# BIOFUELS: PRODUCTION AND POTENTIAL

*JOHN I. ZERBE*

*John I. Zerbe manages the Energy Research, Development, and Application Program for the U.S. Forest Service's Forest Products Laboratory The laboratory is maintained in cooperation with the University of Wisconsin.*

Today, about 3.7 percent (2.7 quads) of U.S. energy is derived from biomass-plant material and animal waste used as a source of fuel.[1] Various estimates have been made of biomass's production potential, ranging from 13.5 percent to 27 percent (10 to 20 quads) of current energy use. The United States will not attain more than 5.5 percent (4 quads) in the foreseeable future, however, without a comprehensive plan to significantly increase research and production.

The 1987 Energy Security Report to the President described biomass energy production as a "mature" technology. The report stated that current Department of Energy (DOE) projects could increase the nation's use of biofuels by 30 percent by 2005. If this projection is correct, consumption would rise to 3.8 quads or approximately 5.2 percent of current use. DOE's estimate is not insignificant (it equals 1.8 million barrels of oil a day), but it does suggest that there are serious limits to the contribution that biofuels can make to the nation's energy needs.[2]

With a modestly increased commitment for research and development, however, four quads could be attained by 1995. A strong commitment could lead to the production of 6.2 quads by then and 10 quads by 2000.

We cannot be satisfied with the status quo. These technologies are not mature: harvesting biomass fuels is costly, combustion efficiencies are below those for fossil fuels, emission control is in its infancy, and gasification and liquefaction technologies are ripe for improvement.

The Energy Security Report acknowledged that for renewable resources to contribute fully to the nation's security, continued research will be required to develop economical conversion technologies and to supply suitable feedstocks for the production of methanol, ethanol, and other renewable-based liquids and gases. This assessment conforms to past practices that emphasized biomass fuels in times of national emergencies (for example, during the 1973 and 1979 oil crises) and neglected them after the crises subsided.

There are many reasons why we should seek to develop biomass as an energy source, not the least of which is energy security. Nevertheless, we will not be prepared to increase the use of biomass fuels in response to another crisis unless we plan now for such a contingency.

## HISTORICAL CONTEXT

Since the late 19th century, the United States has depended on fossil fuels for energy. Coal was the primary source until the 1920s when oil came into its own. Throughout this period, U.S. energy consumption rose in almost direct proportion to the rise in Gross National Product (GNP). However, as a result of energy conservation efforts beginning in the early 1970s, U.S. energy consumption fell slightly as GNP continued to rise (see Figure 1).

For 100 years before the early 1970s, the use of biomass fuels dropped as fossil fuel consumption rose (see Figure 2). This long-term trend in the diminishing importance of biomass energy was reversed following the 1973 OPEC oil embargo. Biomass received another boost after the Iranian revolution in 1979. Residential, industrial, and institutional wood energy use rose from about 0.3 quads in 1972 to about one quad in 1984. There has not been much gain since. Steady gains in industrial, commercial, and institutional use have been counterbalanced by a decrease in residential use. Since the early 1980s, however, electrical power generation and cogeneration plants in Maine, New Hampshire, Vermont, Michigan, Wisconsin, and California have become significant new users of wood boiler fuel.

Recent technological improvements have increased the use of biomass. Machines for chipping wood residue in the forest were introduced during the first oil crisis. As a result, forest residues maybe harvested more economically. There have been advances in machinery for harvesting small roundwood as well. Combustion equipment has been improved to permit more efficient burning of wood. In fact, new types of combustors, such as fluidized beds and suspension burners, are in various stages of development. Much experimental effort has been spent on biomass gasification and pyrolysis research. Improved processes for wood hydrolysis and fermentation of glucose to ethanol are also being tested.

The research required to develop these technologies at first received strong public support. With lower oil prices, however, public support diminished. For example, federal investment and business energy tax credits have declined in the 1980s. Exempting gasohol production (ethanol blended with gasoline) from federal excise taxes represents the most far-reaching biomass tax credit. That subsidy is scheduled to remain in effect until 1993.

