DOE/ET-0022/1

FUELS FROM BIOMASS PROGRAM

MASTER

PROGRAM
SUMMARY
JANUARY
1978

DIVISION OF SOLAR TECHNOLOGY
WASHINGTON, D.C. 20545

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U.S. DEPARTMENT OF ENERGY

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DOE/ET-0022/1
UC-61

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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 viable source for meeting future energy requirements. In response to the mandates of this act, major efforts were conducted within the Division of Solar Energy of the Energy Research and Development Administration (ERDA) to work with industry to develop and introduce, at the earliest possible date, economically competitive and environmentally acceptable solar energy systems.

These responsibilities were transferred to the new U.S. Department of Energy (DOE), on October 1, 1977. ERDA's Division of Solar Energy (SOLAR) was simultaneously reorganized into two distinct organization components:

- The Division of Solar Technology (SOLAR/ET), which functions as a part of the Office of the Assistant Secretary for Energy Technology.
- The Division of Solar Applicants (SOLAR/CS), which functions as a part of the Office of the Assistant Secretary for Conservation and Solar Applications.

As a result of this reorganization, the Solar Heating and Cooling Program, and the Technology Transfer Program, were transferred into SOLAR/CS. An overview of the current DOE 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), the Federal Nonnuclear Energy Research and Development Act of

1974 (PL 93-577). 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 will work to promote a fully-coordinated solar energy program and to complement efforts in the private sector to develop solar energy resources.

The major programs and subprograms of the Solar Energy Program during 1977 were:

- a. Solar Electric Systems
 - (1) Wind Energy Conversion.
 - (2) Photovoltaic Energy Conversion.
 - (3) Solar Thermal Electric Conversion
 - (4) Ocean Thermal Energy Conversion.
 - (5) Solar Satellite Power Systems.
- b. Fuels from Biomass
 - (1) Production and Collection of Biomass.
 - (2) Conversion of Biomass.
- c. Technology Support and Utilization
 - (1) Technology Transfer.
 - (2) Environmental and Resource Assessment.
- d. Solar Heating and Cooling
 - (1) Barriers and Incentives.
 - (2) Demonstration.
 - (3) Research and Development.
 - (4) Agricultural and Industrial Process Heat.

A Program Summary is issued for each program annually. It is an overview of the ongoing research, development, and demonstration efforts of the preceding fiscal year.

This Program Summary describes the Fuels from Biomass projects funded during Fiscal Year (FY) 1977 (October 1, 1976 through September 30, 1977). The accomplishments of the Fuel from Biomass Program are highlighted and plans for continued activities are included.

DEPARTMENT OF ENERGY

FIGURE 1. DOE Organization Overview

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Introduction

The overall objective of the Fuels From Biomass (FFB) program is to develop the capability for converting renewable biomass resources into clean fuels, petrochemical substitutes, and other energy-intensive products that can supplement similar products made from conventional fossil fuels. The program offers a significant potential for reducing this country's dependence on fossil fuels through the conversion of a renewable energy source to useful liquid and gaseous fuels, electric energy, and petrochemical substitutes.

Living plants absorb solar energy and through photosynthesis convert it to biomass, which is essentially stored chemical energy. The FFB program concentrates on plant materials grown on land (terrestrial) and those grown in water (aquatic). These materials include forest and crop residues, crops grown on energy farms for their energy content, and animal manures. The program does not include conversion of municipal solid wastes or industrial wastes.

The FFB program overview, which appears in Figure 2, lists the four major sources of biomass and several of the processes that can be used to convert them into energy-intensive products. These products, in order of program priority, are:

- a. *Liquid Fuels.* The most important of these are methanol (wood alcohol) and ethanol (grain alcohol). Liquid fuels can be mixed with gasoline to extend supplies of motor fuel, or used as peaking fuels to generate electric power.
- b. *Gaseous Fuels.* These include methane, medium-Btu gas for onsite application, upgraded Synthetic Natural Gas (SNG) fed into natural gas pipelines, hydrogen, and ammonia.
- c. *Petrochemical Substitutes and Other Energy-Intensive Products.* These include alcohols, ketones, turpentine, and resins.
- d. *Heat from Direct Combustion.* This is used to produce process heat and to generate pressurized steam and electric power.

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The Fuels From Biomass Program

Plants transform solar energy into chemical energy or biomass, which can then be harvested and converted into usable energy products. The biomass resources of residues and terrestrial and aquatic plants are renewable; they can potentially supply significant amounts of the future U.S. energy requirements. These resources can be converted by a number of technologies into liquid transportation fuels, gaseous energy products, and other forms of energy.

The Fuels From Biomass (FFB) research and development efforts are focused on:

- a. Growing terrestrial and aquatic crops on energy farms,
- b. Harvesting, collecting transporting, and storing biomass, and
- c. Converting biomass to fuels and petrochemical substitutes.

a. Biomass Production

(1) *Terrestrial Biomass Production.* The most important issue facing the production of terrestrial energy crops is the availability of land and water resources to be allocated to such an enterprise. If water could be made available at reasonable cost, marginal lands including some desert areas could be used for energy farms. Unfortunately, water is a relatively scarce resource in many parts of the U.S., and this may seriously restrict the use of marginal lands.

A multitude of factors must be considered in the allocation of land resources to energy production. High product costs, small farm units, higher value crop alternatives, climatic limitations, and other economic considerations influence the decision to dedicate land to biomass production. The consolidation of currently fragmented acreage in some U.S. areas into profitable units depends upon the size of tracts, types of owners, and proximity to existing farmlands. A considerable amount of the land will require special conservation projects and practices to minimize soil and water erosion.

In addition, energy farm investors will have to be assured of a long term profit in order to offset the capital costs associated with bringing marginal lands into production. If biomass farming is to represent a viable alternative energy source, it must not only be economically competitive with other energy sources, but must also pro-

vide a favorable return in comparison with food and fiber crops.

(a) *Residues.* The present availability of biomass residues (field crop residues, animal manures, and forest and mill residues) is estimated to be 100 million dry tons, with a theoretical maximum of 427 million dry tons. Biomass residues are currently being used in animal feeds, fiber-board products, fertilizer, soil tilth, and as soil conditioners.

The cost of biomass residues varies greatly according to type, application, region of the U.S., and location with respect to potential users. Field crop residues vary from \$4.00 per ton for wheat and other small grain straws to \$15 per ton for corn stover. Manure residues range from \$0.50 per ton for cattle manure to \$17 per ton for poultry manure. The cost associated with collecting, reducing, and transporting forest residues is estimated to range from \$25 to \$60 per ton, depending on location.

(b) *Silviculture Energy Farms.* The overall research objective in the growth of woody plants is to provide maximum energy content at minimum cost. In this context, costs include all outlays associated with growing the resource and delivering it to the conversion point, including harvest, collection, transportation to the conversion point, and storage until the conversion process begins.

Within the framework of this objective, program goals include selecting and improving the most promising species, minimizing risks and costs of establishing growing stock, determining the most cost-efficient cultural treatments and management systems, and obtaining optimum yields. Yields and costs must be considered both in terms of dollars and net energy obtained.

The major factor which will control the contribution of the energy farm concept to the nation's energy supply is biomass productivity, or the yield that can be produced annually per acre. Productivity levels vary with the species planted, the cultural practices used, and the site conditions, including climate, weather, and soil characteristics. All of these factors may be controlled or modified to some extent by man. Promising species can be selected through experimentation and improved by genetic breeding programs. Cultural practices for each species and region of the U.S. may also be selected and optimized through experimentation to provide cost-effective approaches to energy crop management.

FIGURE 2. *Fuels From Biomass Program Overview*

Site-specific factors can be modified by cultural practices (e.g., irrigation, fertilization, and weed and disease control) and accommodated by appropriate species selection. Biomass productivity is a technological factor that can be, within certain biological limits, molded and fashioned by man to best fit the needs of the concept. Success in optimizing biomass yield will largely depend on the time and research dollars spent on the problem.

A comprehensive systems study providing information about promising tree species, management practices, availability of land for silviculture energy farming, sources of residues, and conversion processes has recently been completed by the Mitre Corporation. The major conclusions of the system study are:

1. At least 30 million of the nation's 1.3 billion acres of grassland and forest could be made available for wood energy farms.

2. Biomass productivity under close-spaced, short-rotation conditions is estimated to range from 5 to 13 dry-ton-equivalents per acre each year with current production technology, depending upon species and site selection.

3. The quality of energy produced in the form of wood biomass by the process of energy farming is estimated to be 10 to 15 times the amount of energy consumed, depending upon the level of productivity achieved.

The energy farm, as envisioned in the systems study, would consist of selected, rapidly growing tree species planted at close spacings. The crop would be harvested at appropriate intervals or rotations, with succeeding crops growing by coppicing (sprouting from stumps), precluding the need to replant after each harvest. Since most conifers do not coppice, planting would be restricted in most cases to selected hardwood species. Intensive crop management would be practiced, including fertilization; irrigation, and weed and disease control. In this regard, energy crop production would be more similar to field crop production than to conventional forestry.

The FFB program will be substantially expanded in FY 1978 to include research programs to improve the yield and decrease costs of growing and harvesting woody plants, and the development of a harvesting system for small-diameter, closely spaced trees. A 1000-acre silviculture test plantation will be established to investigate the short-rotation forestry concept on DOE-owned land near Aiken, South Carolina. Elements of the project will include site preparation, seedling supply, stand establishment, cultural practices, irrigation, harvesting, and conversion of the harvested material. The economics and energy balance of the operations will be determined.

Beginning in FY 1980, the program will include other silviculture research demonstrations, using farms of 1,000 to 3,000 acres.

(c) *Agricultural and Nonwoody Plants.* The research objectives for agricultural and nonwoody plants are similar to those for woody plants. These objectives include selecting the most promising species, preparing sites, establishing growing stock, and using appropriate management techniques to obtain optimum yields in terms of economics and energy production. Studies include the impact of row spacing, nitrogen fertilization, irrigation, and frequency of harvest yields of sugar cane and sweet sorghum crops.

Sugar cane and tropical grass production is being investigated in Puerto Rico, including evaluation of harvest frequencies, yields, and regrowth after cutting. A series of species screening projects will be initiated beginning in FY 1978. These projects will be designed to identify plant species that have a high Btu content, growth rate, disease resistance, and dry weight production per unit area.

(2) *Aquatic Biomass Production.* The FFB program is currently supporting research in three aquatic resource areas: freshwater systems, open ocean systems, and shoreline brackish systems.

The program includes screening various species for yield, potential growth, nutrient assimilation, fermentability, and economic feasibility. The effort also entails determining possible sites, energy balances, and operating concepts within the three resource areas and selecting systems for detailed engineering design and cost analysis. Various marine and freshwater biomass sources being investigated include red, brown, green, and blue-green algae, water hyacinth, duckweed, and kelp.

b. Biomass Conversion

Many processing options can be applied to the conversion of biomass to energy or chemicals. These processes range in their stage of development from laboratory scale to commercially proven processes. Commercial combustion facilities have been used for many years, and anaerobic digestion facilities for feedlot manures are scheduled to be operating by 1978. Fermentation to produce ethanol and petrochemical substitutes; gasification to produce ammonia, SNG, hydrogen, and methyl fuel; and liquefaction to produce fuel oil are technically feasible but not yet economically competitive. Photochemical processes are being pursued on a long-term, low-emphasis basis.

Some biomass materials may require pretreatment, which usually consists of drying or further volume reduction. After suitable preparation, biomass can theoretically be processed using any of a number of proven technologies. However, the chemical composition of any biomass feedstock will dictate the probable conversion process and path for utilization. For example, direct combustion or gasification is the most likely alternative for low-moisture content biomass, while anaerobic digestion and fermentation are more adaptable to high-moisture biomass materials.

The processing paths shown in Figure 2 produce a wide range of products. These products are suitable for direct use or can be upgraded further to serve markets with more critical needs or to produce transportable products more economically. The production of steam through the direct combustion of biomass can be used to produce electric power via standard, acceptable technology. In addition, ethanol from the fermentation of biomass can be used directly as a motor fuel or converted to ethylene, a major petrochemical feedstock for polymers. The product priorities for this program are liquid transportation fuels, SNG, and other energy-intensive fuels and chemicals.

Each processing path that produces a primary product has a different conversion efficiency, requires a different level of capital investment, and has a distinct economy of scale. Because of these unique features, it is necessary to conduct a detailed analysis of market needs and process economics based on each possible biomass feedstock which will then be ranked on a comparable basis. Each of the conversion paths will be discussed/presented separately, with emphasis on unique requirements and product outputs.

(1) *Bioconversion*

(a) *Anaerobic Digestion.* Anaerobic digestion involves the consumption of treated biomass to produce methane. Almost any material from biological sources can be digested by anaerobic microbial processes to yield carbon dioxide and methane.

