NREL Advances in Technology at the National Renewable Energy Laboratory

Technology Brief

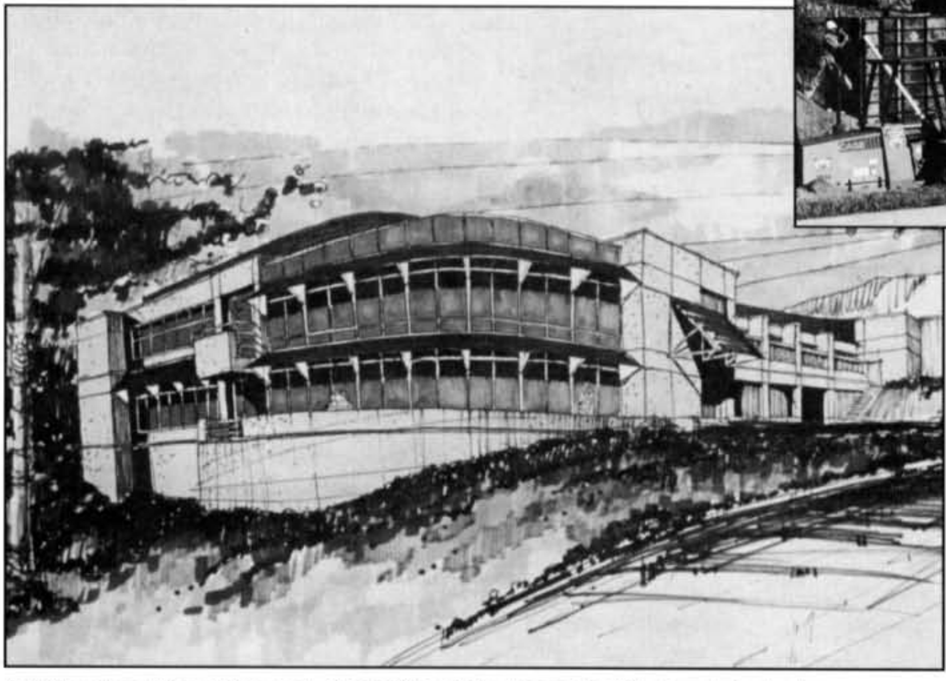
NREL to Build Major Biofuels Facility

Industry to Help Demonstrate Viability of Fuel of the Future

The capability of American technology and industry to develop a "homegrown" motor fuel to meet national energy policy goals will take a major step forward in the next year. During 1994, the National Renewable Energy Laboratory (NREL), with U. S. Department of Energy (DOE) support, will begin operating a $2.2 million Alternative Fuels Users Facility (AFUF) at its Golden, Colorado site. NREL engineers and their industry partners will use the AFUF for initial scale-up and integration of ethanol production technology (see sidebars, next two pages) that shows great promise in the laboratory. DOE believes funding of such activities is critical for determining the commercial potential of a major new industry for the United States—an industry with vast potential economic and environmental benefit.

Researchers and engineers from industry and academia, as well as from NREL and other national laboratories, will now be able to test at pilot-plant scale promising ethanol production technologies. NREL scientists have high expectations for technologies that convert lignocellulosic biomass (the fibrous portion of plant material) to ethanol. In addition to specially grown grasses and trees, other potential feedstocks include agricultural and forestry residues, along with paper and other municipal solid waste—a major portion of the waste generated in the United States.

NREL and DOE are eager to work with industry to test methods for producing ethanol from biomass on a scale leading to commercial application.



Artist's conception of the new Alternative Fuels Users Facility. Inset photo shows construction site in October 1993.