The Public Utilities Regulatory Policies Act of 1979 provided incentives for cogeneration and small power production facilities. Some state regulatory commissions have ordered utilities to pay favorable rates for electricity produced by wood fuel This incentive, which has led to the construction of several woodburning generating facilities, is designed to avoid the capital costs associated with building expensive central power generating units.[3]

**FIGURE 1**
**Energy Use and GNP**

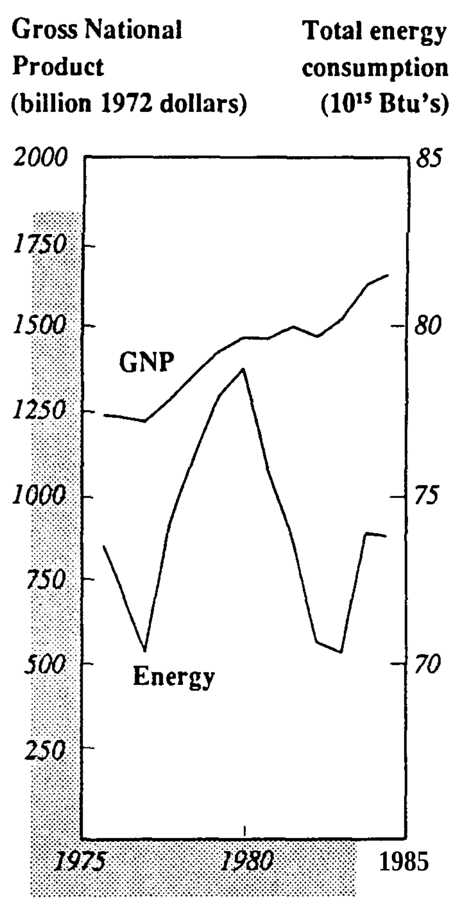
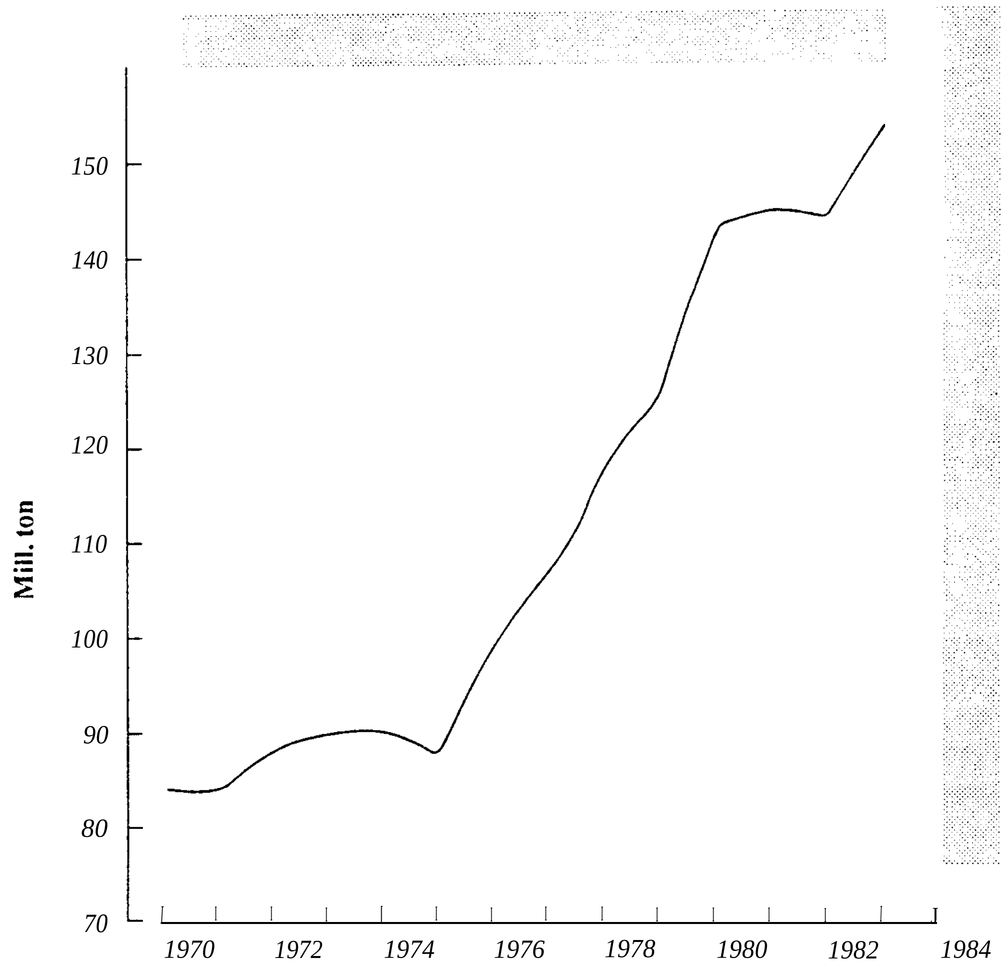


