/Residue Production
D-18	Emory University	Screening of Non-commercial Woody Plants as Biomass Fuel Producers	Production Systems/ Silviculture	Production and Harvest	---
D-19	Michigan State University	Tree Species for Biomass Production in Northern Michigan	Production Systems/ Silviculture	Production and Harvest	---
D-20	Garrett Energy Research and Engineering Co.	Investigation of Woody Biomass Species for Fuel Production in Warm-Climate, Non-agricultural Land Irrigated by Brackish or Saline Water	Production Systems/ Silviculture	Production and Harvest	---
D-21	Utah State University	Selection of High-Producing Shrubs of the Western United States for Energy Biomass Production	Production Systems/ Silviculture	Production and Harvest	---

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Current Program Category as of January 1979 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Updates Published in September 1978 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Program Summary Published in January 1978 (Element/Sub-element)</u>
D-22	University of Massachusetts	Assessment of Tree-Harvesting Machinery for Non-commercial Timber	Production Systems/ Silviculture	Production and Harvest	---
D-23	University of Houston	Cultural and Management Practices for the Chinese Tallow Tree as a Biomass Fuel Source	Production Systems/ Silviculture	Production and Harvest	---
D-24	University of Vermont and State Agricultural College	The Production of Biomass for Energy on Abandoned Farmlands in the Northeast	Production Systems/ Silviculture	Production and Harvest	---
D-25	The MITRE Corp.	Structuring Pilot Silvicultural Biomass Farm Development	Production Systems/ Silviculture	---	Production and Collection of Biomass/Silviculture Production
D-26	The MITRE Corp.	Near-Term Use of Wood as a Fuel	Production Systems/ Silviculture	---	---
D-27	U.S. Department of Agriculture	Fuel Farm Research (Chemically Induced Oleoresin as a Petrochemical Substitute)	Production Systems/ Silviculture	---	Production and Collection of Biomass/Silviculture Production
D-28	University of Georgia	Biomass Production of Short-Rotation Coppice Forests	Production Systems/ Silviculture	---	Production and Collection of Biomass/Silviculture Production
D-29	University of Minnesota	Use of Wetlands for Production of Woody Plants for Fuels and Petrochemical Substitutes	Production Systems/ Silviculture	Production and Harvest	---
D-30	University of Florida	Energy from Woody Species in Florida	Production Systems/ Silviculture	Production and Harvest	---
D-31	SRI International	Land and Water Availability for Energy Farming	Production Systems/ Silviculture	Production and Harvest	---
D-32	Oak Ridge National Laboratory	Management Support to the Fuels from Woody Biomass Program	Production Systems/ Silviculture	Production and Harvest	---
D-33	Mathtech, Inc.	Harvesting of Close-Spaced Short-Rotation Woody Biomass	Production Systems/ Silviculture	Production and Harvest	---
D-34	Seattle City Light	Cultural Treatment of Selected Species for Woody Biomass Production in the Pacific Northwest	Production Systems/ Silviculture	Production and Harvest	---