This process is commonly applied today as a waste treatment for removing organics and producing methane from domestic and industrial wastes. The process takes place at low temperatures (up to 65°C) and requires a moisture content of 80 percent or more. Product gases consisting mainly of methane and carbon dioxide can be burned directly or can be upgraded to SNG by removing the carbon dioxide and other impurities such as hydrogen sulfide. Recently, the possibility of using anaerobic digestion to convert biomass other than animal manures into usable energy has received increased attention because almost all biomass has a relatively high moisture content.

(b) *Fermentation of Biomass.* The technology involving the production of ethanol from the fermentation of sugars by yeast is well established and presently commercial, but industrial alcohol is produced at a lower cost from petroleum. The main opportunity for cost reduction in the ethanol fermentation process lies in finding less expensive sources of sugars from fermentation substrates. Cellulose is the most abundant carbohydrate polymer and can be hydrolyzed to glucose, a very desirable fermentation substrate.

Thus far, the FFB program has concentrated on the hydrolysis of cellulose to sugars and their subsequent fermentation to ethyl alcohol. Ethanol is a versatile product because it can be blended with gasoline to extend supplies or used directly in modified internal combustion engines.

There can be five main steps in the production of ethanol from cellulose: (1) separate fermentation to produce cellulase enzymes, (2) recovery of the enzymes, (3) enzymatic hydrolysis of cellulosic biomass, (4) fermentation to produce ethanol, and (5) ethanol recovery. The D supports process development in each of these areas. Enzyme costs are high; thus, searching for better organisms or mutant strains which produce more enzyme activity is very important.

A range of candidate cellulosic raw materials, mainly in the form of specifically grown agricultural crops and agricultural and forest product residues, are being analyzed for chemical composition and assessed for potential yields of sugars and ethanol under various processing conditions. Important basic problems to consider include the kinetics of enzymatic hydrolysis, the production of hydrolyzing enzymes, and enzyme reuse. Recently, progress has been made in the development of a highly effective continuous process for the production of a cellulase enzyme and new ethanol fermentation methods employing dense yeast cultures.

Current objectives include developing economical methods for removing lignin from cellulosic materials to enhance enzymatic hydrolysis, developing more powerful mixed-enzyme systems, prompting better fermentation of pentose sugars, optimizing the processes for ethanol production, and investigating other fermentations for various products. Economic studies are under way to assess the relative cost of advanced alcohol production processes.

(c) *Biophotolysis.* Hydrogen production is being sponsored by the FFB program as a long-term, low-emphasis activity. The major source of hydrogen, natural gas, is being rapidly depleted. The objective of the program is to develop processes that offer the potential of producing hydrogen from water, which is an abundant, renewable resource. Hydrogen is a clean fuel, but special pipelines are needed for this highly diffusible gas. It can be used to provide heat or to produce electrical power in fuel cells or engine generators.

In the biophotolysis program, research efforts have concentrated on conditions known to promote algae hydrogen production and to alter them in ways that will optimize yield. A photo-electrolysis program to produce hydrogen is also being pursued.

Certain filamentous blue-green algae contain specialized cells, heterocysts, where the hydrogen-evolving enzymes are localized and protected from oxygen. Experiments are being performed on those and other species to establish their basic potential in biophotolysis by demonstrating a sustained conversion of sunlight energy into hydrogen energy. This research includes converter design and conversion economic analysis.

(2) *Thermochemical Conversion*

(a) *Gasification and Liquefaction.* Pretreated biomass may be converted to energy products by gasifica-

tion to produce synthesis gas, methane, methyl fuel, etc., or by liquefaction to produce fuel oil.

In the gasification process, biomass such as forest residues corn stover can be reacted with steam and oxygen at elevated temperature and pressure to produce a medium-Btu gas. This product may be utilized as a fuel directly, or upgraded to SNG or methyl fuel.

The Battelle process for the production of methane from forest residues involves the reaction of shredded forest residues with a calcium oxide slurry at elevated temperatures and pressures. The gaseous product produced in the gasifier are then exposed to a methanation catalyst which to expected to increase the methane content of the raw gas.

Gasification and liquifaction comprise a wide range of processes that depend on thermal decomposition of organic matter to produce other usable fuels. The types and amounts of fuel produced depend primarily on the temperature used in the process. Thus, low temperatures (generally those under approximately 1,200°F) produce large quantities of char and oil together with lesser amounts of fuel gas, while high temperatures (greater than 1,800°F) produce primarily fuel gas and possibly some char, but no oils. The FFB program emphasizes the development of gasification processes which produce gaseous products at higher rates than those achievable in waste treatment and cool conversion processes. Thermal efficiency of gasification processes can be as high as 80 percent but is expected to be about 65 percent for the production of SNG from agricultural or forest biomass.

An experimental facility for the production of fuel oil from cellulosic materials has begun operation in Albany, Oregon. Based on a Bureau of Mines process developed at the Pittsburgh Energy Research Center, this plant operates on a scale which permits a meaningful analysis of process economics. It is equipped for the pretreatment of biomass and for reaction with carbon monoxide and hydrogen at elevated temperatures and pressures. The plant is sufficiently flexible in design to permit the technoeconomic evaluation of a variety of biomass-to-oil processes with a minimum of equipment modification. Future studies are expected to include such biomass sources as corn stalk, rye grass, and other plant materials. Current project objectives include the identification of product oil stability, reactor pressure requirements, and oil recycling practicality.

A prototype thermochemical conversion reactor which produces medium-Btu gas from animal residues at the rate of three dry tons per day is under development. This prototype unit will provide vital kinetic models and other processing information on which to base the conceptual designs of a 100 ton- and a 300 ton-per-day unit.

e FFB program is also investigating the production of methane via gasification of biomass at super-critical pressures. This project is in the early stages of development.

(b) *Direct Combustion.* Combustion is an efficient method of using the direct energy potential of biomass. Thermal efficiency is limited by the heat recovery equipment downstream from the combustion chamber. Theoretically, thermal efficiencies as high as 85 percent can be achieved for direct-fired furnaces and steam boilers. Generally, biomass with moisture content below 30 percent can be combusted directly. Biomass with higher moisture content may have to be predried or fired with supplementary fuel. Either process requires expenditure of additional energy and lowers efficiency.

The overall direct combustion efficiency of biomass used to produce electricity is 20 to 30 percent depending upon feedstock moisture content, ash content, and plant design. This efficiency is somewhat lower than that of coal combustion plants, which is typically 35 to 40 percent.

The direct combustion process is old and well-established. Many coal or oil-fired units could be converted to burn wood or other biomass if uniform biomass feeds were provided. Although financially attractive in many locations over the short term, direct burning may become less attractive when new biomass energy technologies become available. Future large-scale funding of conventional, non-innovative direct combustion projects is not anticipated because technology has advanced so that private development efforts are widespread, as in the case of fluidized bed combustion utilizing biomass as the energy source.

(3) *Photochemical Conversion (Photoelectrolysis).* A second process for producing hydrogen is photoelectrolysis. The decomposition of water by solar-induced photoelectrolysis is a new technique for producing hydrogen fuel that could have significant, long-term applications. The process involves splitting water into hydrogen and oxygen catalyzed by solar energy-driven means. Several development areas are being investigated including the assembly and testing of superior reactor materials (electrodes, cells, and input water purities), the demonstration of novel reactor configurations using catalysts that allow hydrogen production process scale-up, mathematical reactor modeling, and an economic evaluation associated with reactor scale-up. Like biophotolysis, photoelectrolysis is funded at a relatively low level because of its long-term program possibilities.

c. Future Program Thrust

One of the more promising management systems in the biomass production area is short-rotation forestry. Ongoing research will not provide substantial results for 10 years, although both test plots and test farms will provide an earlier indication of success trends. The growth period for short-rotation forestry is 3 to 6 years, and at least two rotations are needed to obtain reliable research results.

As indicated in Figures 3 and 4, the series of field experiments to establish promising species and yields will be followed by the establishment of test farms for both terrestrial and aquatic biomass, with corresponding conversion experiments and pilot and demonstration plants. Time sequences shown are set to provide both maximum impetus to the program and use of results at each stage as a basis for subsequent research.

Currently, research efforts are being focused on 25- to 30-acre test plots. During 1978 through 1979, studies will be initiated on test plantations of 1,000 to 3,000 acres. The FFB goal is to produce an assured supply of biomass on energy farms at a price not to exceed \$1.00 per million Btu (1978 dollars) by the year 2000.

The potential benefits of intensive agriculture (closer spacing and more frequent crops) should be more quickly assessable. Experiments with sugar cane are now under way; results will be available in 1978. Potential increases of up to double the current yields (11 dry tons per year) may be possible through closer spacing and species selection. The Battelle-Columbus study on sugar crops estimates the cost of fermentable solids at \$100 per ton and combustible organics at \$25 per ton with the cost of future material reduced by 20 percent and 40 percent, respectively. This will not result in a major increase in feedstock, however, because additional U.S. continental land that could grow sugar cane for energy uses is limited to approximately one million acres. However, the impact for Hawaii and Puerto Rico could be much greater; further analysis is necessary to determine expected yields.

Aquatic resources, including both freshwater and marine biomass, are being investigated. These include red, brown, and blue-green algae, water hyacinth, duckweed, kelp, and other species. Several of these algae and freshwater aquatic weeds are considered to have potential for large-scale growth and conversion to energy. The aquatic resources program involves screening various species for yield, potential growth, nutrient assimilation, fermentability, and economic feasibility.

The results from conversion processes should be discernable during the 1980's. The key to anaerobic digestion is to reduce the retention time of the feedstock in the process and to increase conversion efficiency. Costs to produce SNG from manures are currently approximately \$2.00 per million Btu (based on gas utility financing calculations).

The target is to reduce this cost to \$1.50 per million Btu within five years. One technique that shows promise is the reprocessing of residues from the initial digester cycle. This technique may reduce the costs by as much as percent, not a major breakthrough, but a significant reduction nevertheless.

In the fermentation area, the cost of sugars is a major factor. Enzymatic or acid hydrolysis of cellulosic biomass to produce sugars shows promise. Possible fermentation products are ethanol, butanol, acetone, and acetic acid. The enzyme process is undergoing pilot plant trials and could be ready for scale-up by 1980. Production costs of ethanol are expected to range from \$0.50 to \$1.20 per gallon.

Gasification processes offer potential for near-term commercialization. The key to gasification is the rate at which gas can be produced by the gasifier and the yields of fuel products that can be obtained (such as SNG) directly from the gasifier. Research indicates a potential reduction of up to 30 percent in the cost of medium Btu gas by 1980, to reduce it to \$2.00-\$2.50 per million Btu. The liquefaction process, which produces boiler fuel oil, is long-term in nature. This process uses high pressure technology and is relatively costly, but there is a chance that process modifications can reduce costs significantly by the early 1980's. Other results are not likely to be available before the late 1980's. Although direct burning is important as a short-term option, it is evolutionary in its development, and thus no breakthroughs are expected.

FUELS FROM BIOMASS PLAN

Continuing and planned future efforts of the Fuels from Biomass Program are summarized in Figures 3 and 4. Key milestones, tasks, and decision points for the program are forecast through FY '80.

Key milestones anticipated during FY '78 are the expansion of silviculture field experiments, the initiation of regional silviculture energy farms, the completion of aquatic biomass production systems study, the construction of the anaerobic digestion pilot plant, the continuation of the wood-to-oil process development unit, and the design of prototype gasification facilities.

The overall plan is continuously updated to reflect significant results and is used as a tool in the program decision-making process.

FIGURE 3. Key Milestones of the Fuels from Biomass Program—Terrestrial Biomass Production and Harvesting.

FIGURE 4. Key Milestones of the Fuels from Biomass Program—Conversion Technologies

Organizational and Functional Responsibilities

SOLAR'S Fuel from Biomass Systems Branch has the primary program management responsibility for the biomass energy Research, Development, and Demonstration (RD&D) effort. This DOE headquarters organizational element provides the technical direction and day-to-day management of all projects through program managers who maintain close control on individual projects through verbal communications with field manager, status reports issued by contractors, and field visits when appropriate. The RD&D activities administered by the DOE headquarters element are supported by DOE's National Laboratories and Operations Offices. Projects awarded to National Laboratories are coordinated with DOE's field operations offices which provide project management, technical direction, and administrative support. In addition to support rendered by National Laboratories and field offices, the Department of Agriculture (Agricultural

Research Service and U.S. Forest Service) also supports the Fuels from Biomass program. Some in-house research activities are conducted by the National Laboratories, but their primary role is coordinating, directing and monitoring the activities of industry, universities, and other research organizations.

The Fuels from Biomass Systems Branch is headed by a Branch Chief, and there are currently three Program Managers responsible for the areas of Thermochemical Conversion, Terrestrial Production, and Anaerobic Digestion. Other program areas are covered by the Branch staff.

Program Funding

Levels of funding for the Fuels from Biomass program are shown by program element in Table 1.

