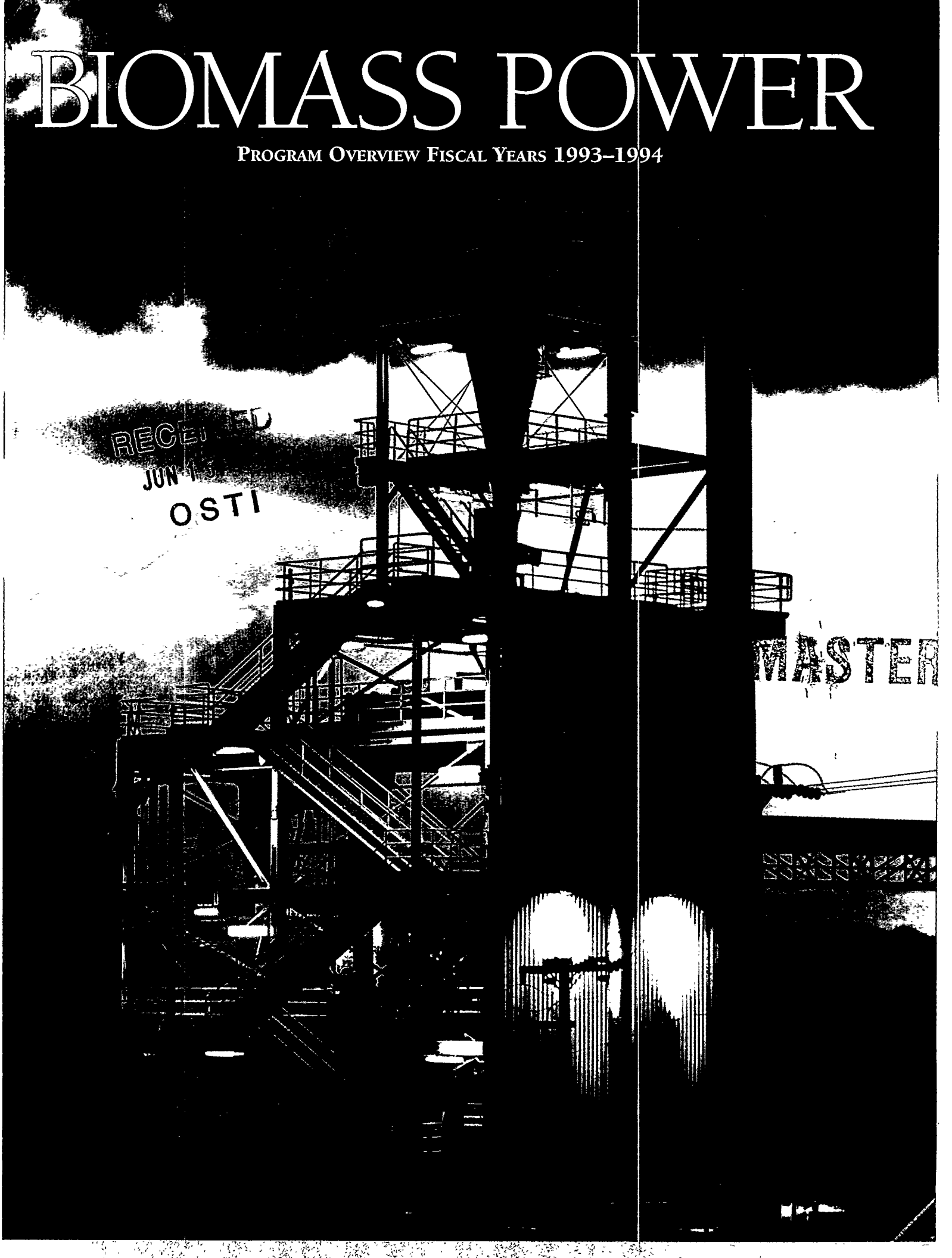
BIOMASS POWER

PROGRAM OVERVIEW FISCAL YEARS 1993–1994



FY 1993–FY 1994 Biomass Power Program Accomplishments

Promoted Commercialization of Biomass Power Through Joint Ventures

- Dedicated an industrial-scale biomass gasification facility.
- Tested a hot-gas cleanup system with gasified biomass.
- Supported 10 feasibility studies for integrating feedstock supply with biomass power facility development.
- Issued a solicitation for a 5-year, $80 million program to demonstrate Biomass Power for Rural Development.

Improved Today's Technology Through Partnerships with Industry and Power Producers

- Conducted cofiring studies and tests with the Tennessee Valley Authority.
- Worked with biomass power plant operators, industry, and researchers to characterize the chemical and physical mechanisms of alkali deposits in boilers.
- Supported development of direct-fired gas turbine operating on wood and coal.
- Developed the Advanced Transportable Molecular Beam Mass Spectrometer to bring analytical laboratory capabilities to biomass power plants developed by the Biomass Power Program.

Developed New Technologies

- Operated the world's first system using biogas from a gasifier to fuel a natural gas turbine-generator.
- Produced and tested "biocrude" oil for combustion properties.

Reduced Technical and Nontechnical Barriers to Commercialization

- Supported efforts of the National Biofuels Roundtable to develop principles and guidelines for biomass energy systems.
- Sponsored the First Biomass Conference of the Americas and made plans for the second.
- Supported work of the Utility Biomass Energy Commercialization Association.

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Cover Photo: This new biomass facility on Maui produces biogas from the fibrous by-product of milled sugarcane. The biogas can fire efficient gas turbine-generators or be converted to methanol.

Photo Credit:
Warren Gretz, National Renewable Energy Laboratory

The Biomass Power Program

Biomass is all around us. It can be found in trees, grasses, and ocean plants. Biomass is produced from these growing, living plants through photosynthesis—the process by which plant matter is formed using the energy of sunlight. The leaves, stems, bark, and wood ignite processes to generate electricity. If biomass is cultivated and harvested in a sustainable cycle that is repeated, there is no net contribution to global warming.

Biomass energy is used to make electricity, liquid fuels, gaseous fuels, and a variety of useful chemicals, including those currently manufactured from petroleum. Because the energy in biomass is less concentrated than the energy in fossil fuels, new technologies are required to make this energy resource competitive with coal, oil, and natural gas. Industry and agriculture need superior energy crops and cost-effective conversion technologies to expand the use of renewable biomass.

The Biomass Power Program and industry are developing technologies to expand the use of biomass that include methods of feedstock production and the equipment to convert feedstocks into electric power or process heat. With the help of advanced biomass power technologies and new feedstock supply systems, as much as 50,000 megawatts (MW) of biomass power capacity will be in place by the year 2010.

The Biomass Power Program supports the development of three technologies—gasification, pyrolysis, and direct combustion—from the laboratory bench scale to the prototype commercial scale. Gasification equipment produces biogas that is burned in high-efficiency turbine-generators developed for the electric power industry. Pyrolysis processes produce oils from renewable biomass that burn like petroleum to generate electricity. In direct combustion technology, power plants today burn bulk biomass directly to generate electricity. Improving the direct combustion technology of these plants increases efficiency and reduces emissions.