FIGURE 2
**Growth in Wood Energy Consumption**




WOOD FUELS IN FOREST PRODUCTS INDUSTRIES

Until the early 1970s, many U.S. sawmills had “teepee” burners to incinerate nonmarketable leftovers, and most used fossil fuel, not wood, to meet their energy needs. Pulpmills burned some wood, bark, and black liquor for fuel, but also relied heavily on coal, gas, and oil for their energy supplies.

The National Environmental Policy Act of 1969 created air quality standards too stringent for continued use of most teepee burners. Moreover, the rapid rise in fossil fuel prices and natural gas shortages in the mid- 1970s created additional incentives for forest product firms to use wood fuel.

Many sawmills installed woodburning facilities. Pulp and paper industries, which were about 38 percent energy self-sufficient in 1973, started to generate more of their energy with wood fuel, and some new plants were built to operate entirely on wood fuel.

Natural gas use by the U.S. paper industry declined by 34.9 percent between 1972 and 1986. In 1972, oil represented 21.3 percent of the total energy consumed by the U.S. paper industry; in 1986, it represented 8.5 percent. On the other hand, self-generated and residue sources of energy accounted for 56.7 percent of total energy consumption by 1986.[4]

## WOOD FUELS IN OTHER INDUSTRIES AND INSTITUTIONS

Forest products companies, because of their proximity to timber resources, usually are best situated to take advantage of wood as a fuel. Other industries located close to sources of timber also can benefit.

Russell Corporation, a large textile firm in Alexander City, Alabama, in 1975 became the first modern nonforest products industry to install wood-fired boilers.[5] Two boilers were built, each with a capacity of 60,000 pounds of steam per hour. The company faced a shortage of natural gas, an inadequate allocation of fuel oil, and expensive renovations to meet Environmental Protection Agency standards for two old pulverized coal boilers. The woodburning boilers proved an economic success and alleviated several potential environmental problems.

In 1980, the Jack Daniel Distillery in Lynchburg, Tennessee, installed two wood-coal-oil-gas fired boiler systems.[6] The systems were designed to use primarily green wood wastes from area sawmills and lumber yards. This project also has been an economic success.

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In Concord, New Hampshire, wood heat supplies energy for several state office buildings. In central Minnesota, Iron Works, Inc., installed a wood-powered combustion system in 1982. Boilers are connected to a steam distribution system and the steam is piped underground to 16 buildings. Customers include a church and rectory, public school, fire department, public utilities building, bank and pizza parlor.

The Georgia Forestry Commission is a leader in establishing woodburning installations among the state's industries and restitutions. Among its projects are a 25-million Btu/h gasifier at the Northwest Georgia Regional Hospital in Rome, and a 30,000-pound/h steam system at the Georgia Industrial Institute in Alto.[7]

## CURRENT TRENDS IN FUELWOOD USE

During the 1970s and early 1980s, high oil and gas prices and uncertain availability prompted the forest products industries' conversion to wood fuel. Today such factors, although still a constant threat, are no longer critical. Nonetheless, the cost advantage of wood fuel remains a valid reason for turning to woodburning, and such conversions are continuing. Pierce Lumber Company in Iowa uses sawdust and scrap from its planing and sawing operations as a fuel source. The company estimates a savings in energy costs of $120,000 per year (compared to natural gas). Even if wood had to be purchased (at an estimated cost of $41,000), there would be significant savings.