PROGRAM ELEMENTS AND FUNDING (X \$1000)¹

PROGRAM ELEMENTS	FY 1975	FY 1976/TQ ²	FY 1977	FY 1978
Production and Collection of Biomass	\$569	\$1,431/451	\$3,069	\$6,720
Conversion of Biomass				
Anaerobic Digestion		1,084/30	1,634	1,200
Fermentation		189/455	1,370	3,460
Biophotolysis and Photoelectrolysis			386	400
Thermochemical Conversion		1,730/1,396	2,872	7,375
Miscellaneous and Support	33	158/21	537	1,085
Biomass Conversion Facility				3,000
TOTALS	\$602	4,592/2,353	9,868	23,240

TABLE 1

1 Obligations

2 FY 1976 & Transition

Quarter (July - Sept. 1976)

Fiscal Year 1977—Summary Tables

TABLE 2

FY 1977 SUMMARY TABLES

Program Element

PRODUCTION AND COLLECTION OF BIOMASS

● Program Sub-Element

RESIDUE PRODUCTION

The objective of this sub-element is the development of processes to utilize field crop residues, animal manures, and forest and mill residues as a source of biomass.

<i>Organization</i>	<i>Title</i>	<i>Projected Contribution</i>
U.S. Forest Service	Construction and Field Trials of a Prototype Forestland Residue Machine (Mobile Hog) to Harvest Fuel from Forest Residues or from Energy Plantations	Harvest forest residues for fuel with a prototype machine.
Wheelabrator CleanFuel	Advanced System Demonstration for Utilization of Biomass as an Energy Source	Demonstrate the feasibility of utilizing agricultural residues, forest residues, and new plant growth for conversion to energy.

TABLE 3

FY 1977 SUMMARY TABLES

PROGRAM ELEMENT

PRODUCTION AND COLLECTION OF BIOMASS

● Program Sub-Element

SILVICULTURE PRODUCTION

The objective of this sub-element is the growth and harvest of woody plants to provide maximum energy content at minimum costs.

<i>Organization</i>	<i>Title</i>	<i>Projected Contribution</i>
University of Georgia	Biomass Production of Short Rotation Coppice Forestry	Obtain high-yield biomass production from sycamore, sweet gum, and alder trees in field trials.
Inter/Technology Corporation	Photosynthesis Energy Factory	Develop a general technoeconomic model of a photosynthesis energy factory.
Lawrence Berkeley Laboratory	Hydrocarbons and Energy from Plants	Evaluate the potential of growing latex-producing <i>Euphorbia</i> plants and economically extracting hydrocarbons.
Marelco, Inc.	Demonstrating the Feasibility of a Fuel Plantation on a New Source of Energy	Evaluate the potential of eucalyptus trees in silviculture energy farms.
Mitre Corporation, Metrek Division	Structuring Silviculture Farm Development	Develop a detailed plan for a pilot-scale silviculture energy production/conversion facility.
U.S. Forest Service	Establishment of <i>Populus</i> Energy Plantations	Establish field plots to determine optimal stand establishment and management strategies for using poplar hybrid trees in energy plantations.
U.S. Forest Service	Fuel Plantation Research	Increase chemically-induced lightwood formation in pines, and test commercial-scale processing.

TABLE 4

FY 1977 SUMMARY TABLES

PROGRAM ELEMENT

PRODUCTION AND COLLECTION OF BIOMASS

● Program Sub-Element

AGRICULTURAL PRODUCTION

The objective of this sub-element is the optimization of agricultural production to provide maximum energy at minimum cost from this biomass source.

<i>Organization</i>	<i>Title</i>	<i>Projected Contribution</i>
Agricultural Research Service	Sugar Cane Spacing Study	Increase Louisiana sugar cane yields by using the double drill system.
Joseph E. Atchinson Consultants, Inc.	Preliminary Evaluation of New Process for Separ- ation of Components of Sugar Cane, Sweet Sorghum, and Other Plant Stalks	Develop new cane separations process to separate components of the sugar cane stalk.
Battelle-Columbus Laboratories	Energy Farming Concepts Based on Sugar Cane, Sweet Sorghum, and Sugar Beets	Reduce costs and increase availability of fermentable solids and bagasse.
University of Florida	Planting of Sugar Cane in Florida Row Spacing and Experiment	Evaluate sugar cane biomass yields in close- spacing field trials.
Louisiana State University	Harvesting and Trans- portation of Sugar Cane	Process total cane plants to yield sugars used for the production of alcohols.
Midwest Research Institute	System Study of Sugar Cane from Grains and Grasses	Assess the current and potential availability of biomass from grain and grasses.
University of Puerto Rico	Production of Sugar Cane and Tropical Grass as a Renewable Energy Source	Establish field plots to evaluate sugar cane, napier grass, and related tropical grasses as renewable energy sources.

TABLE 5

FY 1977 SUMMARY TABLES

PROGRAM ELEMENT

PRODUCTION AND COLLECTION OF BIOMASS

● Program Sub-Element

AQUATIC PRODUCTION

The objective of this sub-element is improvement in production yield, growth, nutrient assimilation, fermentability, and economic feasibility of aquatic biomass.

<i>Organization</i>	<i>Title</i>	<i>Projected Contribution</i>
California Institute of Technology	Biological Investigation of Marine Farms	Determine the chemical and physical environment of kelp growth.
California, University of	An Integrated System for Conversion of Solar Energy Using Waste Grown Filamentous Blue-Green Algae Biomass	Grow and harvest filamentous algae in ponds for energy purposes.
Dynatech R&D Company	Cost Analysis of Algae Biomass System	Obtain operating and harvesting costs of an algal biomass system.
Woods Hole Oceanographic Institute	Cultivation of Macroscopic Marine Algae and Freshwater Aquatic Weeds	Cultivate aquatic plants for fermentation to methane.
Woods Hole Oceanographic Institute	Fuels from Solar Energy: Photosynthetic Systems State-of-the-Art and Potential for Energy Production	Analyze existing photosynthesis models as they apply to energy farms and determine yields using various systems and geographic locations.

TABLE 6

FY 1977 SUMMARY TABLES

PROGRAM ELEMENT

CONVERSION OF BIOMASS

● Program Sub-Element

ANAEROBIC DIGESTION

The objective of this sub-element is the development of processes for the production of methane from treated biomass.

<i>Organization</i>	<i>Title</i>	<i>Projected Contribution</i>
Agricultural Research Service	Anaerobic Fermentation of Livestock Manures and Crop Residues	Recover high protein biomass methane, and plant nutrients from livestock manures and crop residues through anaerobic processes.
Columbia University	Algal Concentration by Ultrafiltration	Harvest microalgae by a non-fouling membrane process.
Columbia University	Permaselective Membrane Control of Algal and Wood Digesters for Increased Production and Chemical Recovery	Control algal and wood digesters with permselective membrane.
Cornell University	Anaerobic Fermentation of Agricultural Residues Potential for Improvement and Implementation	Optimize fermenter designs for use in large-scale pilot plants.
Dynatech R&D Company	Engineering Evaluation of Program to Recover Fuel from Gas Waste	Evaluate various methods of methane production, and monitor technical anaerobic digestion projects.
Ecotope Group	Monitor, Test, and Evaluate an Operational Digester for 350 Cattle Units	Apply the knowledge of digester applications to full-scale dairy farm operations.
Hamilton Standard Company	Feedlot Energy Reclamation Demonstration	Produce fuel gas to achieve feedlot energy self-sufficiency.
Hamilton Standard Company	Pipeline Fuel Gas from an Environmental Cattle Feedlot	Produce fuel gas and other products from animal residues, and to promote commercialization of the process.
Illinois, University of	Biological Conversion of Biomass to Methane	Convert organic refuse to methane in an efficient, cost-effective manner.
Stanford University	Heat Treatment of Organics for Increasing Anaerobic Biodegradability	Increase biodegradability and methane production from waste organic materials by heat treatment under pressure.

TABLE 7

FY 1977 SUMMARY TABLES

PROGRAM ELEMENT

CONVERSION OF BIOMASS

● Program Sub-Element

FERMENTATION

The objectives of this sub-element are development of methods to enhance hydrolysis, development of enzyme systems, optimizing processes for ethanol production, and investigating other fermentation processes.

<i>Organization</i>	<i>Title</i>	<i>Projected Contribution</i>
Battelle-Columbus Laboratory	Production Costs of Ethanol by Various Methods	Determine the feasibility of the commercial manufactures of liquid fuels from agricultural residues and the cost of such manufacturing based upon the conceptual process design.
Dartmouth College	Acid Hydrolysis of Concentrated Slurries of Cellulosic Biomass	Produce glucose from acid hydrolysis of cellulosic biomass.
Dynatech R&D Company	Acetic Acid Production from Marine Algae	Produce acetic acid from algal feedstocks based on controlled anaerobic fermentation.
General Electric Company	Bioconversion of Plant Biomass to Ethanol	Develop the two-stage biological delignification and mixed culture fermentation process to produce ethanol from cellulose.
Lawrence Berkley Laboratory	Pilot Plant Studies of the Bioconversion of Cellulose and Production of Ethanol	Use cellulose as a feedstock and use enzymatic hydrolysis and fermentation of resultant sugars to produce ethanol.
Massachusetts Institute of Technology	Degradation of Cellulosic Biomass and Its Subsequent Utilization for the Production of Chemical Feedstocks	Ferment sugars derived from cellulosic biomass using cellulase produced from <i>Clostridium</i> as the cellulose hydrolizing agent.
Pennsylvania, University of	Biological Production of Organic Solvents from Cellulosic Wastes	Derive glucose from the hydrolysis of cellulosic materials.
Purdue University	Conversion of Biomass from Agriculture into Useful Products	Convert agricultural residues and food processing wastes to fuel products, and develop a solvent extraction process to separate mixed feedstocks.
Rensselaer Polytechnic Institute	Fuels and Petrochemical Substitutes from Fermentation of Biomass	Perform technical monitoring and coordination of fermentation research and development.
Rutgers University	Producing Mutants of <i>Trichoderma Virde</i>	Produce higher yields of cellulose through the development of mutant strains of the enzyme <i>Trichoderma virde</i> .
Stanford Research Institute	Economic Feasibility of Cellulose to Sugar by Enzymatic Hydrolysis and Fermentation to Alcohol	Convert cellulose to sugars by enzymatic hydrolysis and then ferment sugars to produce fuel grade ethanol.

FY 1977 SUMMARY TABLES

PROGRAM ELEMENT

CONVERSION TO BIOMASS

● Program Sub-Element

BIOPHOTOLYSIS

The objective of this sub-element is the development of processes that offer the potential of producing clean hydrogen fuel from water.

<i>Organization</i>	<i>Title</i>	<i>Projected Contribution</i>
Booz, Allen & Hamilton, Inc.	Biosol Process	Construct a batch-type reactor system to produce hydrogen photosynthetically using blue-green algae.
California, University of	Solar Energy Conversion through Biophotolysis	Use nitrogen-fixing heterocystous blue-green algae to produce hydrogen by the biophotolysis of water.

TABLE 9

FY 1977 SUMMARY TABLES

PROGRAM ELEMENT

CONVERSION OF BIOMASS

● Program Sub-Element

THERMOCHEMICAL CONVERSION

The objective of this sub-element is the development of thermal and chemical processes for cost-effective conversion of biomass to energy.

<i>Organization</i>	<i>Title</i>	<i>Projected Contribution</i>
Aerospace Research Corporation	Development of Wood as an Alternative Fuel for Large Power Generator Systems	Provide data for design and fabrication of a prototype combustion module which will generate the design information for the retrofitting of large-scale boiler systems.
Arizona, University of	Modified Extruder for Feeding Fine Ground Cellulosic Slurries to Pressure Systems	To support the developmental activities now underway at the wood-to-oil process development facility at Albany, Oregon.
Battelle-Columbus Laboratory	Conversion of Forest Residues to a Methane Rich Gas	Increase gasification activity and enhance the formation of methane through a catalytic pretreatment process applied to forest residue products.
Bechtel Corporation	Experimental Programs for the Albany, Oregon Wood-to-Oil Experimental Facility	Operation of wood-to-oil experimental facility, to evaluate promising biomass-to-oil processes using a range of feedstocks and operating conditions.
Garrett Energy Research and Engineering Company	Thermal Conversion of Biomass to Gaseous Products	Thermochemically convert biomass to a medium-Btu fuel gas using a modified hearth reactor.
Georgia Institute of Technology	Development of an Integrated Chemical Process for Utilization of Complete Paraquat Treated Pine Trees	Use complete, paraquat-treated pine trees to produce petrochemical substitutes.
Lawrence Berkeley Laboratory	Albany, Oregon Process Development Unit/Biomass Conversion into Oil	Formulation of a development program for the liquefaction of biomass at the Albany facility, evaluation of experimental results, modification of program based on experimental results, and technical direction of the program for DOE.
Texas Tech University	Application of SGFM Technology to Other Feedstocks	Develop the technology of producing synthesis gas from manure, thus converting biomass materials to ammonia synthesis gas and ethylene.
Wright-Malta Corporation	Low Temperature, Critical Pressure Water/Steam Gasification of Biomass	Develop technology and assess economic feasibility of producing medium-Btu gas by a low temperature water/steam gasifier process.