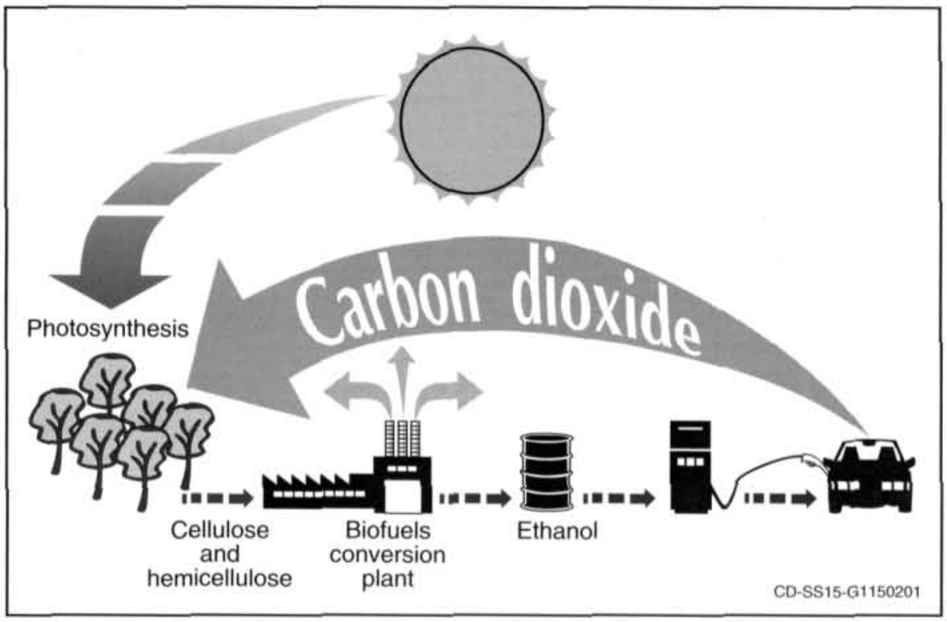
Making Biofuels a Reality

Ethanol is an alternative fuel that can be used in pure form or blended with gasoline to help reduce carbon monoxide and hydrocarbon emissions from mobile sources. Many of the recent advances in biomass fuel technology relate to the breakdown

What is Ethanol?

Ethanol (C_2H_5OH), commonly known as grain alcohol, is the same ancient brew as that made by fermentation of sugar for beverages. It is also one of the most promising biofuels. Biofuels are made from biomass—plant material or wastes derived from plant material. The carbon dioxide released when these renewable resource materials burn is roughly balanced by the carbon dioxide consumed in photosynthesis as they grow. In contrast, fossil fuels obtained their energy from photosynthesis of plants that lived millions of years ago. Their supply cannot be replaced and their burning adds "new" carbon dioxide to the atmosphere.

Cellulose and hemicellulose make up the bulk of the biomass in most plants. Unlike starches and sugars, cellulose and hemicellulose are carbohydrates that humans cannot digest and most yeasts cannot ferment. But scientists have made substantial gains in using acids and enzymes to convert these fibrous carbohydrates into simple sugars so they can be fermented into ethanol.



Carbon dioxide released when biofuels burn is roughly balanced by carbon dioxide consumed in photosynthesis as source materials grow.

of lignocellulosic material so it can be fermented into ethanol.

Conversion of lignocellulosic material could substantially reduce ethanol costs and enormously expand available feedstocks. NREL and DOE are eager to work with industry to test methods for producing ethanol from biomass on a scale large enough to identify and overcome problems associated with progress toward commercial application.

The new AFUF will provide the facilities needed to move ethanol and other biomass research advances into the development phase. The facility includes a pilot plant and integrated start-to-finish process development capabilities. Two existing buildings will be joined to house the pilot plant. A new 1,580-square-meter (17,000-square-foot) building will house laboratories and offices.

Process Development Unit Pilot Plant

The core of the AFUF is a 743-square-meter (8000-square-foot) Process Development Unit (PDU). Researchers will use this pilot plant to explore fermentation technologies at a much larger scale than possible in the laboratory. The PDU's 900 kg (1 dry ton) per day feedstock capacity will improve assessment of the operability of the biomass-to-ethanol process and allow testing of commercially available equipment. The increase in scale will enable researchers to employ instrumentation to accurately confirm material and energy balances. They will also be checking heat and mass transfer effects, which will be measurable in the pilot-scale equipment.

When the PDU starts up in 1994, it will employ four 9000-liter (2308-gallon) fermentation tanks. In 1995, five additional fermenters will be added to the PDU. This will allow the simultaneous fermentation of cellulose and hemicellulose sugars as well as production of cellulase enzyme.

Additional AFUF Facilities

The AFUF will contain two bioprocess integration laboratories where researchers can test operations and processes linked as they would be in actual production. Process integration will identify key chemical and biological interactions between the various steps. NREL will utilize process integration results to identify the best processes for pilot plant trials in the PDU.

Other AFUF facilities will include research laboratories for bench-scale

NREL views the opportunity for cooperative research with biomass processing industries as a primary benefit of the new AFUF.

DOE and NREL seek to demonstrate that ethanol can be commercially produced from biomass at prices competitive with gasoline.