An energy center being developed by Kimball Corporation in southwest Indiana will burn a combination of wood and coal to provide steam, chilled water, compressed air, and electricity for a 360-acre industrial complex. Dry wood fuel will be supplied from Kimball's onsite wood products operations. The burners will be able to use 100 percent wood, 100 percent coal, or any combination of the two. Maximum payback on the center is estimated at seven years.

Use of wood fuel in residential applications has not been tracked nationwide since 1984, but the level appears to have remained about the same or declined slightly. In some areas, notably Missoula, Montana, and places in Colorado, burning of wood in stoves is prohibited during atmospheric inversions. In Oregon, newly purchased wood stoves must meet stringent environmental requirements. Such requirements probably have caused a decline in the use of wood stoves. Other factors are decreased oil and natural gas prices and disenchantment with the effort required to obtain and use wood for residential use.

## BIOMASS LIQUID AND GASEOUS FUELS

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Production of ethanol fuel from biomass has increased from about 4 or 5 million gallons per year in 1978 to about 850 million gallons per year in 1986. Most fuel alcohol is blended with gasoline in a ratio of 10 percent ethanol to 90 percent gasoline; this mixture is commonly called "gasohol." In 1978, production was mainly from a single plant that produced ethanol as a byproduct during the manufacture of wood pulp. Today, production is mainly from corn.

The increased use of biomass ethanol has been aided by favorable legislation. The U.S. Department of Agriculture's (USDA) Office of Energy lists 17 laws that have had significant impact. The most important was the Energy Tax Act of 1978. It exempted fuel containing at least 10 percent alcohol from renewable resources from the four-cents-per-gallon federal gasoline excise tax through October 1, 1984, and provided an energy investment tax credit for equipment that converted biomass into alcohol using a primary energy source other than oil, natural gas, or their derivatives.[8] Later laws increased the total excise tax to nine cents for gasoline and 15 cents for diesel fuel. Both gasoline and diesel fuels containing at least 10 percent alcohol from biomass have been exempt from six cents of the excise tax through September 1993.[9]

According to the USDA's report, *Fuel Ethanol and Agriculture: an Economic Assessment*, the ethanol industry cannot survive through 1995 without massive government subsidies (given the outlook for petroleum prices).[10] The report estimates that the cost of producing ethanol in 1986 was between $1.41 and $1.52 per gallon, whereas the wholesale price of gasoline was 55 cents per gallon. It concludes that unless federal subsidies, which at the time of the report were scheduled to expire at the end of 1992, are extended, fuel ethanol production likely will be terminated or sharply curtailed after 1992,

Producing fuel alcohol from biomass other than grains is possible, but such production has been deterred by low oil prices. Using wood, instead of grain, as a feedstock has both advantages and disadvantages. Wood residues are lower in cost and generally available for year-round harvest, which saves on storage. Unlike grains, such as corn, wood residues have no alternative use as food. These advantages, however, are somewhat negated because the conversion of wood biomass into alcohol involves a more difficult process.

If conversion costs can be lowered or if oil prices rise significantly, alcohol from wood could become a competitive motor fuel. Because Middle East oil imports are under constant threat, it is in the nation's interest to be better prepared to obtain motor fuels from alternative sources such as biomass. The

**FIGURE 3**

Additional Sources of Wood for Energy

| | Million Dry Tons |
|---|---|
| Logging residues and cull trees | 160 |
| Standing live and dead trees | *20* |
| Growth over cut | 215 |
| Mortality | 95 |
| Urban tree removals and wood wastes | *70* |
| Industrial residue and land clearing | *40* |
| Total | 600 |

nation's abundance of wood, including an estimated 600 million dry tons grown annually but not used, provides sufficient justification to give more consideration to wood as an alternative source of motor fuel (see Figure 3).

The U.S. Forest Service's Forest Products Laboratory (FPL) has made steady progress toward developing liquid fuel from wood for use as gasoline or diesel fuel. Ethanol research at FPL dates back to the laboratory's founding in 1910. FPL assisted in developing the technology that was operational at two plants during World War I. During World War II, improvements were made on a German process (later known as the Madison process), and an ethanol plant was built in Oregon. It did not come into full commercial production, however, until the end of the war.