FY 1977 SUMMARY TABLES

PROGRAM ELEMENT

CONVERSION OF BIOMASS

● Program Sub-Element

PHOTOELECTROLYSIS

The objective of this sub-element is the development of processes for decomposition of water by catalyzed, solar-energy-driven means to produce hydrogen.

<i>Organization</i>	<i>Title</i>	<i>Projected Contribution</i>
Battelle-Columbus Laboratories	Evaluation of Commercial Feasibility of Hydrogen Production of Solar Photoelectrolysis of Water	Evaluate the commercial feasibility reducing hydrogen through solar photoelectrolysis of water.
Exxon Research and Engineering Company	Sensitized Photoelectrolysis of Water with Sunlight	Use heterogeneous catalysts for the sensitized photodecomposition of water to oxygen and hydrogen.
Princeton University	Hydrogen Fuel Generation by Catalyzed Cleavage of Water Using Solar Energy	Produce hydrogen by splitting water through catalyzed processes driven by solar energy.

Current Projects

Fuels From Biomass Program

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PRODUCTION AND COLLECTION OF BIOMASS

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Residue Production

TITLE

Construction and Field Trials of a Prototype Forestland Residue Machine (Mobile Hog) to Harvest Fuel from Forest Residues or From Energy Plantations

ORGANIZATION

USDA Forest Service
The Southern Forest Experiment Station
2500 Shreveport Highway
Pineville, LA 71360

AMOUNT

\$200,000

PRINCIPAL INVESTIGATOR

Peter Koch

WORK LOCATION

Pineville, LA

DURATION-AWARD DATE

12 months—October 14, 1976

CONTRACT NO.

IAG E(49-26)-1045

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 U.S. Forest Service project is to manage a cooperative effort involving five forest products companies and Nicholson Equipment, a logging equipment manufacturer.

The project's principal task involves constructing the forest residue machine ("mobile hog") and evaluating it at sites provided by the forest products companies.

In a typical Southern woodland, about 20 tons per acre (dry basis) of forest residues 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 energy plantations which might yield up to 6 dry tons per acre per year.

Residue Production

TITLE		ORGANIZATION
Advanced System Demonstration for Utilization of Biomass as an Energy Source		Wheelabrator CleanFuel Corp. 1050 17th St., N.W., Suite 1100 Washington, DC 20036
AMOUNT	PRINCIPAL INVESTIGATOR	
Pending	S. Brown Milligan	
WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Maine	Pending	Pending

PROJECT SUMMARY:

This contract covers Phase I of a three-phase program which is intended to demonstrate the technical and economic feasibility of utilizing agricultural residues, forest residues, and/or new terrestrial plant growth for conversion to energy.

The objective of Phase I is the demonstration of systems selection and design.

Project tasks include:

- 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. Where appropriate, develop specifications for harvesting systems equipment.
- 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 bioamss fuel. This site will raise steam and/or 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 assessment, including socio-economic impacts.

Silviculture Production

TITLE Biomass Production of Short Rotation Coppice Forestry		ORGANIZATION University of Georgia School of Forest Resources Athens, GA 30602
AMOUNT \$258,817	PRINCIPAL INVESTIGATOR Dr. Klaus Steinbeck Dr. Claude Brown	
WORK LOCATION Piedmont & Coastal Plains Province	DURATION-AWARD DATE 12 months—June 17, 1977	CONTRACT NO. EG-77-S-09-1015

PROJECT SUMMARY:

The objective of this study is to evaluate the potential of sycamore, sweet gum, and alder for high-yield, renewable energy sources. Three 50-acre plantations have been established to test pure and mixed strains of these tree species using appropriate cultural techniques, fertilizer, and irrigation.

To increase biomass per unit area and growth rate, emphasis will be on field research to determine the growth rate of mixed plantations. Mixing different species of hardwoods in the same planting will improve ecological aspects of coppice forestry by eliminating a monoculture. This will result in better wildlife habitat, better utilization of land, and better maintenance of soil productivity. Management techniques for increased sustained yields of silviculture are being assessed.

Silviculture Production

TITLE The Photosynthesis Energy Factory		ORGANIZATION Inter/Technology Solar Corporation 100 Main Street Warrenton, VA 22186
AMOUNT \$225,652	PRINCIPAL INVESTIGATOR George Szego	
WORK LOCATION Warrenton, VA	DURATION-AWARD DATE 9 months—September 30, 1976	CONTRACT NO. EX-76-C-01-2548

PROJECT SUMMARY:

The objective of this program is to develop a general technoeconomic model of a Photosynthesis Energy Factory (PEF). A PEF is an integrated system consisting of a dryland energy plantation top, a wood-fired power plant, and an algae waste water treatment system. An operating PEF would demonstrate the cost effectiveness of recycling certain byproducts from one system to another. Possible products of the PEF would be electricity, fertilizer, and gas.

In the project, the model is used to investigate possible interactions between the PEF and various subsystems. Cost-effectiveness studies of the subsystems show that electricity could be produced at prices competitive with coal-derived electricity. A typical municipal-owned PEF could consist of a 65 MWe power plant, a 144 acre algae pond, and a 33,000 Energy Plantation producing electricity as low as 35 mills/kWh. Preliminary results show that the primary benefit of the algae pond in the system is to obtain a cost credit for treating municipal wastewater, and that the yield per acre of the algae is not sufficient to produce methane at reasonable costs.

Silviculture Production

TLE

Hydrocarbons and Energy from Plants

ORGANIZATION

Lawrence Berkeley Laboratories
University of California
Berkeley, CA

AMOUNT

\$37,000

PRINCIPAL INVESTIGATOR

Marvin Calvin

WORK LOCATION

Santa Ana, CA
San Jose, CA

DURATION-AWARD DATE

12 months—February 1, 1977

CONTRACT NO.

S-189

PROJECT SUMMARY:

The objective of this research project is to develop preliminary information on the problems of growing, harvesting, and converting latex-producing plants fuels or petrochemical substitutes.

Field trials are being conducted at two California sites for preliminary assessment of the concept. The selected species are *Euphorbia lathyris*, *Euphorbia tirucalli*, and *Asclepias erosa*, all of which are native and produce oil-rich latex. A report of findings and an evaluation of the economics of producing hydrocarbons from latex-producing plants will be presented.

Silviculture Production

TITLE Demonstrating the Feasibility of a Fuel Plantation on a New Source of Energy		ORGANIZATION Marelco, Inc. P.O. Box 5084 Alexandria, VA	
AMOUNT \$73,000		PRINCIPAL INVESTIGATOR Eliseo Mariani	
WORK LOCATION California, Florida	DURATION-AWARD DATE 10 months—October 20, 1978	CONTRACT NO. EC-77-01-2557	

PROJECT SUMMARY:

The objective of this project was to study the use of eucalyptus trees in silviculture energy farms. Eucalyptus trees were introduced into the U.S. from Australia and have been widely planted for shelterbelts, and more recently, for fiber production. There are over 500 species of eucalyptus in the world, many of which are fast growing and coppicing (sprouting from stumps) and are therefore desirable for silviculture energy farming. Eucalyptus wood has been used in Argentina and Brazil for decades to provide charcoal for the steel industry.

Following extensive literature review, consultation with eucalyptus experts in Australia and the U.S., and surveys of land suitability, the project identified four sites of 20 acres each in California and Florida as suitable field plots. These sites are all in areas of marginal non-farming land and would be available for possible future field testing of eucalyptus species tolerant to flooding, drought, and frost, with high growth rates under selected site conditions.

Silviculture Production

TITLE

Structuring Silviculture Farm
Development

ORGANIZATION

Mitre Corporation, Metrek Division
1820 Dolly Madison
McLean, VA 22101

AMOUNT

\$147,600

PRINCIPAL INVESTIGATOR

Robert Inman

WORK LOCATION

Savannah River

DURATION-AWARD DATE

12 months—August 8, 1977

CONTRACT NO.

EC-77-C-01-4101

PROJECT SUMMARY:

The objective of this research program is to formulate a detailed working plan to initiate development and construction of a pilot-scale silviculture energy production conversion facility. The Metrek Division of the Mitre Corporation is providing assistance in the planning of DOE's pilot silviculture plantation. The site for the plantation chosen by DOE is 1,000 acres at the DOE-owned Savannah River Plant near Aiken, S.C.

The working plan includes choice of species, management practices, schedule, and criteria for choosing conversion processes and products. The time frame, cost estimates, and determination of the sequence of activities will also be identified.

Silviculture Production

TITLE Establishment of <i>Populus</i> Energy Plantations.		ORGANIZATION USDA Forest Service North Central Forest Experiment Station 1992 Folwell Avenue St. Paul, MN 55108
AMOUNT \$243,000	PRINCIPAL INVESTIGATOR David Dawson	
WORK LOCATION Rhineland, WI	DURATION-AWARD DATE 12 month—June 13, 1977	CONTRACT NO. USDA/ERDA IAG-77-A-29-1094

PROJECT SUMMARY:

In the past, research on the requirements for efficient tree harvesting, plantation structure, and the breeding of superior trees has resulted in significant advances in intensive silviculture. In this project, forty acres of the genus *Populus* (Poplars) are being used as demonstration plantations.

The objectives of this research include:

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

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

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

Silviculture Production

LE
Fuel Plantation Research

ORGANIZATION
USDA Forest Service
Southeast Forest Experiment Station
P.O. Box 2570
Asheville, NC 28802

AMOUNT
\$113,000

PRINCIPAL INVESTIGATOR
Jack Stubbs

WORK LOCATION
Aiken, SC

DURATION-AWARD DATE
12 months—October 1, 1976

CONTRACT NO.
S-189-77-36

PROJECT SUMMARY:

The objective of this research program was to determine the feasibility of producing and processing chemically-induced lightwood on a commercial scale. The herbicide paraquat will induce lightwood formation (resinosis) in pines over a period of 6-12 months when applied once to a basal wound. The oleoresin so produced can be recovered in draft pulp mills, wood naval stores extraction plants, and specialized extraction plants, thus providing an additional source of oleoresin hydrocarbons (turpentine and rosin).

The project includes determination of yields, the degree of insect pest protection required, costs in dollars and energy, and the solution to technical problems in woodland and extraction plant operations. This proof-of-concept experiment will facilitate efficient commercialization of the process.

Agricultural Production

TITLE Sugar Cane Spacing Study		ORGANIZATION Agricultural Research Service U.S. Sugar Cane Field Laboratory P.O. Box 470 Houma, LA 70361	
AMOUNT \$40,000		PRINCIPAL INVESTIGATOR James E. Irvine	
WORK LOCATION Houma, LA	DURATION-AWARD DATE 12 months—April 27, 1977	CONTRACT NO. USDA/ERDA IAGEG-77-A-29-1077	

PROJECT SUMMARY:

The objective of this project is to determine increases in Louisiana sugar cane yields as a result of using the double drill system, which can be used at essentially no additional cost to the grower. With a slight cost increase and moderate changes in technology, planting patterns which combine double drill and 3-foot spacings can result in even greater increases. Studies over the past ten years show that close-row spacing brings increased yields with no change in sucrose content. However, a radical departure from current cultural, harvesting and processing procedures is required to attain the increases achieved with 1- and 2-ft. spacings.

The current research program tasks involve a test of four spacings (conventional 6-ft. rows, double drill 6-ft. rows, 8-ft. rows, and 2-ft. rows) replicated five times. Subplots are established with granular fertilizer applications and with liquid fertilizer applied by drip irrigation. Ground preparation and furrowing are done by conventional equipment. Soil, climate, yield, and plant analysis variations are measured.

Agricultural Production

TITLE		ORGANIZATION	
Preliminary Evaluation of New Process for Separation of Components of Sugar Cane, Sweet Sorghum, and Other Plant Stalks		Joseph E. Atchison Consultants, Inc. 30 East 42nd Street New York, NY 10017	
AMOUNT		PRINCIPAL INVESTIGATOR	
\$9,800		Joseph Atchison	
WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.	
	5 months—April 15, 1977	G-01-77-2460	

PROJECT SUMMARY

The objective of this project had been to evaluate the development of a new cane separations process which separates the solid components of sugar cane stalks before extracting sugar juices.

The research program tasks involved reviewing and analyzing the potential uses and advantages of this process to determine if it will result in greater utilization of biomass in the production of fuel and energy.

Agricultural Production

TITLE Energy Farming Concepts Based on Sugar Cane, Sweet Sorghum, and Sugar Beets		ORGANIZATION Battelle-Columbus Laboratories 505 King Avenue Columbus, OH 43201
AMOUNT \$445,830	PRINCIPAL INVESTIGATOR Edward S. Lipinsky	
WORK LOCATION Belle Glade, FL; Houma, LA; Baton Rouge, LA; Weslaco, TX	DURATION-AWARD DATE 12 month—August 1, 1977	CONTRACT NO. W-7405-ENG-92

PROJECT SUMMARY

The primary objective of this research program is to evaluate the feasibility of reducing the costs and increasing the availability of fermentable solids and bagasse.