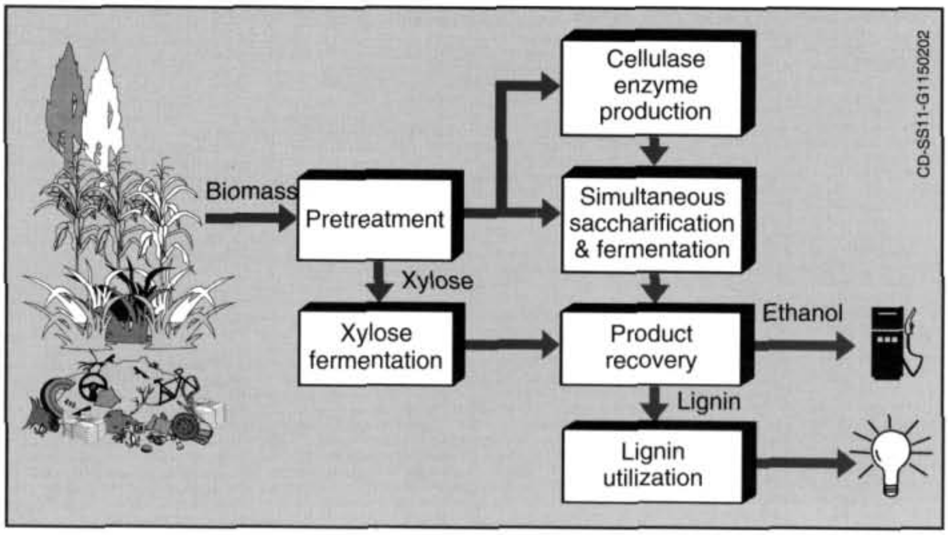
fermentation and enzyme production; a feedstock pretreatment laboratory; analytical laboratories; and office, conference, and observation areas for cooperative research partners, outside researchers, and NREL staff.

Cooperative Work with Industry a Primary Goal

Initial PDU operations will support a major cooperative research and development agreement (CRADA) between NREL and the Amoco Corporation. This agreement may lead to Amoco constructing a commercial demonstration facility for producing ethanol from biomass. Through agreements such as this, the PDU and all the other AFUF facilities can be made available for additional cooperative projects.

NREL views the ability to conduct cooperative projects with industries and researchers interested in ethanol or other biofuels processing as a primary benefit of the new AFUF. Many forestry products, as well as agriculture, food processing, and other industries, have lignocellulosic waste streams that may present particularly good opportunities for near-term biofuels production. NREL will also continue to develop conversion technologies for large-scale ethanol production from dedicated energy crops such as grasses and fast-growing hardwoods.

Researchers will use the PDU to explore ethanol conversion operations with the greatest technical and economic promise. Possible candidate technologies include those advanced by NREL (see sidebar at right), those developed elsewhere,



Initial pilot plant operations will follow this general design.

Conversion of lignocellulosic biomass to ethanol involves the following process steps:

Pretreatment—following mechanical milling, dilute sulfuric acid hydrolyzes hemicellulose to soluble sugars such as xylose, leaving solid cellulose and lignin, and makes the cellulose more receptive to hydrolysis.

Cellulase Enzyme Production—selected fungi and bacteria and genetically engineered bacteria produce cellulase enzymes that convert cellulose to sugar.

Simultaneous Saccharification and Fermentation (SSF)—compatible enzymes and yeasts, respectively, hydrolyze cellulosic material into sugars and ferment those sugars to ethanol in a single vessel.

Xylose Fermentation—selected yeasts or genetically engineered bacteria directly ferment xylose to ethanol.

Product Recovery—the ethanol is recovered from the fermentation broth by distillation or newer techniques such as permeable membranes.

Lignin Utilization—the lignin and other solid residue can be burned to provide heat or electricity to power the process.

Other biofuel technologies under investigation by NREL include:

Methanol from Biomass—thermochemical processes are used to gasify biomass, condition the resulting synthesis gas, and then convert it to methanol.

Reformulated Gasoline Components from Refuse—fast pyrolysis catalytic cracking converts municipal solid waste or other biomass to olefins, which are then converted to ethers for reformulated gasoline.

Biodiesel from Microalgae—selected natural or genetically engineered microalgae produce lipids (oils), which are then converted into esters suitable for use in place of diesel fuel.

Wastepaper such as this is one of many potential biofuel feedstocks for ethanol production.

and those that will be identified by new AFUF research.

Matching the Cost of Gasoline

The facility's PDU will operate at a rate of 900 kilograms (one dry ton) of feedstock per day. Building on results from PDU operations, the next likely step would be engineering demonstration facilities on a scale of 36,000 to 90,000 kilograms (40 to 100 dry tons) per day. Immediate industrial commercialization of successful operation techniques (on the order of 2 million kilograms or 1800 dry tons per day) may even be possible. Either path will help meet DOE and NREL long-term goals to demonstrate technology for commercially producing biofuels at prices competitive with gasoline.

Ethanol and other biofuels from lignocellulosic biomass could reduce pollution and the threat of global warming while improving America's energy independence and balance of payments. The new AFUF will help NREL and its industrial partners make such biofuels a reality.

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