In addition to developing these three technologies, the Biomass Power Program supports joint ventures to plan and construct facilities that demonstrate the benefits of biomass power. Cost-shared contracts with industry, utilities, and agriculture are building the consortia and networks necessary to integrate feedstock production, processing, and combustion to generate electricity. The Program is supporting joint ventures to conduct 10 case studies of dedicated feedstock supply systems. In the coming years, an $80 million project entitled Biomass Power for Rural Development will enable prototype commercial projects to demonstrate integrated feedstock production and power generation systems.

The Biomass Power Program's goal is to promote an economically and environmentally sustainable biomass power industry based on advanced technologies.

DISCLAIMER

Promoted Commercialization of Biomass Power Through Joint Ventures

More than 1000 power plants across the country use biomass fuels to generate electricity. The biomass power industry employs more than 66,000 people nationwide. Even by today's standards, these numbers are commendable. But the Biomass Power Program still strives to double these numbers by the year 2000. To achieve this goal, the Program is working with industry to increase the supply of biomass fuels and develop more efficient electrical generating technologies.

Increasing Efficiency Through Gasification

Doubling electrical production from each ton of the sugarcane by-product, "bagasse," is the goal of the Biomass Power Program's gasification facility project in Hawaii. Most of Hawaii's sugar mills today burn bagasse to drive conventional steam turbine-generators. The mills generate electricity to power the operations and feed any excess electricity into the utility grid. Generating electricity with modern gas turbine-generators is more efficient than using steam turbines. Rather than burning sugarcane by-products, the gasification facility project gasifies them to fuel gas turbine-generators. This new gasification and generation system will be twice as efficient as the old direct combustion system used in sugar mills.

Demonstrating biomass gasification is an important part of the Biomass Power Program because gasifying biomass has several advantages over the direct burning techniques used today. One advantage is the ability of gasified biomass to fuel a new generation of efficient gas turbine-generators. Another advantage is that even fuels, such as grasses that clog conventional boilers with ash and alkali deposits, can be gasified and filtered to run gas turbines.

WARREN GRETZ, NATIONAL RENEWABLE ENERGY LABORATORY

Demonstrating a more efficient way to generate electricity with the by-product of milling sugarcane is a way for U.S. technology to tap into worldwide power markets.

One of the gasifier approaches supported by the Department of Energy (DOE) is being developed by the Institute of Gas Technology (IGT). Engineers operate a Process Development Unit (PDU) incorporating the IGT RENUGAS™ process. The process includes a gasifier and a gas turbine engineered to operate on biomass-derived fuels. The PDU gasifies about 9 megagrams (Mg) or 9.9 tons of biomass per day. The Program now supports the construction of a larger scale, industrial-size, engineering development unit (EDU) for the facility dedicated on Maui in 1994.

The biomass gasification facility will convert biomass feedstock to biogas. Then the facility will clean and burn the biogas to generate electricity in a modern, combined-cycle gas turbine.

The industrial-size biomass gasification facility is a joint venture between industry and government. The DOE Biomass Program, the State of Hawaii, and the Pacific International Center for High Technology Research shared the cost to build the gasification facility that operates at the Hawaiian Commercial & Sugar Company mill in Paia, Maui. In addition, the University of Hawaii, IGT, the Ralph M. Parsons Company, Westinghouse Electric Corporation, and Gilbert/Commonwealth, Inc., contributed to the project.

The success of this project will benefit the sugar industry and the local economy, in addition to demonstrating an important technology. And generating more electricity with the same resources helps keep Hawaiian sugar competitive in worldwide markets.

The project will progress through several test and construction phases during the next few years. Today, the facility processes more than 90 Mg (99 tons) of sugarcane by-products per day into biogas. This gas has about one-eighth the heating value (energy content) of natural gas.

After the gasifier has passed initial tests, the demonstration will expand to generate electricity with the biogas it produces. Researchers will install a 5-MW combustion turbine-generator and hot-gas cleanup system developed under supporting contracts. The Program will document performance and electrical production of the facility. The experience gained will guide the Biomass Power Program's research efforts and accelerate commercial availability of gasification technology.

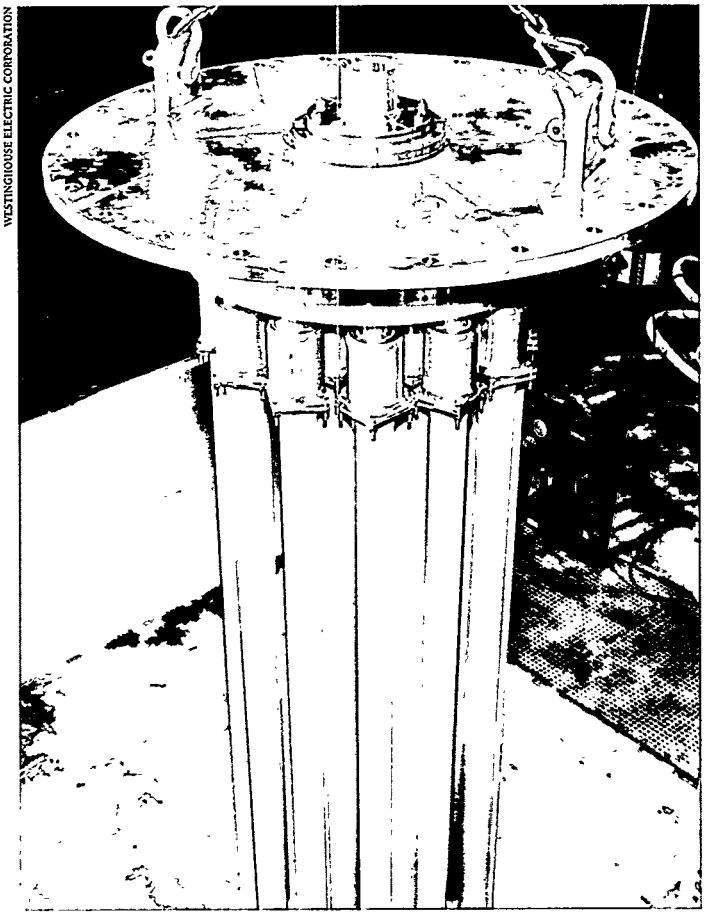
Demonstrating biomass gasification technology is an important part of the Biomass Power Program. Using feedstocks more efficiently is an attractive way to fuel expanded biomass-powered generating capacity with today's resources. In addition, the worldwide sugar industry is a ready market for U.S. industry's gasification technology.

Supporting Research Develops Efficient Gas Cleaning Systems

Demonstrating new technology, such as the biomass gasification facility, incorporates the results of several research projects within the Biomass Power Program. For example, researchers are developing efficient ways to clean biofuels before they enter the gas turbine-generator in Maui. Biomass-derived gaseous fuels (biogas), much like fuels derived from coal gasification, contain unwanted constituents that could reduce turbine life and efficiency. Particulates, tar, and alkaline compounds are removed from the gas stream to prevent erosion of components and buildup inside the turbine.