After the fuel crises of 1973 and 1979, FPL again worked on improving the technology for making ethanol from wood. In cooperation with the Tennessee Valley Authority (TVA), a two-stage rapid high-temperature process for hardwoods was developed. TVA is now advancing this process in a small pilot plant. Although the United States has no full-scale commercial plants, there are plants operating in the Soviet Union and Bulgaria.

Methanol from wood also has potential as a liquid fuel, but it is most easily made from natural gas—a feedstock currently in adequate supply in the United States, Canada, and Mexico. Methanol also can be made from coal, which the United States has in abundance. However, there are advantages in making methanol from wood instead of coal. Wood is more easily gasified and usually has fewer troublesome contaminants such as sulfur.

Methanol is more economical than ethanol and burns cleanly. Indeed, it is the specified fuel for Indianapolis Speedway racers. To blunt the impact of another natural gas shortage, we should be moving to implement dependable technologies that convert wood and coal into methanol. Today, the nation has only one plant with suitable technology in operation: the Tennessee Eastman plant in Kingsport, Tennessee, that uses coal as a feedstock.

The efficient production of methanol from wood depends on a gasification process. Gasification also is important for converting wood into an improved fuel. Producer gas or low-Btu gas, for example, may be used in internal combustion engines or boilers. Wood gasification is an old, but not mature, technology. During World War II in Europe and Japan, many automobiles and even tanks were powered by internal combustion engines fueled by wood or charcoal gasifiers. Problems of reliability, power, and maintenance caused these vehicles to be junked soon after the war.

Since the mid- 1970s, improved gasifiers for internal combustion engines and for converting oil- and natural gas-fired boilers to wood- and gas-fired boilers have been under development in the United States and Canada. Because of reliability problems, few of these units have been in constant service. Thus biomass gasifier technology must be improved before it is widely accepted.

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Wood fuels also may be refined through pyrolysis or destructive distillation—that is, producing fuel products from wood through heating without oxygen, or with insufficient oxygen for complete combustion. Charcoal is a product of pyrolysis. Other products include liquid mixtures of acids, alcohols, tars, and other compounds and gaseous products such as hydrogen and carbon monoxide. Today, charcoal is the only major product derived from wood pyrolysis in the United States, although liquid wood smoke flavoring also is made in small quantities.

## DETERRENTS TO GROWTH

What accounts for the relatively slow growth in the use of biomass as an alternative fuel? It has many energy applications, a signflcant potential for expansion (particularly in light of the nation's timber, grain, and coal reserves), and acknowledged environmental advantages. Yet, the United States continues to move cautiously in the development of conversion technologies and appropriate feedstocks.

Deterrents include the high cost of harvesting and collecting biomass; lack of infrastructure for marketing biomass fuel products; obsolete conversion technologies; disproportionate emphasis on competing fuels; and failure to give appropriate weight to environmental, national security, and economic benefits.

**High Costs.** An enigma in the economics of wood is that wood used for energy, which is usually valued less than wood used for other purposes, is often more expensive to harvest. Harvesting operations have been geared to removing large, valuable logs, rather than tops, limbs, or roots. With the increasing need for fuel, equipment and operations are being designed to recover more "leftovers."

Researchers at the Forest Service's Intermountain Forest Range and Experiment Station field laboratory in Missoula, Montana, have field-tested and evaluated harvesting systems that handle small trees more efficiently than conventional harvesting. In New Hampshire, Maine, California, and Vermont, installation of wood-fueled power plants has created a demand for wood chips. This has encouraged logging and chipping of whole trees for power plant fuel. In other states—Wisconsin, Michigan, and Minnesota, for example—the construction of power plants that would use whole-tree chips as fuel is under consideration.

A new type of fuel, chunkwood, is being studied at the North Central Forest Experiment Station and FPL. Chunkwood, like chip wood, is a particulate fuel, but the particles are larger—about the size of a fist. Like chip wood, the particles are more readily transportable than roundwood or whole trees. Compared to chips, however, chunkwood is produced with less energy, and it is more easily stored and dried. It also combusts more efficiently.