Subcontracts have been made with Texas A & M University, the Audubon Sugar Institute at Louisiana State University and F. C. Schaffer and Associates. Technical monitoring is performed for contracts at University of Florida, Louisiana State University and the Agricultural Research Service at Houma, Louisiana and Weslaco, Texas.

In separate experiments in Louisiana and Florida, the project is reviewing the impact of close-row spacing on the yield, composition, and cost of fermentable solids and bagasse. The Louisiana experiments use a relatively short growing season. The Florida experiments are conducted under long growing season conditions with soils that supply an infinite amount of nitrogen. Close monitoring of growth permits estimation of the degree to which the close spacing techniques can be used to increase yields in various agronomic situations.

In the sweet sorghum production experiments in Louisiana and Texas, the program is using a variety of sweet sorghum high in fermentable solids. Yields and composition are measured, and data is collected for estimation of costs.

Plant processing of sugar cane and sweet sorghum are investigated using several different process schemes. The yields of fermentable solids and bagasse are measured, as well as the composition of these major products and the effect of whole-plant processing on mill production and maintenance. Estimates are made of the costs of fermentable solids and bagasse by whole-plant processing and by conventional processing.

Agricultural Production

TITLE Planting of Sugar Cane in Florida Row Spacing and Experiment		ORGANIZATION University of Florida Belle Glade, FL 33430	
AMOUNT \$4,320		PRINCIPAL INVESTIGATOR Donald L. Myhre	
WORK LOCATION Belle Glade, FL	DURATION-AWARD DATE 12 months—December 1, 1976	CONTRACT NO. EG-77-G-05-5374	

PROJECT SUMMARY

The objective of this research program is to collect sugar cane biomass production and plant composition data to use in energy farming studies.

Project tasks include investigating changes in biomass production, composition, nutrient uptake, and leaf area index over a period of time for plants grown at 0.5 and 1.5 meter spacing. The project also assesses rainfall, solar radiation, temperature, and other climatic factors in relation to biomass and plant composition. Estimates of water requirements of sugar cane grown at the two spacings are also being made.

Agricultural Production

TITLE Harvesting and Transportation of Sugar Cane		ORGANIZATION Louisiana State University Baton Rouge, Louisiana 70803	
AMOUNT \$11,200		PRINCIPAL INVESTIGATOR Dr. Joe A. Polack	
WORK LOCATION Baton Rouge, LA	DURATION-AWARD DATE 12 months—November 15, 1976	CONTRACT NO. EG-77-G-05-5373	

PROJECT SUMMARY

The research objective of this project is to study the yield of sugars (used for the production of alcohols) when the total cane plant (stalks, leaves, and tops) is processed through a sugar mill.

Six processing runs (2.5 tons cane each) are being conducted by the project. There will be control runs using conventionally harvested burned cane. Sucrose, reducing sugars, starch, gums, and dextrans are measured. Bagasse samples are forwarded to Battelle for gasification.

Agricultural Production

TITLE System Study of Fuels from Grains and Grasses		ORGANIZATION Midwest Research Institute 425 Volker Avenue Kansas City, MO 64110	
AMOUNT \$187,337		PRINCIPAL INVESTIGATOR Walter R. Benson	
WORK LOCATION Kansas City, MO	DURATION-AWARD DATE 12 months—September 12, 1977	CONTRACT NO. E(29-2)-3729	

PROJECT SUMMARY

The objective of this program is to evaluate the potential of grain and grass crops as sources of biomass for energy.

Phase 1 of this three-phase study consisted of identifying grains and grasses which have high yields, and appropriate physical and chemical characteristics. The state-of-the-art of conversion processes was analyzed to develop specifications and economic data for various processes. A data management system was developed to organize and quantify production capabilities throughout the U.S.

Phase 2 of this study consists of making a detailed analysis of conversion processes and geographic regions, and the development of promising crop sets. Economic and environmental feasibility of such systems are also assessed.

Phase 3 will focus on the development of conclusions and recommendations concerning grain and grass biomass conversion to energy systems. This phase will identify those systems which are feasible with current technology, those which may be feasible with further R&D, and those systems which will not be economically feasible in the foreseeable future.

Agricultural Production

TITLE Production of Sugar Cane and Tropical Grass as a Renewable Energy Source		ORGANIZATION University of Puerto Rico Rio Piedras, PR
AMOUNT \$213,612	PRINCIPAL INVESTIGATOR Alex G. Alexander	
WORK LOCATION Rio Piedras, PR	DURATION-AWARD DATE 12 months—March 1, 1977	CONTRACT NO. EG-77-G-05-5422

PROJECT SUMMARY:

The primary objectives of this program include:

- a. Determining the agronomic and economic feasibility of mechanized, year-round production of solar-dried biomass through the intensive production of sugar cane and napier grass as tropical forages.
- b. Examining alternate tropical grasses as potential sources for intensive biomass production.

The secondary objective consists of enagaging 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 wer th first to b 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 frequency of harvest on yield.

Aquatic Production

TITLE		ORGANIZATION	
Biological Investigation of Marine Farms		California Institute of Technology Division of Engineering and Applied Science 1201 E. California Blvd. Pasadena, CA 91125	
AMOUNT		PRINCIPAL INVESTIGATOR	
\$577,925		James J. Morgan Wheeler J. North	
WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.	
Dana Point, CA	12 months—July 1, 1977	E (04-3)-1275	

PROJECT SUMMARY:

The objective of the California Institute of Technology project is to conduct detailed physiological studies on the influence of the chemical and physical environment on *Macrocystis* (giant kelp) growth.

Researchers at the Lamont-Doherty upwelling facility at St. Croix are testing a range of mixtures of deep and surface water to determine optimum conditions for kelp growth. Biometrical studies on adult *Macrocystis* fronds collected from differing depths are being conducted to provide data for the engineering design of marine farms. The bulk of the physiological work is being performed under controlled laboratory conditions, with supporting data occasionally gathered in field observations. The primary factors to be explored are water temperature and dissolved nutrients such as nitrogenous compounds, phosphates, and trace substances. Juvenile *Macrocystis* sporophytes weighing from one to ten grams are being used as the principal experimental material.

A few ancillary studies may be conducted with gametophytes or with somewhat larger sporophytes. Supplemental studies will evaluate the chemistry of trace metals in seawater in an effort to solve the problems of using upwelling water. These studies will also assess the yields of kelp transplanted on the American Gas Association's ocean farm module.

Aquatic Production

TITLE An Integrated System for Conversion of Solar Energy Using Waste Grown Filamentous Blue-Green Algae Biomass		ORGANIZATION University of California College of Engineering Sanitary Engineering Research Lab. 1301 South 46th Street Richmond, CA
AMOUNT \$154,000	PRINCIPAL INVESTIGATOR William J. Oswald	
WORK LOCATION Richmond, CA	DURATION-AWARD DATE 12 months—October 1, 1977	CONTRACT NO. EY-76-5-03-0034

PROJECT SUMMARY:

The objective of this project is to investigate the growth of filamentous algae in ponds. Microscopic algae grown in in lagoons cannot be cultivated economically for conversion to energy because no easy means for harvesting has been discovered. Filamentous algae are larger and can be collected with a screening device called a microstrainer.

Species are being controlled by such means as recycling part of the desired organisms, controlling pond conditions, and adjusting the growth medium. In addition, a total system is being developed and evaluated using municipal sewage for its nutrient value and carbon dioxide to overcome carbon limitations. The project is also studying the digestion of the harvested algae to methane. Process development is being performed on each step, and the scale-up and economics of a large system are being analyzed.

Aquatic Production

TITLE		ORGANIZATION	
Cost Analysis of Algal Biomass System		Dynatech R&D Company	
AMOUNT		PRINCIPAL INVESTIGATOR	
\$149,187		Don Wise (617) 686-8050	
WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.	
Cambridge, MA	12 months—June 27, 1977	EG-77-C-01-4000	

PROJECT SUMMARY:

The objective of this project is to determine total capital requirements, operating costs, and harvested algal biomass costs through engineering design analysis for a 100-square mile algal biomass system.

The following alternatives will be considered in selecting the final design:

- a. Freshwater land-based systems.
- b. Open ocean systems.
- c. Shoreline-saltwater/brackish water systems.

Only macrocellular algae can be used for open ocean systems. In the other two systems, both macro and unicellular algae will be considered.

Aquatic Production

TITLE Cultivation of Macroscopic Marine Algae and Freshwater Aquatic Weeds		ORGANIZATION Woods Hole Oceanographic Institute Woods Hole, MA 02543
AMOUNT \$205,713	PRINCIPAL INVESTIGATOR John H. Ryther	
WORK LOCATION Ft. Pierce, FL	DURATION-AWARD DATE 12 month—May 1, 1977	CONTRACT NO. EY-76-S-02-2948

PROJECT SUMMARY:

The objective of this study is to investigate the cultivation of aquatic plants. Several species of seaweeds were studied under a previous ERDA contract. Successful growth in cultures has resulted in high sustained yields of 15 to 25 tons dry weight per acre per year with high efficiency of nutrient removal.

The current research project can be divided into the following tasks:

- a. Screening indigenous species of seaweed for their yield potential and other favorable growth characteristics in artificial cultivation.
- b. Screening higher freshwater plants, both emergent and submerged species, for their yield potential and other favorable growth characteristics in artificial culture.
- c. Studying the periodicity of growth and nutrient assimilation by both seaweeds and freshwater aquatic weeds.
- d. Developing and evaluating nonintensive culture techniques for aquatic plants.
- e. Evaluating the ease and efficiency of fermentation to methane in selected cultivated species of seaweeds and freshwater aquatic weeds, and the recycling of their fermentation residues as a nutrient source for new plant growth.

Aquatic Production

TITLE		ORGANIZATION
Fuels from Solar Energy: Photosynthetic System State-of-the-Art and Potential for Energy Production		Woods Hole Oceanographic Institute Woods Hole, MA 02543
AMOUNT	PRINCIPAL INVESTIGATOR	
\$ 26,162	Joel C. Goldman	
WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Woods Hole, MA	12 month—November 21, 1976	EG-77-S-02-4151

PROJECT SUMMARY:

The objectives of this project were:

- To review the literature on managed plant cultivation systems (both terrestrial and aquatic).
- To compile information concerning ongoing research on mass cultivation systems.
- To analyze existing photosynthetic models as they might apply to "energy farms."
- To estimate the upper limits in yields that may be expected with different systems and varying geographic locations.

The major emphasis of the literature search will be to gather the most up-to-date information on sustained yields for different photosynthetic systems.

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CONVERSION OF BIOMASS

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Anaerobic Digestion

TITLE

Anaerobic Fermentation of Livestock Manures and
Crop Residues

ORGANIZATION

Agricultural Research Service
U.S. Meat Animal Research Center
P.O. Box 166
Clay Center, NE 68933

AMOUNT

\$ 50,000

PRINCIPAL INVESTIGATOR

Dr. Andy Hashimoto

WORK LOCATION

Clay Center, NE

DURATION-AWARD DATE

12 months—December 10, 1976

CONTRACT NO.

USDA/ERDA IAG
E(49-26)-1058

PROJECT SUMMARY:

The objective of this project is to evaluate the technical and economic feasibility of the anaerobic process for recovering high protein biomass, methane, and plant nutrients from livestock manures and/or crop residues.

Specific project tasks include:

- a. Developing design criteria (optimum temperature, mixing requirement, solids loading rate, solids retention time, etc.) for optimum production of biomass and/or methane from anaerobic fermentation of livestock manures and crop residues.
- b. Developing efficient methods to recover high protein biomass from fermented residues.
- c. Evaluating the nutritional value of the biomass for feed and the liquid fraction for plant nutrients.
- d. Determining the capital and operational costs and energy, manpower, and safety requirements for anaerobic fermentation systems associated with livestock operations.

Anaerobic Digestion

TITLE Algal Concentration by Ultrafiltration		ORGANIZATION Columbia University 353 Terrace Building New York, NY 10027
AMOUNT \$ 88,146	PRINCIPAL INVESTIGATOR Harry P. Gregor R. Cardenas	
WORK LOCATION New York, NY	DURATION-AWARD DATE 12 months—September 1, 1976	CONTRACT NO. E (11-1)-4076

PROJECT SUMMARY:

The objective of this project is to develop a non-fouling membrane process for harvesting microalgae.

Project tasks include growing 24 different algal cultures, representing freshwater species grown under different conditions. Ultrafiltration studies are carried out at varying flux rates and constant pressure. The experiments run in the laboratory have shown that concentration cells are yielding up to 500-fold concentrations, exceeding initial estimates.

A preliminary design of a larger device with increased membrane surface area has been completed. The device will use double membranes employed in spiral-wound configurations.