Commercially available low-temperature gas cleanup systems increase power plant energy requirements and lower overall plant efficiency. Designed for coal gasification plants, low-temperature gas cleanup systems require heat exchangers to cool the gas. The gas must then be reheated for combustion, drawing extra energy from the plant.

The Biomass Power Program is developing a new, hot-gas cleanup system to remove unwanted by-products from biogas. The hot-gas cleanup system has several advantages over today's commercially available, low-temperature gas cleanup systems. Initially developed for high-efficiency coal-to-electricity systems, the hot-gas cleanup system requires no cooling or reheating of the gas stream because it operates at temperatures reaching 925°C (1697°F). With a single, high-temperature process the new system removes ash, particulates, and alkaline compounds, while it destroys tars and controls carbon monoxide and nitrogen oxides.



WESTINGHOUSE ELECTRIC CORPORATION

This array of ceramic "candles" filters particulates from biogas as it passes through the hot-gas cleanup system on its way to the turbine-generators.

The Biomass Power Program contracted with Westinghouse Corporation and the IGT to develop and test a hot-gas cleanup system for the Hawaiian biomass gasification facility. In FY 1994, the contractors tested the PDU version of the hot-gas cleanup system at IGT in Chicago. First, test engineers ran a bench-scale gasifier and produced biogas from Hawaiian sugarcane residue. Then they operated the PDU hot-gas cleanup system to purify it. In FY 1995, the Program will move the PDU to Hawaii for testing on the biomass gasification facility itself. Finally, an industrial-scale unit will be built at the Hawaiian facility. Biogas from the gasification facility will pass through the hot-gas cleanup system and into the turbine-generator.

More About Gasification

Biomass gasification is a process in which heat and a gasifying agent, such as air or oxygen, are applied to solid biomass to transform the solid into gaseous fuel molecules. The gaseous fuel can then be burned in a gas turbine to generate electricity.

Replacing less efficient conventional boilers with advanced biomass gasifier or gas turbines can increase the amount of electricity produced from biomass by 50% or more. For even higher efficiency, the gas-turbine cycle can be combined with the steam cycle in either an integrated gasifier combined-cycle or steam injected gas turbine.

Gasification can take advantage of biomass feedstocks unsuitable for direct burning. When biomass fuels are burned in conventional boilers, the inorganic materials that do not burn stick to boiler walls and reduce efficiency. Many fast-growing, desirable energy crops and residues have high proportions of these inorganic compounds. Inorganic compounds are removed during gasification as part of the cleanup process. The filtered by-products are then recycled back to croplands.

According to feasibility studies sponsored by the Program, three types of gasifiers—fixed-bed, fluidized-bed, and entrained-flow gasifiers—make economic sense when used in conjunction with gas turbine-generators. They are used in a direct-fired mode in which air or oxygen is fed directly to the gasifier, or in an indirect mode in which externally supplied heat is used to gasify the biomass.

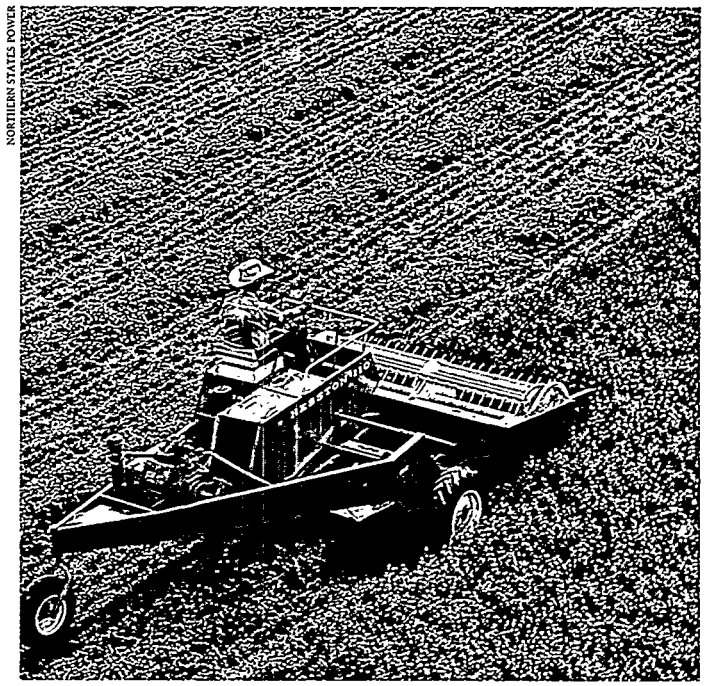
Gasification with air produces a low-Btu gas, with a heating value about one-fifth that of natural gas. Indirectly heated gasification and oxygen-blown gasification produces a medium-Btu gas, with heating values as much as one-half that of natural gas.

Integrating Feedstock Supplies with Power Systems

One way to guarantee a long-term fuel supply for a biomass power plant is to plan and manage a dedicated feedstock supply system (DFSS). A DFSS requires agricultural organizations to manage the feedstock supply, and utility and industrial interests to specify power plant requirements. For the fuel supply to be reliable, long-term partnerships among these types of organizations must develop.

The Biomass Power Program is encouraging partnerships to integrate feedstock production with electric generating plants in the United States. In FY 1993, the Program issued a solicitation for teams to explore ways to integrate the production of biomass feedstocks with power systems. Ten teams, each containing agricultural, industrial, and utility representatives, began site-specific case studies of biomass power plants in 1994.

In one of these studies, Northern States Power, an electric utility headquartered in Minneapolis, Minnesota, is leading a team to evaluate a DFSS. The DFSS will be linked to a biomass power system to be added to the power station in Granite Falls, Minnesota. The DOE Biomass Power Program and the Electric Power Research Institute are sharing the cost of this study with team members including the University of Minnesota, Westinghouse Electric Corporation, the IGT, and Tampella Power Company.



The leaf sections of this alfalfa crop serve as cattle feed, while the stem sections fuel a biomass power plant.

The study team is considering the economics of supplying feedstock to the power plant in Granite Falls. Dedicated farm acreage would produce alfalfa feedstock that is separated into leaf sections and stem sections. The leaf sections may command prices as high as $125 per Mg as animal feed, while the stem sections would be gasified in an integrated gasification combined-cycle power system. Dual use of the feedstock crop adds value to the project.

In another study sponsored by the Program in FY 1994, the Pacific International Center for High Technology Research and the Pioneer Sugar Mill, operated by the AMFAC Corporation, are analyzing the feasibility of different feedstocks for generating electricity at the mill. Researchers are evaluating the supply of feedstocks such as cultivated crops, residues from sugarcane production, and other sources of biomass in the region around a sugar mill. These materials are used to produce electricity, ethanol, and other by-products such as fertilizer.

The case studies will form the basis for the FY 1995 proposals to build demonstration projects. The Biomass Power Program will help fund construction of the most promising supply systems integrated with power plants.

Funding for demonstration plants will come from an initiative of the Biomass Power Program, called Biomass Power for Rural Development. This $80 million, 5-year program will demonstrate integrated systems of feedstock production, processing, and use to generate electric power. Principal among the issues to be addressed are the local economic benefits of this kind of sustainable energy development. The first of these projects will begin in FY 1995 and lead to the design and construction of integrated biomass power systems.