**Lack of Marketing Infrastructure.** The utility industry is reluctant to build power plants fired by nontraditional fuels for which supply systems are not fully developed. The forest products industry is similarly reluctant to make expensive capital investments in its plants without long-term contracts.[11] An inability to obtain long-term government timber sales contracts is another deterrent to suppliers. To provide for more dependable supplies, researchers have proposed the creation of cooperatives to help solve the infrastructure problem.[12] Others contend, however, that this concept is not economically viable without public subsidies.

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**Obsolete Conversion Technology.** Residential heating consumes a major portion of the nation's wood fuel, but is currently inefficient and environmentally disruptive. Much is being done to improve the efficiency of residential heating units and cookstoves. Stoves recently approved in Oregon, for example, have efficiency curves of 60 to 75 percent and emission curves below allowable limits. Despite such examples, research is still needed on stoves, fuels, and environmental impacts to make residential woodburning more efficient.

Even more critical is the need to improve woodburning technology for industrial, institutional, and commercial applications. Today in such applications, wood generally is burned in inefficient combustors. Research needs to be conducted on the fundamental properties of biomass, the kinetics of biomass particle combustion, and the design of efficient combustors.

The technologies used to produce biomass by gasification, pyrolysis, and liquefaction have been available for more than a century. As in the case of woodburning, however, longevity has not meant maturity. Gasification processes remain in an early stage of development. Pyrolytic processes are effective for producing charcoal, but ineffective for producing liquid and gaseous byproducts. Products created by liquefaction still are more costly than the same products made from petroleum. With research and development, many improvements in these "old but immature" technologies are possible.

**Disproportionate Emphasis on Competing Fuels.** A study by the Rocky Mountain Institute in Old Snowmass, Colorado, estimated that the federal government spent more than $50 billion on energy subsidies in fiscal year 1984. Not only were these subsidies unevenly allocated, but the output per dollar varied widely among the technologies. Oil and liquid gas, for example, supplied 2.4 million Btu per dollar of subsidy, coal supplied 5.8 million Btu per dollar of subsidy, and natural gas supplied 3.8 million Btu per dollar of subsidy. Each produced more energy than renewable and each has more potential for energy production than biomass. Thus greater subsidies are justified.

The disproportionate subsidy to nuclear power—although not as substantial as for fossil fuels—is less easily justified. Nuclear power provided 13 percent of U.S. electricity in 1984 or 4.8 percent of the nation's primary energy consumption, counting the heat produced by the reactors. Yet nuclear power got 34 percent of all federal energy subsidies. Each dollar of subsidy yielded only 1/80th as much energy as each dollar of subsidy spent on renewable energy sources (excluding hydro power).

**Environmental, Security, and Economic Benefits.** There is much public discussion about the difficulties of finding space for municipal and county landfills to dispose of solid waste. Such waste consists largely of paper, tree trimmings, and other forms of biomass. If more of this waste were used for fuel, it could reduce the political heat and economic costs now associated with landfills.

In forestland managed by multipurpose principles, much of the expense for harvesting timber is related to clean-up costs. Brush from logging operations often is concentrated and burned to prepare land for new tree growth. This procedure not only costs money, but adds to air pollution. In ***some*** parts of the country, the availability of clean-up credits for harvesting excess wood for energy has minimized broadcast burning. Such programs allow wood to be burned under controlled conditions, not in the open. Emissions are reduced.

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Another increasing concern in the United States and Canada is acid rain. One suspected reason for the increased acidity in precipitation—although by no means proven—is the increased emissions of sulfur and nitrogen oxide into the atmosphere. Biomass usually will produce less of these emissions than coal or petroleum.

Energy security is another factor to consider. The Energy Security Act of 1980 stated that market forces should determine the types and quantities of biomass energy produced and consumed. It also encouraged the federal government to support longer-term biomass energy development projects. The report's goal for liquid fuel production was 8.4 billion gallons of fuel alcohol (ethanol and/or methanol) from biomass. It did not set a goal for nonalcohol biomass energy, but as directed by the conference report that accompanied the act, USDA and DOE have forecast that four quads of nonalcohol biomass energy could be in use annually by 1990. Most of this energy would be provided by the direct combustion of wood for process heat, electricity, and mechanical energy for industry.