Anaerobic Digestion

TITLE		ORGANIZATION
Permsselective Membrane Control Algal and Wood Digesters for Increased Production and Chemical Recovery		Columbia University 353 Terrace Building New York, NY 10027
AMOUNT	PRINCIPAL INVESTIGATOR	
\$ 82,682	Harry P. Gregor	
WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
New York, NY	12 months—June 15, 1977	EG-77-S-02-4292

PROJECT SUMMARY:

The objective of this project is to investigate permsselective membrane control of algal and wood digesters. In this study, various forest product pulps and algal species are digested using two- to four-liter capacity vessels under conventional or high-rate organic loadings. The steady-state process is seeded by an anaerobic sludge and operated with a two-to four-week hydraulic dentention time.

Project tasks include monitoring gas production, solids, percent volatiles, and chemical oxygen demand. The contents of the vessel are then circulated through the appropriate membranes to remove various end products, especially ammonia, methane, and short chain fatty acids such as acetic acid, propionic acid, butyric acid, valeric acid, and isovaleric acid. The project will also monitor separation processes such as ultrafiltration using non-fouling membranes, electrodialysis, reverse osmosis, water-splitting membranes, solvent extraction, and enzyme-coupled membranes. These permsselective membranes not only allow practical separation, but control the operations of digesters.

Anaerobic Digestion

TITLE Anaerobic Fermentation of Agricultural Residues Potential for Improvement and Implementation		ORGANIZATION Cornell University Ithaca, NY 14853
AMOUNT \$125,000	PRINCIPAL INVESTIGATOR W. J. Jewell	
WORK LOCATION Ithaca, NY	DURATION-AWARD DATE 12 months—August 1, 1977	CONTRACT NO. EY-76-S-02-2981

PROJECT SUMMARY:

This contract covers the third year of a three-year project. The objectives of the project include:

- a. Identification of improved fermenter designs using small-scale laboratory models.
- b. Definition of optimized fermenter designs.
- c. Demonstration of new process feasibility in large-scale pilot plants.

A pilot scale reactor, using no mixing, produces one volume of gas per volume of reactor per day. The reactor operates as a plug-flow reactor without recycle, with a feed concentration of 12 percent solids. Solid concentrations of 25 percent result in high methane production; 35 percent result in inhibition of methane production. The project has identified the design of a simplified fermentor as the most promising in terms of total energy generation potential.

Anaerobic Digestion

ITLE

Engineering Evaluation of Programs to Recover
Fuel from Gas Waste

ORGANIZATION

Dynatech R&D Company
99 Erie Street
Cambridge, MA 02139

AMOUNT

\$162,902

PRINCIPAL INVESTIGATOR

D. L. Wise
R. L. Wentworth

WORK LOCATION

Cambridge, MA

DURATION-AWARD DATE

24 months—May 17, 1976

CONTRACT NO.

EY-76-C-02-2991

PROJECT SUMMARY:

The objective of this project is 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 include assisting in information exchange, evaluating engineering design and systems analyses, and reducing economic analyses to a common set of assumptions. This will help 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 was analyzed, and results point out 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.

Anaerobic Digestion

TITLE Monitor, Test, and Evaluate an Operational Digester for 350 Cattle Units		ORGANIZATION Ecotope Group 747 16th East Seattle, WA 98112
AMOUNT \$ 97,660		PRINCIPAL INVESTIGATOR Kenneth D. Smith
WORK LOCATION Monroe, WA	DURATION-AWARD DATE 12 months—June 21, 1977	CONTRACT NO. EG-77-C-06-1016

PROJECT SUMMARY:

The objective of this project is to advance the knowledge of digester applications to full-scale dairy farm operations.

Project tasks will include monitoring, testing, and performing laboratory analyses on a 100,000-gallon anaerobic digester at the State Reformatory Honor Farm in Monroe, Washington. The system is a complete-mix mesophilic digester with a 15-day detention time.

Based on test results, an operator's manual will be prepared for farm personnel, a final report evaluating system viability will be written, and engineering drawings will be updated to show the actual operating system.

Anaerobic Digestion

TITLE		ORGANIZATION	
Feedlot Energy Reclamation Demonstration		Hamilton Standard Company Windsor, CT 06096	
AMOUNT		PRINCIPAL INVESTIGATOR	
\$176,449		Robert E. Breeding	
WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.	
Montfort, CO	12 months—January 1, 1978	EY-76-C-02-2952	

PROJECT SUMMARY:

The objective of this program is to demonstrate to the feedlot industry a process of producing fuel gas to achieve feedlot energy self-sufficiency. Using cattle manure as feedstock, the process will generate methane for fuel and carbon dioxide as a refrigerant. The process will also produce a high protein "residual" which is suitable for an animal food supplement or fertilizer.

The original project contract has been extended to allow work on an alternate start-up method and evaluation of temperature on productivity. This work continues at the Hamilton Standard Mobile Cattle Waste Processing trailer at a Montfort, Colorado feedlot.

Gas yields have been less than anticipated. Operating characteristics and feedstock biodegradability are being reevaluated. System studies on the most useful size demonstration unit, cost analysis, and utility usage have been discontinued.

Anaerobic Digestion

TITLE Pipeline Fuel Gas from an Environmental Cattle Feed Lot		ORGANIZATION Hamilton Standard Company Windsor, CT 06096
AMOUNT \$938,000		PRINCIPAL INVESTIGATOR Daniel J. Lizdas
WORK LOCATION Windsor Locks, Conn.	DURATION-AWARD DATE 28 months—September 30, 1977	CONTRACT NO. EG-77-C-01-4015

PROJECT SUMMARY:

The objective of this program is to determine the technical and economic viability of producing fuel gas and other useful products from animal residues through the anaerobic fermentation process, and 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 monitor their quantity and quality. This information will support an evaluation of its commercial potential relative to existing alternate energy sources.

Anaerobic Digestion

TITLE

Biological Conversion of Biomass to Methane

ORGANIZATION

University of Illinois
Department of Civil Engineering
Urbana, IL 61801

AMOUNT

\$462,550

PRINCIPAL INVESTIGATOR

John T. Pfeffer

WORK LOCATION

Urbana, IL

DURATION-AWARD DATE

12 months—August 1, 1977

CONTRACT NO.

EY-76-S-02-2917

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 operation in 1976. To provide additional information to other ongoing projects, cattle manure was chosen as the substrate. The tanks produce from 50 to 100 liters of gas per hour.

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

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

Residues from the fermentor 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.

Anaerobic Digestion

TITLE Heat Treatment of Organics for Increasing Anaerobic Biodegradability		ORGANIZATION Stanford University Stanford, CA 94305
AMOUNT \$137,055	PRINCIPAL INVESTIGATOR Perry L. McCarty	
WORK LOCATION Palo Alto, CA	DURATION-AWARD DATE 12 months—April 29, 1976	CONTRACT NO. E(04-3)-326

PROJECT SUMMARY:

Experiments are continuing under this two-year study to increase biodegradability and methane production from organic waste materials by heat treatment under pressure. The materials under study include farm residues, forest product wastes, and municipal waste-water sludges. The objective of the project is to develop a general model for heat treatment which is applicable to all organic materials.

Once optimum conditions for heat treatment are found, project tasks will include evaluating bench scale anaerobic digestion and heat treatment systems with the various wastes in order to determine the overall resulting benefits. Among the benefits anticipated are increased methane yield per unit of waste treated, reduced costs for methane production, and a lower quantity of more readily dewatered residue for ultimate disposal. The major variables are temperature (25° to 250°C), time of treatment (0 to 3 hours), and pH (1 to 13).

Past research has shown that many of the single ring aromatic compounds expected to be formed from heat treatment of lignin are fermentable to methane. Direct measurements on methane production are in progress. The effect of heat treatment on waste activated-sludge is being evaluated. Preliminary data shows increased biodegradability can be achieved by heat treatment.

Further project tasks will include studying possible sources of toxic substances and the fate of specific nitrogen compounds. Studies on aromatic biodegradability have produced a reliable method of long-term culture maintenance. Cultures were acclimated to higher substrate concentrations; volatile fatty acids and acetic acid have been detected. In future research, substrate concentration will be increased and the cultures monitored.

Fermentation

TITLE

Production Costs of Ethanol by
Various Methods

ORGANIZATION

Battelle-Columbus Laboratory
Columbus, Ohio

AMOUNT

\$9,900

PRINCIPAL INVESTIGATOR

David M. Jenkins

WORK LOCATION

Columbus, Ohio

DURATION-AWARD DATE

3 months—June 29, 1977

CONTRACT NO.

W 7405 ENG-92

ADOL
3.01A

PROJECT SUMMARY:

The objective of this study had been to review the economic feasibility of manufacturing ethanol by hydrolysis of cellulosic residues and the continuous fermentation of sugars.

To achieve this objective, an integrated process flow sheet was developed for the analysis. Also, for the purpose of this analysis, major off-site equipment associated with a plant manufacturing section was included in the cost for that section. Thus, ethanol storage had been included in the total cost of manufacturing ethanol.

Fermentation

TITLE Acid Hydrolysis of Concentrated Slurries of Cellulosic Biomass		ORGANIZATION Dartmouth College Hanover, NH
AMOUNT \$109,243	PRINCIPAL INVESTIGATOR Hans Grethlein	
WORK LOCATION Hanover, NH	DURATION-AWARD DATE 11 months—October 1, 1977	CONTRACT NO. Pending

PROJECT SUMMARY:

Based on previous kinetic studies and preliminary plant designs, acid hydrolysis of cellulosic biomass for glucose production may be more economical than enzymatic hydrolysis when glucose is used for fermentation to ethanol. This assumption is based on a new process design for acid hydrolysis which features a continuous isothermal plug flow reactor with 10 to 30 percent solids in the slurry feed.

The objective of this experimental program is to demonstrate the key reactor concept in bench scale apparatus. New scientific and engineering data will be obtained.

This program will focus on:

- The kinetics of hydrolysis as a function of temperature, acid concentration, slurry concentration, and substrate type.
- The transport properties of concentrated cellulosic slurries.
- The evolution of by-products.

Data will be used to develop the technical and economic potential of a continuous acid hydrolysis process plant design.

Fermentation

TITLE
Acetic Acid Production from Maine
Algae

ORGANIZATION
Dynatech R&D Company
99 Erie Street
Cambridge, MA 02139

AMOUNT
\$221,895

PRINCIPAL INVESTIGATOR
D. L. Wise

WORK LOCATION
Cambridge, MA

DURATION-AWARD DATE
12 months—June 1, 1977

CONTRACT NO.
EG-77-C-02-4388

PROJECT SUMMARY:

The objective of this project is to develop a process for acetic acid production from algal feedstocks based on the controlled anaerobic fermentation of the algal feedstock in a fixed packed bed fermenter.

Extrapolating from solid waste experiments at Dynatech, these fermenters are charged with high solids content algae. Recirculation of liquid from the fermenter provides mass transfer in the bed and acid removal in an external sub-system. Maximum acetic acid production is being achieved by experimenting at selected bed heights, liquid recirculation rates, total solids content, nutrient/buffer requirements, and at mesophilic and thermophilic conditions.

Engineering analysis of experimental results, including model development to gain an understanding of process operating parameters, will be conducted to obtain cost evaluation of the process and a first approximation of acetic acid costs.

Fermentation

TITLE Bioconversion of Plant Biomass to Ethanol		ORGANIZATION General Electric Co. Research and Development Center P.O. Box 43 Schenectady, NY 12301	
AMOUNT \$170,916		PRINCIPAL INVESTIGATOR T. M. Su W. D. Bellamy	
WORK LOCATION Schenectady, NY	DURATION-AWARD DATE 24 months—December 15, 1976	CONTRACT NO. EG-77-C-02-4147	

PROJECT SUMMARY:

The research objective of this project is to develop a unique, all-biological conversion process for the production of ethyl alcohol fuel from plant biomass. The study will assess the technical feasibility of integrating biological delignification and mixed-culture fermentation of cellulose to produce ethanol in two-stage conversion process.

The critical biological transformations required to achieve an efficient bioconversion technology have recently been demonstrated by General Electric with thermotolerant microorganisms selected from the culture bank. Therefore, the two major technical barriers to the utilization of lignocellulosic materials (i.e., lignin, solubilization, and cellulose accessibility) can be biologically pretreated as an alternative to costly chemical and mechanical preprocessing technology. Subsequent operations which previously involved separate unit operations for enzyme production, cellulose hydrolysis, and fermentation of soluble sugars can now be performed by a simplified combined unit operation.

The General Electric project uses a thermotolerant lignocellulosic mold to pretreat concentrated plant biomass slurries to solubilize lignin and render the cellulose accessible to rapid saccharification. A second stage, mixed-culture fermentation to ethanol, is then conducted using a cellulolytic thermotolerant anaerobic strain of sporocytophaga and a compatible bacillus strain which converts cellobiose and glucose to ethanol.

Fermentation

TITLE

Pilot Plant Studies of the Bioconversion
of Cellulose and Production of Ethanol

ORGANIZATION

Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

AMOUNT

\$190,000

PRINCIPAL INVESTIGATOR

J. M. Hollander
C. R. Wilke

WORK LOCATION

Berkeley, CA

DURATION-AWARD DATE

12 month—October 1, 1976

CONTRACT NO.