WARREN GRETZ, NATIONAL RENEWABLE ENERGY LABORATORY

Energy crops represent an attractive option for better use of fallow crop lands. Millions of acres of set-aside land could produce energy crops that protect against erosion but do not depress food prices.

Dedicated Feedstock Supply Systems

Utilities and independent power producers must have reliable, abundant supplies of low-cost biomass feedstocks before they build additional biomass power facilities. Today's biomass power plants use residues from paper mills, sawmills, wood products manufacturing, urban wood surpluses (such as tree trimmings or used pallets), biomass resulting from good forest management practices, orchard prunings, agricultural by-products, and food processing remains (such as nut shells). Tomorrow's biomass power plants will be fueled from dedicated feedstock supply systems that use energy crops destined for specific facilities.

TOMORROW'S BIOMASS POWER PLANTS WILL BE FUELED FROM DEDICATED FEEDSTOCK SUPPLY SYSTEMS THAT USE ENERGY CROPS DESTINED FOR SPECIFIC FACILITIES.

Energy crops are trees and grasses selected for high yields and resistance to drought and pests. Trees are harvested on 5- to 15-year cycles. Most grasses can be harvested one or more times during the annual growing season and may be baled like hay. Some annual crops, including grasses, grains, and oilseeds, are already part of the biomass energy market.

Tomorrow's feedstocks will consist of dedicated plantings of fast-growing woody crops such as willow and poplar trees, and herbaceous crops such as tall grasses and canes. The Department of Energy is developing hybrid poplar and other energy crops for these dedicated acres. Establishing such crop lands dedicated to supplying reliable, low-cost, renewable fuel will enable biomass power plants to make a substantial contribution to the nation's electric power supply.

Improved Today's Technology Through Partnerships with Industry and Power Producers

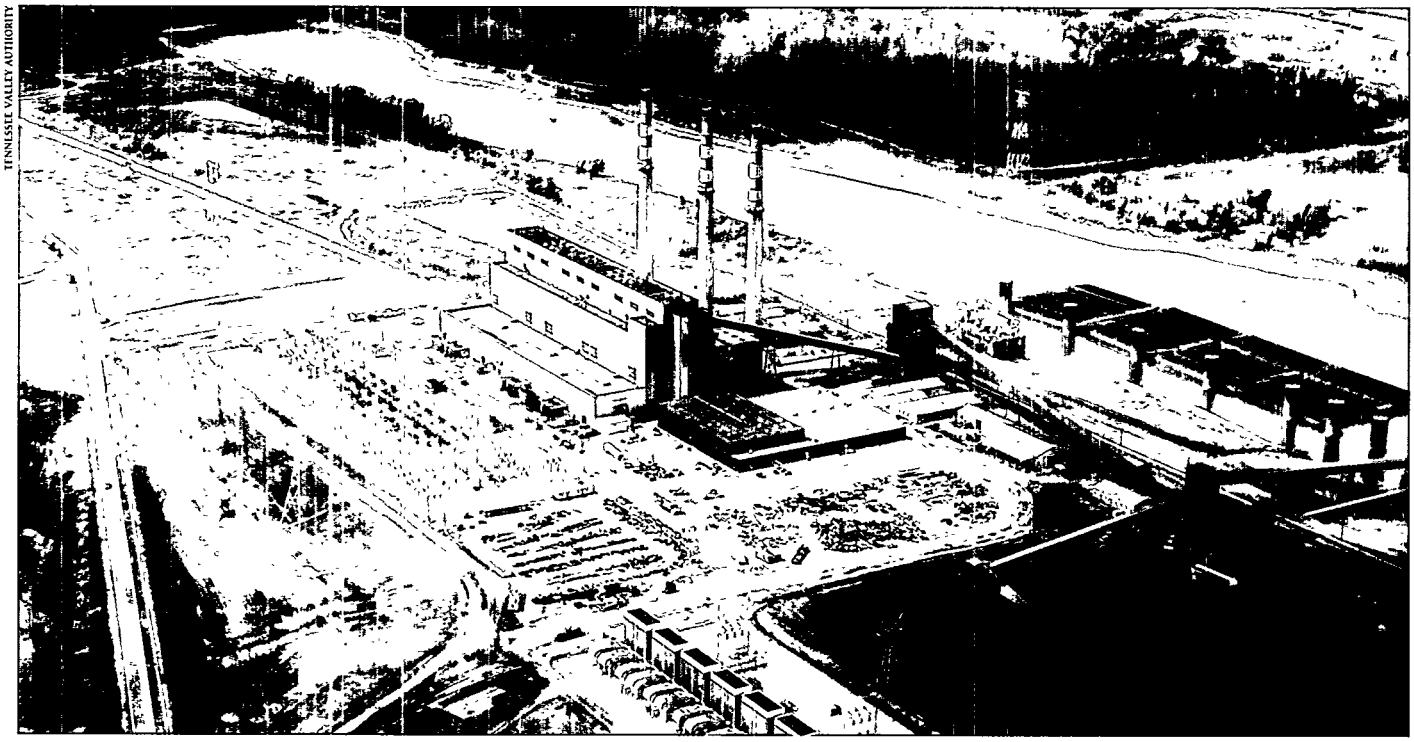
Today's commercial biomass conversion technologies use direct-combustion equipment that burns biomass as a bulk material in a boiler. The Biomass Power Program works with industry and utilities to improve the efficiency and reduce manufacturing costs of these technologies. The Program also expands the range of acceptable feedstocks for direct-combustion systems.

Cofiring Power Plants Help Utilities Meet New Emission Standards

In an effort to reduce acid rain problems, the Clean Air Act Amendments call for substantial reductions in sulfur dioxide emissions from utility power plants. As a fuel with minimal sulfur content (less than 0.1% by weight), biomass is "cofired" or burned along with coal in existing power plants to reduce overall sulfur emissions. Cofiring small amounts of biomass with coal (2%–5% of heat input) requires no modifications to existing coal facilities for handling and burning biomass fuel. In addition, existing pollution control equipment can be used often.

Reducing emissions and rejuvenating the region's agricultural economy are two reasons the Tennessee Valley Authority (TVA) teamed with DOE and the Electric Power Research Institute to study cofiring. TVA wanted to use higher proportions of biomass at fossil-fuel-fired power plants than had been tested at other utilities. The study team first evaluated the biomass resource potential in 201 counties served by TVA. Researchers inventoried local supplies of mill and logging residues and short-rotation intensive culture crops near each power plant. (No native forest harvesting for energy is being pursued.) Then the team determined the technical feasibility of cofiring three types of power plants. Finally, TVA conducted cofiring tests at plants where the technical feasibility and the resource potential seemed most promising.

Two cofiring tests were completed in 1994, and the results were encouraging. Biomass was cofired with pulverized coal at the Kingston Plant near Knoxville, Tennessee, where clean wood residues are plentiful. Wood by-products were also cofired in a cyclone coal-fired power plant at the Allen Steam Plant near Memphis. At the Allen Plant, researchers added biomass fuel, as much as 10% of heat input, to the coal with no loss in generation efficiency. Biomass from local sawmills continues to supply the biomass fuel needs of this plant. As tests continue, TVA is planning a wood burning initiative that would cofire wood at a number of other coal-fired power plants.