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D-35	University of California	Collection, Propagation, and Evaluation of <i>Prosopis</i> Species for Growth Rate Under Controlled Moisture and Nitrogen Treatments	Production Systems/ Silviculture	Production and Harvest	---
E-1	University of Puerto Rico	Production of Sugarcane and Tropical Grasses as a Renewable Energy Source	Production Systems/ Herbaceous	---	---
E-2	Arthur D. Little, Inc.	Herbaceous Species Screening Program (Phase I)	Production Systems/ Herbaceous	---	---
F-1	University of Illinois	Biological Conversion of Biomass to Methane	Conversion Systems/ Anaerobic Digestion	---	Conversion of Biomass/Anaerobic Digestion
F-2	Dynatech R/D Co.	Engineering Evaluation of Programs in the Area of Methane from Residues/Biomass	Conversion Systems/ Anaerobic Digestion	---	---
G-1	Purdue University	Selective Solvent Extraction in Utilization of Stored Solar Energy in Cellulosic Biomass	Conversion Systems/ Fermentation	---	---
G-2	Dartmouth College	Acid Hydrolysis of Concentrated Slurries of Cellulosic Biomass	Conversion Systems/ Fermentation	---	Conversion of Biomass/ Fermentation
G-3	University of California, Lawrence Berkeley Laboratory	Process Development Studies on the Bioconversion of Cellulose and Production of Ethanol	Conversion Systems/ Fermentation	---	Conversion of Biomass/ Fermentation
G-4	Rensselaer Polytechnic Institute	Coordination of Fermentation Contractors	Conversion Systems/ Fermentation	---	Conversion of Biomass/ Fermentation
H-1	Catalytica Associates, Inc.	Catalytic Conversion of Biomass to Fuels and Chemicals	Conversion Systems/ Thermochemical: Gasification	Thermochemical Conversion/ Gasification	---
H-2	Texas Tech University	Application of SGFM Technology to Other Feedstocks (Phase II)	Conversion Systems/ Thermochemical: Gasification	---	Conversion of Biomass/ Thermochemical Conversion
H-3	Battelle Pacific North- west Laboratories	Investigation of Gasification of Biomass in the Presence of Catalysts	Conversion Systems/ Thermochemical: Gasification	Thermochemical Conversion/ Gasification	---

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Current Program Category as of January 1979 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Updates Published in September 1978 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Program Summary Published in January 1978 (Element/Sub-element)</u>
H-4	Battelle Columbus Laboratories	Conversion of Forest Residues to a Methane-Rich Gas	Conversion Systems/ Thermochemical: Gasification	---	Conversion of Biomass/ Thermochemical Conversion
H-5	Gilbert Associates, Inc.	Research and Evaluation of Biomass Resources Conversion - Utilization Systems (Market/Experimental Analysis for Development of a Data Base for a Fuels from Biomass Model)	Conversion Systems/ Thermochemical: Gasification	---	---
H-6	Garrett Energy Research and Engineering Co.	Conversion of Biomass Materials into Gaseous Products	Conversion Systems/ Thermochemical: Gasification	---	Conversion of Biomass/ Thermochemical Conversion
H-7	Gorham International, Inc.	Assessment of Technical and Economic Feasibility of Converting Wood to Fuels Using Coal Conversion Technology	Conversion Systems/ Thermochemical: Gasification	Thermochemical Conversion/ Gasification	---
H-8	Wright-Malta Corp.	Catalyzed Water/Steam Gasification of Biomass	Conversion Systems/ Thermochemical: Gasification	---	---
I-1	University of Arizona	Modified Extruder for Feeding Fine-Ground Cellulosic Slurries to Pressure Systems	Conversion Systems/ Thermochemical: Liquefaction	---	---
I-2	Battelle Pacific Northwest Laboratory	Bench-Scale Research in Thermochemical Conversion of Biomass to Liquids in Support of the Albany, Oregon, Experimental Facility	Conversion Systems/ Thermochemical: Liquefaction	---	---
I-3	Wheelabrator Cleanfuel Corporation	Operations of the Biomass Liquefaction Facility at Albany, Oregon	Conversion Systems/ Thermochemical: Liquefaction	---	---
I-4	Bechtel National, Inc.	Experimental Program for the Albany, Oregon, Wood-to-Oil Experimental Facility	Conversion Systems/ Thermochemical: Liquefaction	---	Conversion of Biomass/ Thermochemical Conversion
I-5	University of California, Lawrence Berkeley Laboratory	Albany, Oregon, Process Developmental Unit/Biomass Conversion into Oil	Conversion Systems/ Thermochemical: Liquefaction	---	Conversion of Biomass/ Thermochemical Conversion