189-4754

PROJECT SUMMARY:

The objective of this project is to conduct fundamental studies on the enzymatic hydrolysis of cellulose, fermentation of the resultant sugars to ethanol, and other problems related to the utilization of cellulose as a chemical and energy source.

Processing characteristics of biomass such as wheat straw, barley straw, rice straw, corn stalks, and logging residues are being investigated. These results will serve as a basis for the final design of a hydrolysis pilot plant.

Specific research objectives for FY 1978 include a raw material evaluation of whole trees, multistage fermentation with *Trichoderma viride*, and an assessment of the counter-current flow system versus co-current flow. Preliminary hydrolysis process design and cost analysis for the pilot plant will be completed and scale-up problems will be assessed.

The program also receives funding from the Division of Physical Research at DOE and the National Science Foundation.

Fermentation

TITLE Degradation of Cellulosic Biomass and Its Subsequent Utilization for the Production of Chemical Feedstocks		ORGANIZATION Massachusetts Institute of Technology Cambridge, MA 02139
AMOUNT \$339,000	PRINCIPAL INVESTIGATOR Daniel I. C. Wang	
WORK LOCATION Cambridge, MA	DURATION-AWARD DATE 12 month—December 1, 1976	CONTRACT NO. EG-77-S-02-4198

PROJECT SUMMARY:

The objective of this project was to study the fermentation of sugars produced from cellulosic biomass and the use of the processed biomass for the production of substitute fuels and chemical feedstocks.

To produce sugars from cellulosic biomass, cellulose is hydrolyzed directly to sugars. One cellulose hydrolyzing agent, cellulase, is produced by thermophilic anaerobic *Clostridium*. Project tasks include studying the means to economically increase cellulase production by *Clostridium*. Fermentation of the resulting sugars derived from cellulose to products such as butanol, methane, and hydrogen had been studied. This project employed both genetics and environmental means to develop the new fermentation. The yield for acrylate from cellulose provides for efficient utilization of cellulose and commercialization.

Fermentation

TITLE The Biological Production of Organic Solvents from Cellulosic Wastes		ORGANIZATION University of Pennsylvania College of Engineering and Applied Science Philadelphia, PA 19174	
AMOUNT \$282,588		PRINCIPAL INVESTIGATOR E. K. Pye A. E. Humphrey	
WORK LOCATION Philadelphia, PA	DURATION-AWARD DATE 15 month—September 15, 1976	CONTRACT NO. E(11-1)-4070	

PROJECT SUMMARY:

The primary objective of this project is to investigate the economic potential of a multistep fermentation process, using modern biotechnology and deriving the key substrate, glucose, by hydrolysis of cellulosic materials.

In this project cattle feedlot wastes are selected as a source of cellulose because of availability. The biomass is pre-treated to render the organic material digestible by cellulase enzymes. The high temperature cellulase from *Thermo-actinomyces* has been selected because its uniquely high-temperature optimum (65°–70°C) favors rapid kinetics, greater stability, and the potential use of nonsterile reactors. The pretreated cellulose is hydrolyzed to glucose in a high temperature counter-current reactor. Anaerobic fermentation of the glucose yields primarily butanol, with yields of over 30 percent. This fermentation process is expected to become a fully competitive butanol production process when ethylene costs rise slightly above their current level.

Fermentation

TITLE Conversion of Biomass from Agriculture into Useful Products		ORGANIZATION Purdue University West Lafayette, IN	
AMOUNT \$118,654		PRINCIPAL INVESTIGATOR George Tsao (317) 749-2591	
WORK LOCATION West Lafayette, IN	DURATION-AWARD DATE 12 month—June 1, 1977	CONTRACT NO. EG-N-5-02-4298	

PROJECT SUMMARY:

The objective of this project is to investigate the use of agricultural residues and food processing wastes by examining possible applications of the waste material's individual components.

Carbohydrates are considered the most important waste component, based on both the quantity available and their presence in a variety of wastes. Carbohydrates such as cellulose, hemicellulose, starch, chitin, glucose, and lactose are found in practically all known waste materials from farms and food production factories. In terms of available heating value, these carbohydrate wastes are equivalent to about 25 percent of the U.S. annual petroleum consumption.

Project tasks include studying applications of fermentation and pyrolysis using agricultural and food wastes. A method of solvent extraction to separate cellulose, hemicellulose, and lignin will also be explored using corn and wood residues and paper.

Fermentation

TITLE Fuels and Petrochemical Substitutes from Fermentation of Biomass		ORGANIZATION Rensselaer Polytechnic Institute Troy, NY 12181	
AMOUNT \$76,500		PRINCIPAL INVESTIGATOR Henry Bungay (518) 270-6369	
WORK LOCATION Troy, NY	DURATION-AWARD DATE 12 month—December 28, 1976	CONTRACT NO. EG-77-G-01-4001	

PROJECT SUMMARY:

The objective of this project was to coordinate, analyze, report, and plan research on the fermentation of biomass to produce fuels and petrochemical substitutes.

Project tasks included:

- a. Visiting research installations to assess programs and discuss results.
- b. Arranging and conducting meetings for reporting data and coordinating research programs.
- c. Analyzing reports and preparing digests.
- d. Preparing drafts of RFP's and other documents.
- e. Assisting in the planning and establishment of fermentation programs.
- f. Assigning master's thesis topics dealing with the Fuels from Biomass program.

Fermentation

TITLE Producing Mutants of <i>Trichoderma Virde</i>		ORGANIZATION Rutgers University New Brunswick, NJ 08903	
AMOUNT \$22,270		PRINCIPAL INVESTIGATOR Douglas E. Eveleigh	
WORK LOCATION New Brunswick, NJ	DURATION-AWARD DATE 14 month—September 1, 1976	CONTRACT NO. EY-76-G-01-2539	

PROJECT SUMMARY:

The objective of this project was to develop mutant strains of the enzyme *Trichoderma virde* to produce higher yields of 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 evaluated individual and synergistic contributions of cellobiohydrolases, endoglucanases, and cellobiases.

Fermentation

ITLE

Economic Feasibility of Cellulose to
Sugar by Enzymatic Hydrolysis and
Fermentation to Alcohol

ORGANIZATION

Stanford Research Institute
Menlo Park, California 94025

AMOUNT

\$10,000

PRINCIPAL INVESTIGATOR

Robert G. Muller

WORK LOCATION

Menlo Park, California

DURATION-AWARD DATE

3 month—September 1, 1977

CONTRACT NO.

P7702219

PROJECT SUMMARY:

The objective of this project was to examine the conceptual cellulose hydrolysis processes designed by the University of California and select what appears to be the most favorable process on a technical and economic basis.

To accomplish this objective, the conversion of cellulose to sugars by enzymatic hydrolysis followed by the fermentation of the sugars to produce fuel grade ethanol was evaluated for its economic feasibility. All processes are then considered and the most technically and economically favorable process was selected.

Biophotolysis

TITLE Biosol Process		ORGANIZATION Booz, Allen & Hamilton, Inc. Florham Park, NJ 07932	
AMOUNT \$72,068		PRINCIPAL INVESTIGATOR A. H. Pelofsky	
WORK LOCATION Florham Park, NJ	DURATION-AWARD DATE 12 month—June 22, 1977	CONTRACT NO. EG-77-C-01-4048	

PROJECT SUMMARY:

The objective of this project is to design, construct, and operate a batch type reactor system that will produce hydrogen photosynthetically using blue-green algae (axenic *Anabaena cylindrica*, strain B629).

Project tasks include evaluating the feasibility of using an algal reactor with optical fibers throughout the growth medium to provide even illumination at intensities which allow for high-efficiency photosynthesis. The optical fiber technique will permit the generation of hydrogen in a well-sealed vessel, rather than in a larger system where the hydrogen is lost by diffusion.

Biophotolysis

TLE

Solar Energy Conversion through
Biophotolysis

ORGANIZATION

University of California
College of Engineering
Sanitary Engineering Research Laboratory
301 South 46th Street
Richmond, CA 94804

AMOUNT

\$70,433

PRINCIPAL INVESTIGATOR

W. J. Oswald

WORK LOCATION

Richmond, CA

DURATION-AWARD DATE

12 month—April 1, 1977

CONTRACT NO.

E4-76-S-03-0034

PROJECT SUMMARY:

The objective of this project is to conduct experiments on the feasibility of using nitrogen-fixing heterocystous blue-green algae in solar energy convertors which produce hydrogen by the biophotolysis of water.

Previous work established that these algae may be used for continuous production of hydrogen and stoichiometric oxygen from water and light energy. The limitations of this system are being investigated. Project tasks include tests on improving the present rate of hydrogen production, refining field culture methodologies, and the comparison of *in vivo* and *in vitro* interacting hydrogenases. An engineering analysis will be performed to determine whether this method of solar energy conversion is economically feasible.

Thermochemical Conversion

TITLE Development of Wood as an Alternative Fuel for Large Power Generation Systems		ORGANIZATION Aerospace Research Corporation 5454 JAE Valley Road S.E. Roanoke, Virginia
AMOUNT \$130,000	PRINCIPAL INVESTIGATOR J. T. Hamrick	
WORK LOCATION Roanoke, Virginia	DURATION-AWARD DATE 8 month—December 1, 1977	CONTRACT NO. Pending

PROJECT SUMMARY:

The objective of this project is to develop a system for retrofitting fossil-fuel fired boilers to burn wood. This effort is expected to 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 boiler systems. Specific goals are:

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

To achieve this objective, a small combustion module has been designed, fabricated, and run as an integral part of this effort. This apparatus is used for parametric studies of wood hydrolysis and combustion with hot air.

Thermochemical Conversion

TITLE		ORGANIZATION	
Modified Extruder for Feeding Fine Ground Cellulosic Slurries to Pressure Systems		University of Arizona Tucson, Arizona	
AMOUNT		PRINCIPAL INVESTIGATOR	
Pending		Dr. Don White	
WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.	
Tucson, Arizona	12 months—January 1, 1978	Pending	

PROJECT SUMMARY:

This work is intended to support the development activities at the wood-to-oil process development facility at Albany, Oregon. There will be investigation of the potential of utilizing extruders as feeding devices to the high pressure reactor used at the Albany facility.

The primary objectives of this project are:

- a. To evaluate the physical properties of the wood-flour/oil slurries.
- b. To prepare and evaluate pelletized slurry feedstocks to determine the advantages of this technique.
- c. To modify an existing extruder and test its suitability to perform as a feeding device to a high pressure reactor.
- d. To conduct field runs in commercial extruders to test the extruder feeder concept.

Thermochemical Conversion

TITLE Conversion of Forest Residues to a Methane Rich Gas		ORGANIZATION Battelle-Columbus Laboratories 505 King Avenue Columbus, OH 43201	
AMOUNT \$195,260		PRINCIPAL INVESTIGATOR Herman F. Feldman	
WORK LOCATION Columbus, OH	DURATION-AWARD DATE 8 months—August 1, 1977	CONTRACT NO. W-7405-ENG-92	

PROJECT SUMMARY:

In this project, a proprietary catalytic pretreatment process will be applied to forest residue products. If successful, the process is expected to increase the gasification reactivity, lower the required reaction temperature, and enhance the formation of methane. This treatment could lead to the development of a simpler and cheaper gasification process for biomass.

Research objectives of the project include:

- Determining the increase in the overall gasification rate brought about by a pretreatment step.
- Establishing the optimum range of conditions for biomass gasification.
- Preparing a technoeconomic assessment of the process for the production of a methane-rich gas from forest residues.

In the Battelle process, shredded forest residues are reacted with a calcium oxide slurry at elevated temperatures and pressure to produce an incorporated and effective gasification catalyst. The gaseous products produced in the gasifier are then exposed to a methanation catalyst which is expected to increase the methane content of the raw gas product.

Thermochemical Conversion

TLE Experimental Program for the Albany, Oregon Wood-to-Oil Experimental Facility		ORGANIZATION Bechtel Corporation Scientific Development Department 50 Beale Street San Francisco, CA 94119	
AMOUNT \$973,000		PRINCIPAL INVESTIGATOR Tom Lindemuth	
WORK LOCATION Albany, OR	DURATION-AWARD DATE 14 months—October 1, 1976	CONTRACT NO. E (04-3)-1194	

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.

The PERC process is not developed beyond bench-scale experiments, and most of the technology required for a commercial process is lacking. It is thus possible that the process, as presently conceived, may not become commercially feasible. Therefore, the Albany facility is designed with the flexibility to be used in the development of other promising biomass-to-oil processes.

Initial operations emphasized wood chips as the biomass feedstock, but agricultural crop residues have also been tested. The PERC process has been 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 have been varied.

Through the DOE program, the initial oil production was accomplished and the reactor successfully pressure tested. Data for the process evaluation had been collected.

Efforts are being expended to solve problems in plant design or equipment that have become apparent through operation.