This coal-fired power plant, operated by the Tennessee Valley Authority, burned as much as 10% biomass in conventional boilers with no loss of efficiency or output. Cofiring biomass in conventional power plants such as this one can help meet new emission standards and dispose of agricultural and wood processing residues destined for landfills.

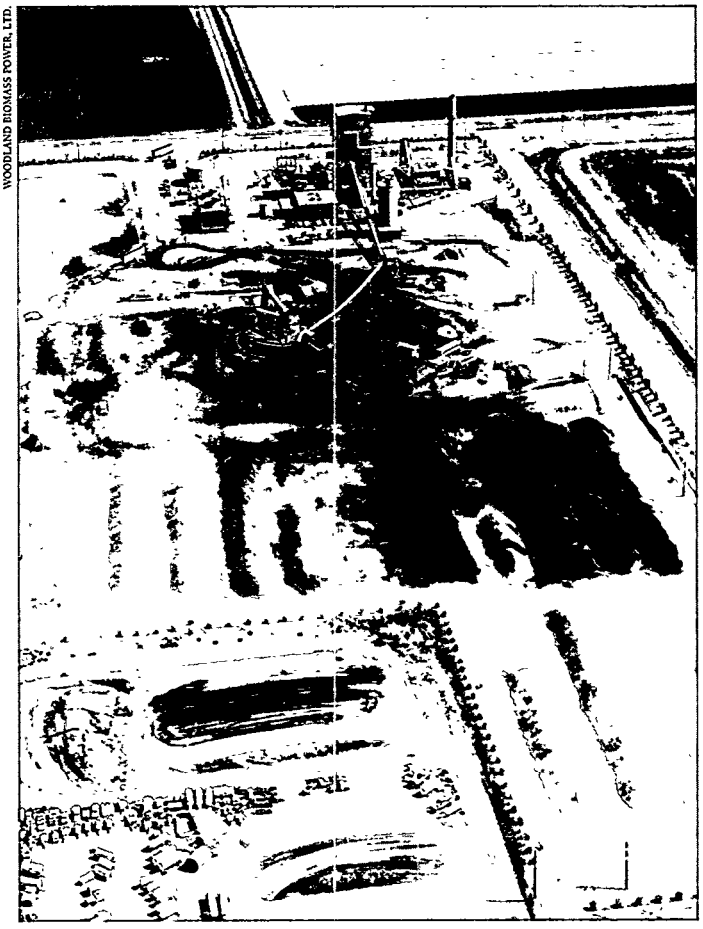
Biomass Power Plant Operators and DOE Study Alkali Deposits

The ash (inorganic compounds) left behind during combustion of hay or straw continues to create technical difficulties for direct-fired systems. The 20%-35% alkali compound content in ash from annual crops and agricultural residues lowers its fusion point from 1300°C (2400°F) for wood ash to 650°C (1200°F) for some straws. Burning straw and annual crops in conventional boilers leaves molten slag (ash that has been melted) and glassy deposits. When molten or partially molten ash particles strike a wall or tube surface, they cool and coat the surface with a hard deposit. Layers of this material on boiler tubes impede heat transfer to the water or steam, increases draft losses, and reduces boiler efficiency.

A collaborative project combining the resources of industry, private design engineers, academia, DOE-supported laboratories, and the Bureau of Mines, is characterizing the chemical and physical mechanisms of alkaline deposits. For 2 years, researchers have studied the properties of commonly used biomass fuels such as wood products and switchgrass. In all, 26 different biofuels were evaluated, resulting in 120 complete fuel analyses.

Researchers confirmed that potassium was the most significant component and the major cause of the ash fouling and slagging problem. Using this information, the research team developed better analysis strategies to establish the alkali compound content of fuels and the appropriate temperature levels for combustion.

The researchers also measured the burning characteristics of biomass fuels. At Sandia National Laboratories, scientists simulated commercial-scale burning conditions in their experimental large-tunnel combustion system. Burning properties of each fuel were measured and recorded to explain why ash deposits occur. This information helps commercial power plant operators make decisions about blending fuels and operating power plants at optimal temperatures to reduce formation of slag and ash.



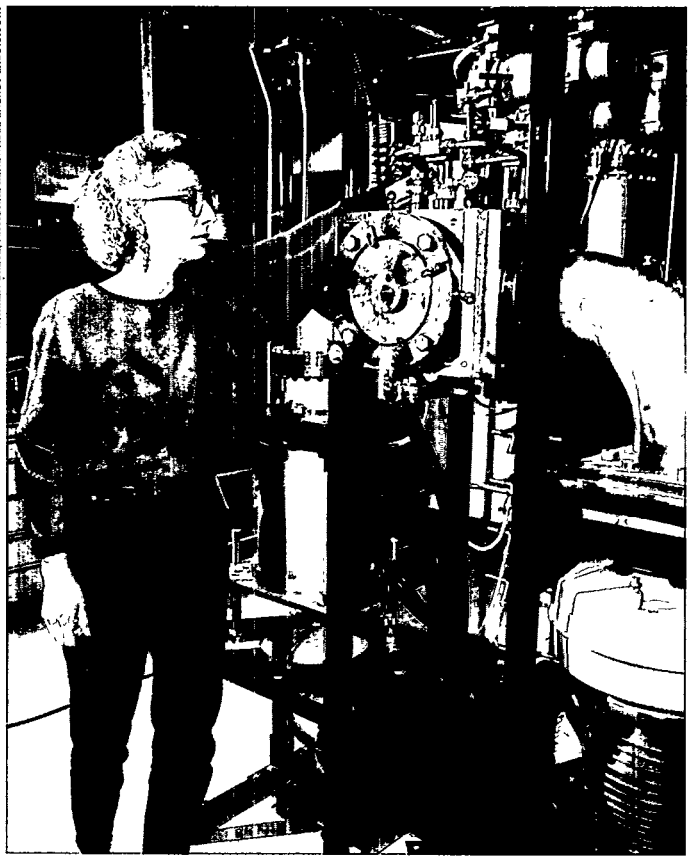
WOODLAND BIOMASS POWER, LTD.

Researchers from industry and the Biomass Power Program studied alkali fouling in this 28-MW power plant in Woodland, California. The plant burns branches pruned from local orchards and other clean wood residues. Data from the study help operators optimize boiler temperatures for different types of wood.

Fuel properties are not the only factors determining the production of slag in a boiler. Other factors include boiler design and operating characteristics. To detail boiler characteristics, researchers sampled ash deposits from nine commercial biomass power plants operating on straw, stalks, stems, and other annual crops or agricultural residues. Analyses of these samples, performed at the National Renewable Energy Laboratory (NREL), Sandia, the Bureau of Mines, and Hazen Research, Inc., helped describe the slagging tendencies of each boiler for various fuels. With this information, designers of future biomass power plants will be able to design boilers that form fewer ash deposits.