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Current Program Category as of January 1979 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Updates Published in September 1978 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Program Summary Published in January 1978 (Element/Sub-element)</u>
J-1	General Electric Co.	Bioconversion of Plant Biomass to Ethanol	Research and Development/ Innovative Conversion	---	Conversion of Biomass/ Fermentation
J-2	Massachusetts Institute of Technology	Degradation of Cellulosic Biomass and Its Subsequent Utilization for the Production of Chemical Feedstocks	Research and Development/ Innovative Conversion	---	Conversion of Biomass/ Fermentation
J-3	Exxon Research and Engineering Co.	Sensitized Photoelectrolysis of Water with Sunlight	Research and Development/ Innovative Conversion	---	Conversion of Biomass/ Photoelectrolysis
J-4	University of Pennsylvania	The Biological Production of Liquid Fuels from Cellulosic Residues	Research and Development/ Innovative Conversion	---	Conversion of Biomass/ Fermentation
J-5	Dynatech R/D Co.	Liquid Fuels from Biomass	Research and Development/ Innovative Conversion	---	Conversion of Biomass/ Fermentation
J-6	Rutgers University	Producing Mutants of Trichoderma	Research and Development/ Innovative Conversion	---	Conversion of Biomass/ Fermentation
J-7	Stanford University	Heat Treatment of Organics for Increasing Anaerobic Biodegradability	Research and Development/ Innovative Conversion	---	Conversion of Biomass/Anaerobic Digestion
J-8	University of California	Solar Energy Conversion Through Biophotolysis	Research and Development/ Innovative Conversion	---	---
K-1	University of California, Lawrence Berkeley Laboratory	Hydrocarbons from Plants	Research and Development/ Advanced Feedstocks	---	Production and Collection of Biomass/Silviculture Production
L-1	Woods Hole Oceanographic Institution	Cultivation of Macroscopic Marine Algae and Freshwater Aquatic Weeds	Research and Development/ Aquatic Systems	---	Production and Collection of Biomass/Aquatic Production
L-2	Woods Hole Oceanographic Institution	Bioengineering Aspects of Inorganic Carbon Supply to Mass Algal Cultures	Research and Development Aquatic Systems	Production and Harvest	---
L-3	California Institute of Technology	Biological Investigation of Marine Farms	Research and Development/ Aquatic Systems	---	Production and Collection of Biomass/Aquatic Production
L-4	CSO International, Inc.	Cost Analysis of Aquatic Biomass Systems (Fresh Water Micro-Algae)	Research and Development/ Aquatic Systems	Program Support	---

<u>No.</u>	<u>Contractor</u>	<u>Project Title</u>	<u>Current Program Category as of January 1979 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Updates Published in September 1978 (Element/Sub-element)</u>	<u>Program Category Listed in Biomass Program Summary Published in January 1978 (Element/Sub-element)</u>
L-5	Dynatech R/D Co.	Cost Analysis of Algal Biomass Systems	Research and Development/ Aquatic Systems	---	Production and Collection of Biomass/Aquatic Production
L-6	Columbia University	Algal Concentration by Ultra- filtration	Research and Development/ Aquatic Systems	---	Conversion of Biomass/Anaerobic Digestion
L-7	Columbia University	Permselective Membrane Control of Algal and Wood Digesters for Increased Production and Chemical Recovery	Research and Development/ Aquatic Systems	---	Conversion of Biomass/Anaerobic Digestion
L-8	University of California	Large-Scale Freshwater Microalgae Biomass Production for Fuel	Research and Development/ Aquatic Systems	---	Production and Collection of Biomass/Aquatic Production
M-1	InterTechnology/Solar Corp.	Follow-on Studies of the Photo- synthesis Energy Factory	Support/Analyses	---	Production and Collection Biomass/Silviculture Production
M-2	SRI International	Mission Analysis for the Federal Fuels from Biomass Energy Program	Support/Analyses	Program Support	---
M-3	SRI International	Preparation of a Cost Data Bank for DOE/Biomass Energy Systems Branch	Support/Analyses	---	---
N-1	University of Arkansas	Evaluation of a Cellulose Waste Converter and Pyrolytic Process	Support/Assessments	---	---

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