## THE VALUE TO LOCAL ECONOMIES

Biomass production also could improve the state of local economies. In the United States, biomass is often an indigenous resource and its use could create jobs at the local level. For example, Minnesota's Department of Energy and Economic Development has said that $1 spent for petroleum energy generates 34 cents of additional economic activity, while $1 spent on biomass generates an additional $1.50 of local economic activity.

The United States may obtain other benefits from the increased use of biomass for energy. Excess forest growth and surplus crops could be channeled into energy industries that boost local economies, especially in depressed rural areas. More secure renewable energy resources could serve as a security blanket if imported supplies of oil and natural gas are jeopardized or embargoed.

## SUMMARY

To realize biomass' potential, recent reductions in funds for research and technology transfer must be reversed. The costs for harvesting and transporting biomass must be reduced, conversion technologies must be advanced, our understanding of the potential environmental threats must be improved, and a better means for marketing biomass products must be established.

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## NOTES

1. Quads is a term for describing the large quantities of energy used in the United States and is equivalent to 1015 Btu's. It is approximately equal to the energy in the oil which the United States consumes in about 11-days.
2. U.S., Department of Energy (DOE), *Energy Security-a Report to the President of the United States* (Washington, DC: DOE, 1987).
3. Bill Gove, "Wood-fueled Power Plants Promise Uncertain Future for Vermont/New Hampshire," Northern Logger and Timber Processor (November 1987).
4. American Paper Institute (API), *U.S. Pulp and Paperboard Industry's Energy Use—Calendar Year 1986 (New* York API, 1987).
5. Jerry W. Scott, "A Textile Firm Converts to Wood Fuel," in *Forest Products Research Society Proceedings, Energy Generation & Cogeneration from Wood* (Madison, Wisconsin: Forest Products Research Society, 1980).
6. Graddy Richard, "Equipment Selections for a Quad-fueled Boiler Facility with Emphasis on Wood Firing," in *Forest Products Research Society Proceedings, Energy Generation & Cogeneration from Wood* (Madison, Wisconsin: Forest Products Research Society, 1980).
7. Smaller projects are located at Franklin County High School, Carnesville; Treutlen County High School, Soperton; Mt. View School, LaFayette; Middle Georgia Correctional Institution, Chester; Union County High School, Blairsville; Walker County Correctional Institution, LaFayette; and the Forestry Center, Macon.
8. The Crude Oil "Windfall Profit Tax Act of 1980 extended the 4-cents-per-gallon federal gasoline excise tax exemption for ethanol blends to December 31,1985.
9. Twenty-nine states also had fuel ethanol tax subsidies in 1986, which ranged from one to 16 cents per gallon. In the case of both federal and state subsidies, the effect of basing the tax exemption on the gasohol blend containing 10 percent alcohol was to provide a bonus for alcohol use that was 10 times the subsidy on the blended fuel.
10. Earle E. Gavett, Gerald E. Grinnell, and Nancy L. Smith, "Fuel Ethanol and Agriculture: An Economic Assessment," *Agricultural Economic Report No. 562* (Washington, DC: U. S., Department of Agriculture, Office of Energy, 1986).
11. Department of Forestry, Wildlife and Fisheries, "Biomass Marketers Face Pacific Northwest Challenges. " in *Analyzing Market Constraints in Woody Biomass Energy Production*, ed. by Timothy M. Young and David M. Ostermeier (Knoxville: University of Tennessee's Agriculture Experiment Station, 1986).
12. John W. Koning, Jr. and Kenneth E. Skog, "Use of Wood for Energy in the United States—a Threat or Challenge?" in *Energy from Biomass and Wastes*, ed. by Donald L. Klass (Chicago: Institute of Gas Technology, 1987).
13. Richard H. Heede and Amory B. Lovins, "Hiding the True Costs of Energy Sources," Wall *Street Journal*, September 17,1985.