The properties of fuels and the emissions from biomass power plants are also being analyzed using the Transportable Molecular Beam Mass Spectrometer developed at NREL. The precise spectral analysis of fuels is correlated with combustion tests and observed boiler slagging behavior to develop an empirical model that predicts feedstock fouling and slagging potentials. The spectrometer, which can be transported to plants around the country, is used to help biomass power facilities assess and control air emissions.

Incremental improvements to direct-fired systems, based on DOE-sponsored research, improve competitiveness by increasing the variety of fuels the systems use and by helping the systems meet environmental requirements for operating permits.



WARREN GRETZ, NATIONAL RENEWABLE ENERGY LABORATORY

This sophisticated measurement tool developed at the National Renewable Energy Laboratory brings the laboratory to the power plant. The Transportable Molecular Beam Mass Spectrometer measures elements of the hot-gas stream that cannot be seen with gas chromatography. Analysis of the gas stream helps evaluate cleanup systems at power plants.

Direct-Fired Gas Turbine Burns Wood and Coal

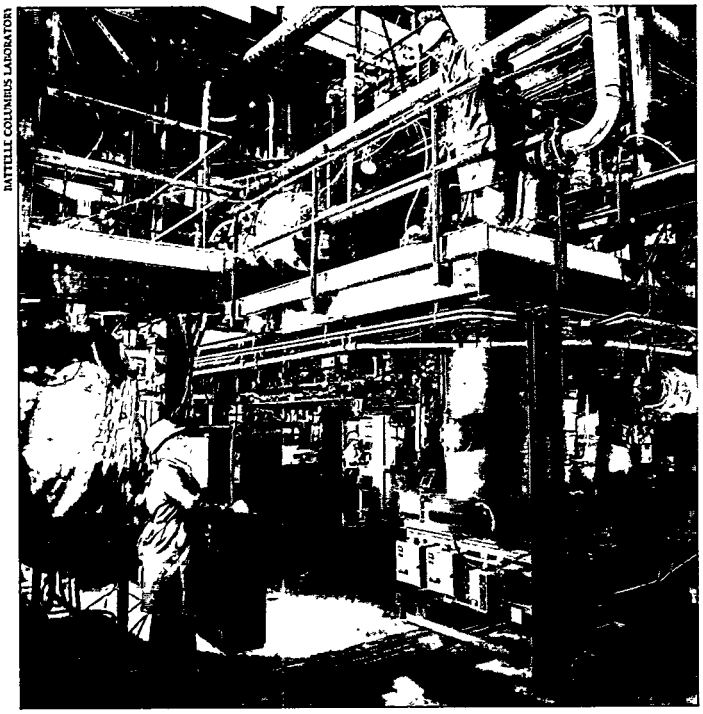
The Biomass Power Program also works to improve today's direct combustion biomass power systems. In one project, the Program helps build and demonstrate an industrial-scale system that burns several types of solid fuel and promises high thermal efficiency rates.

In this demonstration, Power Generating Inc. is sharing the cost with DOE to design, construct, and operate a 400-kilowatt (kW) system at the Western Research Institute in Laramie, Wyoming. First, the system will burn clean wood, and then coal. The project will confirm the technical and economic feasibility of operating the direct-fired gas turbine power system on wood and coal. Later, additional fuels will be tested.

Like all power-generating technologies, biomass power must meet increasingly stringent environmental requirements at a reduced cost. Systems now under development offer significant cost improvements, improved emissions, and higher efficiencies.

Gasifying Biomass for Gas Turbines

In addition to the gasifier/gas turbine demonstration on Maui, the Biomass Power Program supported work leading to the first demonstration of a natural gas turbine operating on biogas. In 1994, researchers at Battelle Columbus Laboratory integrated a biomass gasification pilot plant and a natural gas turbine to engineer the first biomass gas-powered turbine. The indirectly heated gasifier at Battelle converts as much as 9 Mg (9.9 tons) per day of wood or wood by-products into a medium-Btu biogas. The biogas is cleaned by conventional scrubbers or by Battelle's hot-gas conditioning catalyst. It is then compressed and used to fuel a conventional gas turbine-generator. The 200-kW turbine is manufactured by Solar Turbine Inc. to operate on natural gas. More than 50 hours of operation on biomass-derived gas demonstrated that the turbine operates equally well on biogas.



BATTELLE COLUMBUS LABORATORY

For the first time, researchers operated a conventional gas turbine on biogas from a gasifier. This test demonstrates that renewable biomass-derived gas provides an alternative to nonrenewable natural gas.

This promising technology will be demonstrated at a biomass power plant in Burlington, Vermont. The McNeil Generating Station is owned by Burlington Electric Department, Central Vermont Public Service Corporation, Green Mountain Power Corporation, and the Vermont Public Power Supply Authority. The 50-MW biomass power plant has operated since 1984, firing as much as 85 tons per hour of wood residues. The wood comes from tops and cull portions left from trees harvested for lumber or paper.

DOE is sharing the cost of this two-phase demonstration. In the first phase, a 200-dry-ton-per-day gasifier based on the Battelle technology will be constructed by Future Energy Resources Corporation at the McNeil Generating Station. At first, the biogas will be used in the existing boilers to demonstrate the scaled-up gasifier unit. (Most boilers designed to operate on solid fuels also operate on gases.) In the second phase, a 15-MW natural gas combustion turbine will be installed. The turbine will burn biogas from the gasifier and form an integral part of a combined-cycle system. The Battelle system offers increased throughput to the plant and, when the gas turbine comes on line, increased efficiency.

Another gasifier concept supported by the Program is Manufacturing and Technology Conversion International's indirectly heated gasifier. The gasifier operates on biomass feedstocks consisting of woody and herbaceous feed materials. Project researchers confirmed that these types of feedstocks gasify successfully in such a device. To test the commercial potential of this concept, the DOE Office of Industrial Technology funded construction of a larger scale unit that processes about 40 Mg (44 tons) of biomass per day. This unit is currently undergoing tests at a plant owned by Weyerhauser Company in New Bern, North Carolina.