New tasks, which included economic evaluation and a special data package for plant operations, had been added to the program. The economic evaluation task included a conceptual design for a 1,000 ton per day plant, a cost estimation for the plant, and an overall economic evaluation of the process based on capital and operating costs. The data package includes specifications, manufacturers' ratings, and actual performance test information on all equipment at the Albany facility.

Thermochemical Conversion

TITLE Thermal Conversion of Biomass to Gaseous Products		ORGANIZATION Garrett Energy Research and Engineering Co. Claremont, CA 91711	
AMOUNT \$349,730		PRINCIPAL INVESTIGATOR Donald E. Garrett	
WORK LOCATION Claremont, CA	DURATION-AWARD DATE 12 months—May 25, 1976	CONTRACT NO. EY-76-C-03-1241	

PROJECT SUMMARY:

This research project is a further development of the Garrett process for the thermochemical conversion of biomass to a medium Btu fuel gas, utilizing a modified hearth reactor.

The objective of this project is to obtain the vital kinetic models and other processing information on which to base conceptual designs for commercial-scale conversion units. These designs will form the basis for a technoeconomic evaluation of the process. The project has yielded sufficient data to produce conceptual designs for a 100 ton per day and 300 ton per day conversion plant.

Work will begin with additional runs in the bench-scale reactor (constructed in the first phase) to more fully develop the data base for the design of the phototype reactor. This will be followed by the design and construction of a prototype unit which can process up to 3 dry tons per day of animal residues for conversion to a medium Btu fuel gas. The process will then be further developed by means of a program of parametric studies.

Future development will depend on the outcome of the technoeconomic assessment. It is anticipated that additional work, if any, at the pilot plant or demonstration level will be obtained through competitive procurements.

Thermochemical Conversion

TITLE

Development of an Integrated Chemical Process
for Utilization of Complete Paraquat Treated
Pine Trees

ORGANIZATION

Georgia Institute of Technology
Atlanta, GA 30332

AMOUNT

\$207,886

PRINCIPAL INVESTIGATOR

Daniel O'Neil

WORK LOCATION

Atlanta, GA

DURATION-AWARD DATE

18 months—July 1, 1977

CONTRACT NO.

EG-S-05-5543

PROJECT SUMMARY:

The objective of this program is to develop a means of using complete, paraquat treated pine trees for the production of clean fuels and petrochemical substitutes.

Using chips from paraquat-treated trees, the bench-scale process will isolate oleoresinous products with an emphasis on commercial extractor processes. These products will be evaluated for the quality and quantity obtained from each process. From this data, a cost analysis will be performed and recommendations made for a pilot-scale system.

Thermochemical Conversion

TITLE Albany, Oregon Process Developmental Unit/Biomass Conversion into Oil		ORGANIZATION Lawrence Berkeley Laboratory Berkeley, CA
AMOUNT \$210,000	PRINCIPAL INVESTIGATOR S. Ergun	
WORK LOCATION Berkeley, California	DURATION-AWARD DATE 12 months—October 1, 1977	CONTRACT NO. W-7405-ENG-48

PROJECT SUMMARY:

The primary objective of this program, in support of the Albany facility, is to assess the technical economical feasibility of converting lignocellulosic materials into liquid fuels.

To achieve the objective, a developmental program for the liquefaction of biomass, the evaluation of the experimental results, the modification of the program on the basis of experimental results, and the technical direction of the program for SOLAR, has been formulated.

Thermochemical Conversion

ITLE Application of SGFM Technology to Other Feedstocks		ORGANIZATION Texas Tech University Lubbock, TX 79409	
AMOUNT \$249,183		PRINCIPAL INVESTIGATOR William J. Huffman James E. Halligin	
WORK LOCATION Lubbock, TX	DURATION-AWARD DATE 24 months—September 1, 1977	CONTRACT NO. E4-76-S-04-3779	

PROJECT SUMMARY:

The objective of this project is to further develop the Synthesis Gas From Manure (SGFM) technology for the conversion of biomass materials to ammonia synthesis gas and ethylene.

Program tasks include conducting parametric studies in an existing $\frac{1}{2}$ ton-per-day test reactor to determine the influence of temperature, residence time, pressure, and feedstock materials on the yield and quality of the products of reaction. Among the biomass materials to be investigated are forest residues, mesquite, field stover, and cotton gin residues. Tasks also include making economic assessments of the process and utilizing animal manures and other biomass materials as feedstocks. In addition, the effects of reactor geometry and solid/gas contact will be studied in cold models, and relationships for the design of a staged reactor will be developed.

Thermochemical Conversion

TITLE Low Temperature, Critical Pressure Water/Steam Gasification of Biomass		ORGANIZATION Wright-Malta Corporation Ballston SPA, New York 12020
AMOUNT \$310,000		PRINCIPAL INVESTIGATOR John Coffman
WORK LOCATION Ballston SPA, New York	DURATION-AWARD DATE 12 months—January 1, 1978	CONTRACT NO. E-(11-1) 4124

PROJECT SUMMARY:

The objective of this project is to study the feasibility of gasification of biomass to produce a fuel gas in a small critical pressure (3200 psi), low temperature (1100°F) water/steam gasifier. A low-cost system has been proposed and the laboratory work is required to verify the reactions and possibilities of using the process on all types of biomass from grass to wood chips.

The objectives of the continuation phase are:

- a. To establish the kinetic models for reactor scale-up purposes.
- b. To prepare an economic assessment of the biogasifier process for the production of medium BTU gas from biomass residues.
- c. To design a process development unit of 3 dry tons biomass per day capacity based on the results obtained in the experimental program.

Photoelectrolysis

TITLE Evaluation of Commercial Feasibility of Hydrogen Production of Solar Photoelectrolysis of Water		ORGANIZATION Battelle-Columbus Laboratories 505 King Avenue Columbus, OH 43201
AMOUNT \$ 79,500	PRINCIPAL INVESTIGATOR Robert E. Schwerzel	
WORK LOCATION Columbus, OH	DURATION-AWARD DATE 12 months—November 16, 1976	CONTRACT NO. W-7405-ENG-92

PROJECT SUMMARY:

The objective of the Battelle-Columbus Laboratories project is to evaluate the commercial feasibility of reducing hydrogen through solar photoelectrolysis of water.

The program's initial tasks include identifying and obtaining the best combination of anode and cathode materials available. These materials are used to evaluate the response of the photoelectrolysis system to a variety of cost-reducing measures.

This evaluation includes several different electrode configurations, the use of less expensive materials in the fabrication of electrodes and cells, and the use of input water with varying degrees of purity to help estimate the cost of commercial water pretreatment.

Photoelectrolysis

TITLE Sensitized Photoelectrolysis of Water with Sunlight		ORGANIZATION Exxon Research and Engineering Co. Linden, NJ 07036
AMOUNT \$ 76,578		PRINCIPAL INVESTIGATOR Dr. Amal K. Ghosh
WORK LOCATION Linden, NJ	DURATION-AWARD DATE 12 months—May 1, 1977	CONTRACT NO. EG-77-C-02-4271

PROJECT SUMMARY:

The objective of this project is to investigate the use of heterogeneous catalysts for the sensitized photodecomposition of water to oxygen and hydrogen. This system uses an abundant resource (water) to produce a pollution-free fuel (hydrogen) which is easily stored and shipped, and has many applications for producing clean heat and power.

The proposed photoelectrolytic system consists of a conducting aqueous electrolyte, an optically inert metal counter-electrode (platinum cathode), and a photosensitive semiconductor, which serves as the heterogeneous catalyst. Solar energy is absorbed by the semiconductor catalyst and transferred to the aqueous solution in order to decompose the water. Because of their stability, the catalysts are primarily TiO_2 and SrTiO_3 .

The project is concerned with extending the response of these catalysts towards the visible part of the solar spectrum, by doping them with impurities and by heterojunction formation. It is expected that the performance of these systems can be improved by varying the preparation conditions and by analyzing the basic kinetics of the H_2 generation process. The goal is to obtain an overall sunlight efficiency of 5% from the hydrogen produced by the production cell.

Photoelectrolysis

FILE

Hydrogen Fuel Generation by Catalyzed Cleavage
of Water Using Solar Energy

ORGANIZATION

Princeton University
Department of Chemical Engineering
Princeton, NJ 08540

AMOUNT

\$120,361

PRINCIPAL INVESTIGATOR

Dr. Davis F. Ollis

WORK LOCATION

Princeton, NJ

DURATION-AWARD DATE

12 months—February 1, 1977

CONTRACT NO.

EG-77-S-01-4023

PROJECT SUMMARY:

This research project centers on the production of hydrogen by splitting water into its elements through catalyzed, solar energy-driven means. The central objective of the project is to demonstrate a novel reactor configuration using these catalysts which should allow scale-up of hydrogen production.

These catalysts are only active when they are in the form of monomolecular layers of ruthenium complexes absorbed on or attached to solid surfaces. They are coated onto the surfaces of optical fibers having diameters of 10 to 1,000 microns. The fibers are then assembled into macroscopic configurations, such as bundles, and set in a reactor. During the operation of the reactor, water in vapor or liquid form is passed through the vessel, and solar wavelength illumination enters the reactor through the ends of the fibers. As the illumination is repeatedly reflected along the fiber length, it contacts the catalyst along the cylindrical fiber surface, thereby driving the catalyzed cleavage of water into hydrogen and oxygen.

Project tasks include experimental studies, mathematical reactor modeling, and a preliminary technical and economic evaluation of this novel reactor for scaled-up hydrogen production.

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A list of reports follows which has resulted from research contracts supported by the Fuels from Biomass Systems Branch, Division of Solar Technology. Some studies were funded by the National Science Foundation and the Energy Research and Development Administration, prior to the establishment of the Department of Energy on October 1, 1977.

Copies of the following reports may be obtained from:

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 Cornell University
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 University of Illinois
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APPENDIX OF UNSOLICITED PROPOSAL REQUIREMENTS

SOLAR recognizes that the unsolicited proposal is a valuable means by which unique or innovative methods or approaches can be made available in developing energy technology. Unsolicited proposals are offered in the hope that SOLAR will enter into a contract with the offeror for researching, developing, or providing services indicated within the proposal. These proposals should not be merely an advance proposal for a specific requirement which would normally be procured by competitive methods.

It is SOLAR's policy to encourage and foster the submission of unsolicited proposals. Since the preparation of an unsolicited proposal represents a substantial investment of time and effort by the offeror, organizations or individuals who are interested in submitting an unsolicited proposal are encouraged to make preliminary inquiries relating to SOLAR's needs before expending extensive effort in preparing a detailed unsolicited proposal.

Favorable evaluation of an unsolicited proposal is not, in itself, sufficient justification for SOLAR to enter into contract with the offeror. Generally, any unsolicited proposal is unacceptable and must be rejected if it (a) is available to the Government without restriction from another source, (b) closely resembles that of a pending competitive solicitation, or (c) is not sufficiently unique to justify acceptance.

Individuals and organizations may submit unsolicited proposals at any time to SOLAR. Proposals related to solar energy programs may be submitted to:

Office of Unsolicited Proposals
U.S. Department of Energy
Washington, D.C. 20985

Since unsolicited proposals may form the basis for technical evaluation or contract negotiations, each should contain: detailed information on the purpose and objective of the proposed work; an indication of the offeror's background and previous experience; a concise statement of work; information relating to organization, facilities, and qualifications; other pertinent data; and a detailed cost estimate.

Because of the great degree of interest in solar energy programs and the similarities among many proposed concepts and research and development ideas (which preclude funding them on an unsolicited basis), most projects are supported as a result of solicitations. Solicitation mechanisms used by SOLAR include:

- a. *Requests for Proposals.* Requests for Proposals (RFP) are used to contract for a specific scope of work.
- b. *Program Research and Development Announcements.* The Program Research and Development Announcements (PRDA) are used to solicit proposals where a specific need is not sufficiently definable to use the traditional RFP process.
- c. *Program Opportunity Notices.* The Program Opportunity Notices (PON) are used for technological demonstrations where the objective is the acceleration of commercial application of new energy technologies and systems.

By their very nature, demonstration projects for solar energy technology do not lend themselves to consideration on an unsolicited basis. In addition, innovative concepts submitted on an unsolicited basis should promise a clear benefit to the solar energy program by offering a potential for improvement in cost or performance over other approaches.

Additional information on proposal preparation may be found in:

- a. *Guide for the Submission of Research and Development Proposals by Individuals and Organizations*, available at no cost from DOE, Division of Procurement, Washington, D.C. 20545.
- b. *Guide for the Submission of Research Proposals from Educational Institutions*, available at no cost from DOE, Office of University Programs, Washington, D.C. 20545.
- c. *Guide for the Preparation of Proposals for Special Projects in Energy Education and Training*, available at no cost from DOE, Office of Public Affairs, Educational Programs Branch, Washington, D.C. 20545.

Procurement regulations containing additional information concerning contracting policy and procedures are available at nominal cost from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

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