Producing a Liquid Fuel from Biomass

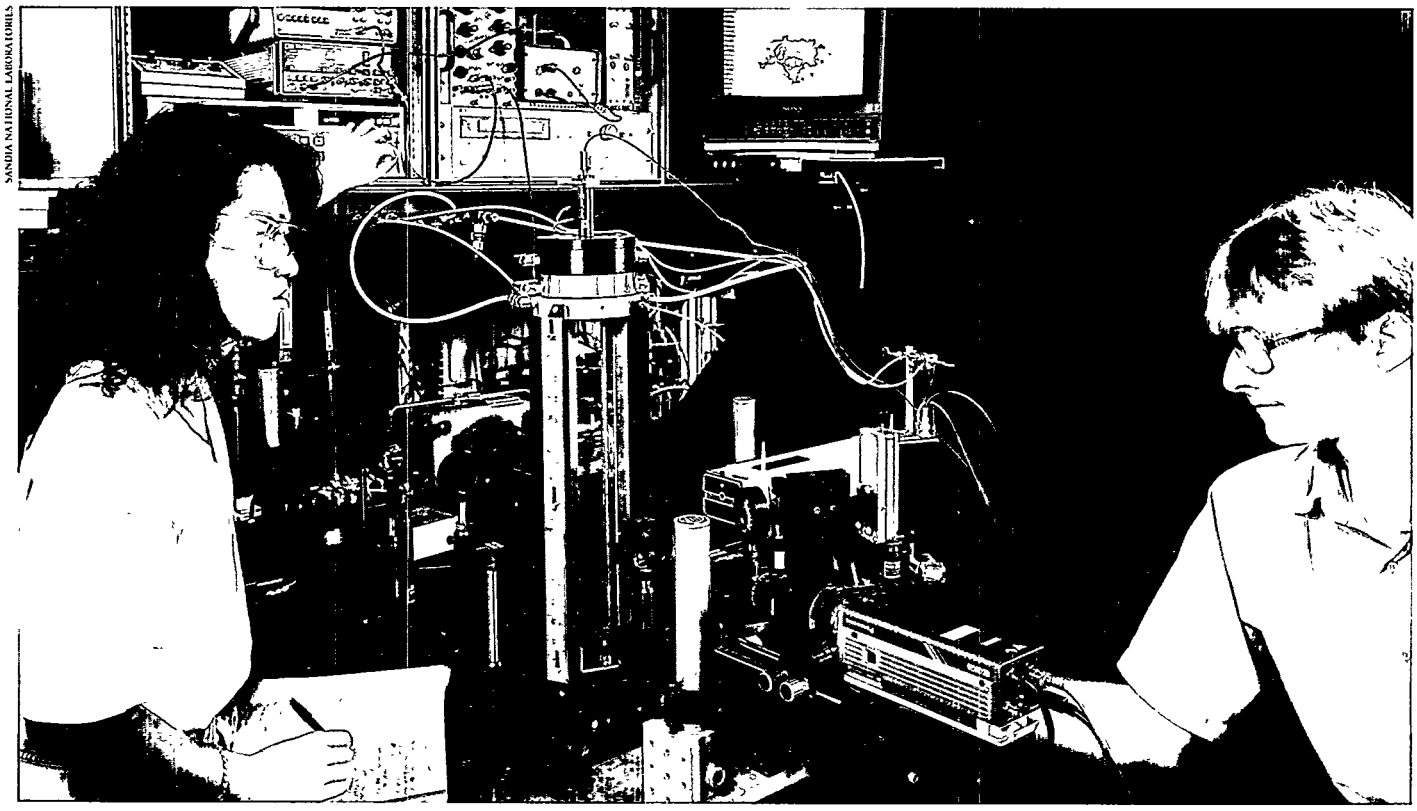
In addition to improving gasifiers and turbines, the Biomass Power Program supports work to explore pyrolysis oils or "biocrude." Biocrude oil is formed when biomass is subjected to heat-induced chemical breakdown (cracking) in the absence of oxygen. The resulting liquid fuel could be stored for later use or transported to power plants in other locations.

Using a liquid fuel derived from biomass in turbine-generators has several advantages over the direct combustion of biomass. Biocrude could be handled like diesel fuel in plants, eliminating the need for special drying, storage, and conveyer systems. Biocrude oil could be easily transported over long distances, and, therefore, could be used in power plants far from the source of biomass production. And, perhaps most important, biocrude contains little sulfur, less than 0.1% by weight, and could be used to offset sulfur emissions in conventional power plants by cofiring it with pulverized coal or using it in place of heavy, No. 6 fuel oil.

The Biomass Power Program is working to increase the availability of biocrude oil. Biocrude is made using fast pyrolysis, a process well understood at the molecular level. However, researchers are learning more about the combustion and products of fast pyrolysis to optimize the energy content, burning characteristics, and purity of biocrude for electric power generation. For example, NREL has developed a Fast Ablative Pyrolysis process that has the potential to generate high-quality oil in large quantities.

An important part of producing biocrude is removing impurities. The Program is funding work to filter char from hot pyrolysis vapors during the production of biocrude. Researchers must determine the optimum operating conditions for hot filtration to prevent condensation of oils in the filter, while minimizing reductions in output. Because each feedstock produces char with different characteristics, pyrolysis experiments help match filters to feedstocks for the most efficient hot filtration.

The Biomass Power Program also conducts physical and chemical measurements to characterize pyrolysis oils. Researchers determine differences among oils and conduct aging studies to establish the useful storage life of biocrude. They also perform tests to confirm the compatibility of biocrude oil with materials used in plant and fuel handling equipment. Understanding the chemical nature of biocrude helps researchers develop safe procedures for handling, storing, and transporting biocrude oil.



This laminar flow combustor at Sandia National Laboratories burns oils generated from various biomass feedstocks, one drop at a time, under carefully controlled conditions.

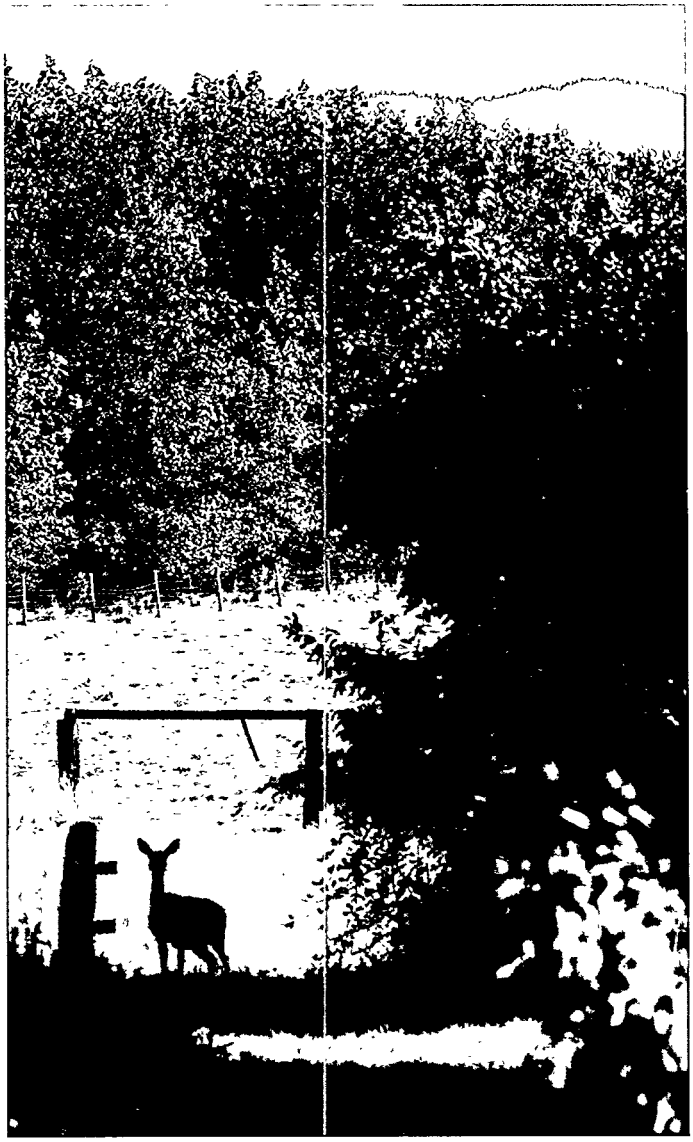
Reduced Technical and Nontechnical Barriers to Commercialization

The Biomass Power Program helps increase market acceptance by working to overcome barriers, both technical and nontechnical, that impede the adoption of technologies. Programmatic research generates information on environmental impacts, operating conditions, feedstock characteristics, turbine operation, and economics. The Program provides systems analysis to the industrial partners of the Program to help them compete in today's power market. The Program also provides information and education to the public, the ultimate consumers of biomass power technology.

The Program communicates basic information and data on the characteristics, costs, applications, and benefits of biomass power to regulators, utilities, industry, and the public. For example, NREL researchers, in conjunction with experts at Oak Ridge National Laboratory, DOE Headquarters, and state energy offices, will develop a model of an integrated plantation and conversion plant system. The model will include cash flow for the operation of the plantation and power plant. In addition, the analysis will include a cost model to evaluate operational proposals.

The development of biomass as renewable energy resources could affect diverse groups of people in the United States. The Biomass Power Program participates in efforts to bring these groups together to identify and resolve issues. The National Biofuels Roundtable attracted 30 experts in social and natural sciences, representing 24 different constituencies of industry, government, academia, and public interest or environmental groups. The final report issued in May 1994 is entitled Principles and Guidelines for the Development of Biomass Energy Systems.

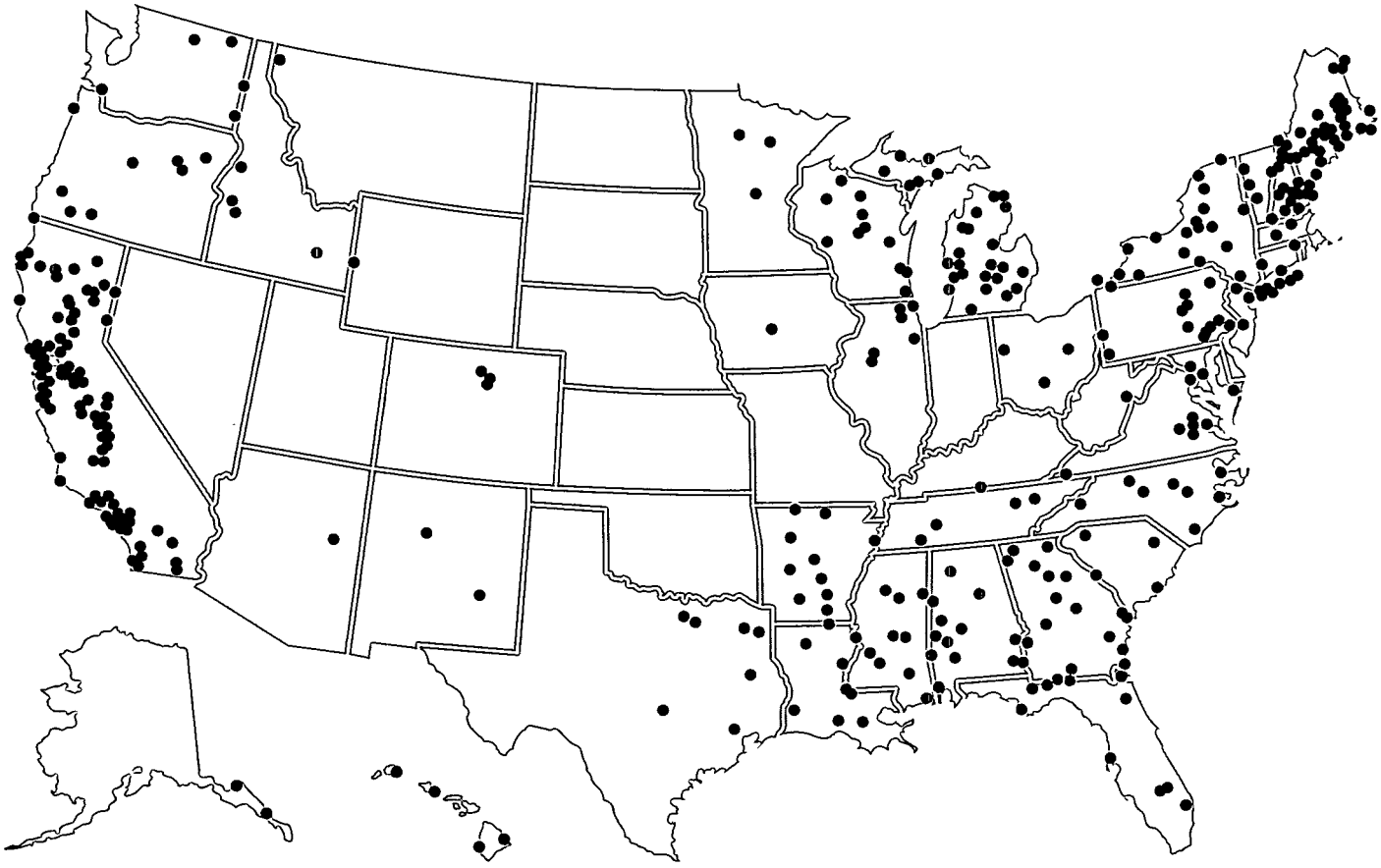
The Biomass Power Program also supports industry efforts to increase awareness of the potential of biomass power. The First Biomass Conference of the Americas was attended by more than 600 people, including representatives from all major groups interested in the development of biomass power. Presented under the auspices of NREL and sponsored by DOE, the U.S. Department of Agriculture, the U.S. Environmental Protection Agency, and the Canadian Department of Energy, Mines, and Resources, the meeting stressed demonstration projects and commercial applications of biomass and wastes. The next conference is scheduled for August 1995 in Portland, Oregon.



WARREN GRETZ, NATIONAL RENEWABLE ENERGY LABORATORY

Energy crops such as these fast-growing hybrid cottonwood trees planted by the James River Corporation in Clatkansie, Oregon, can provide a safe habitat for wildlife. The Biomass Power Program is developing ways to use energy crops in an ecologically sensitive manner.

Biomass-Fired Power Plants



All together, there are more than 350 biomass-fired power plants connected to utility grids throughout the United States with a combined rated capacity of 7000 MW.

In another industry effort supported by DOE, utilities and other power producers established the Utility Biomass Energy Commercialization Association (UBECA). One of UBECA's goals is to assemble and share information about the benefits and opportunities of biomass power for electric utilities, power producers, and customers. UBECA directs information among members and voices the interests of the industry in public forums.

According to a UBECA white paper, "Biomass is the only renewable resource that is widely available and can be fully stored and dispatched. Technology for widespread biomass utilization is here today and familiar to power plant operators... And the benefits of using biomass energy closely intertwine with local economic development, job retention and growth, sustainable agriculture, stronger customer ties, and environmental enhancement of air, land, and water."