Bioenergy Status and Expansion in the United States

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**Abstract**

The U.S. is a large consumer and producer of energy. Current energy consumption is about 100 EJ with bioenergy providing 3% of the total. The U.S. President has charged the Departments of Energy and Agriculture and the Environmental Protection Agency to modify and coordinate their programs to promote an increase by 3 times the amount of biobased products and bioenergy produced in 2010. Legislative actions are also supporting increased bioenergy research and modification of tax incentives to encourage increased bioenergy commercialization. Development of biomass power production technologies and biomass liquid fuels production is being pursued through separate programs with the U.S. Department of Energy (DOE). Each program has differing needs and expectations for biomass feedstock research. The Bioenergy Feedstock Development Program (BFDP) integrates the feedstock needs of both programs. Research is addressing near-term, mid-term and long-term goals simultaneously. Development of new crops and cropping technology comprises the largest component of the current program. More emphasis is being placed on residues, both agricultural and urban, to meet near-term bioenergy goals.

**U.S. Energy Production and Consumption**

The United States= production and consumption of petroleum, coal, and natural gas are among the highest in the World (EIA, 1999). In 1998, the U. S. consumed 100.0 EJ compared to 73.3 EJ consumed by Western Europe (Fig. 1). U.S. consumption included 18.9 million barrels per day of petroleum, almost 26% of world consumption, as well as 21.3 trillion cubic feet of dry natural gas and 1.04 billion short tons of coal. China was the largest consumer of coal at 1.31 billion short tons. While U.S. consumption is exceptionally high, energy consumption per dollar of gross domestic product is moving downward suggesting a continuing trend toward better energy efficiency.

In 1998, the Unites States, Russia, China, Saudi Arabia, and Canada produced 48.4% of the world=s total energy (Fig. 2). The United States supplied 76.8 EJ of primary energy, followed by 43.3 EJ by Russia and 35.0 EJ produced by China. Petroleum was the world=s single most important primary energy source, accounting for 39.8% or 160.4 EJ (1 exajoule = $10^{18}$ Joules; 1 exajoule = 0.948 quadrillion Btu) of world primary energy production (EIA, 1999).

The largest primary energy source in the U.S. is coal. Of the 76.3 EJ of total primary energy produced within the U.S., biomass accounts for 3.16 EJ (Fig. 3). More than half of the biomass energy produced in the U.S. is associated with the wood products industry where bark, sawdust and spent pulp liquors are used to produce heat and electricity for internal use. A total of about 0.58 EJ of electricity is produced from biomass in the U.S. but most is not connected to the electric grid.

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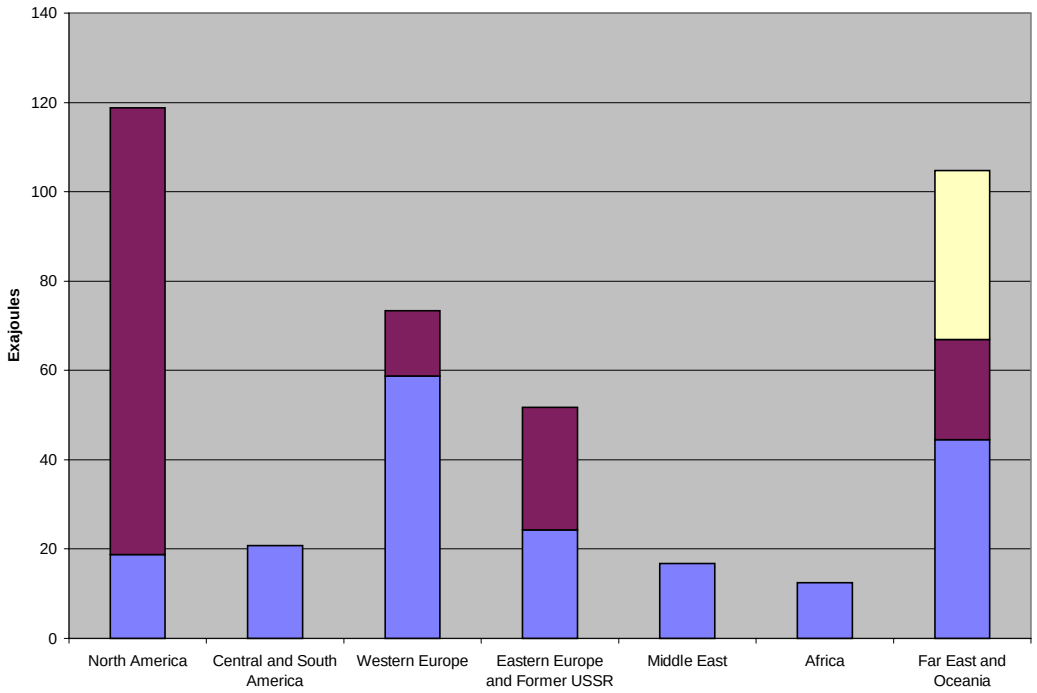


**Figure 1. Consumption of Primary Energy in 1998 (EIA 1999).** Major consumers shown individually: North America (red = U.S, blue = other); Western Europe (red = Germany, blue = other); Eastern Europe (red = Russia, blue = other); Far East (yellow = China, red = Japan, blue = other).

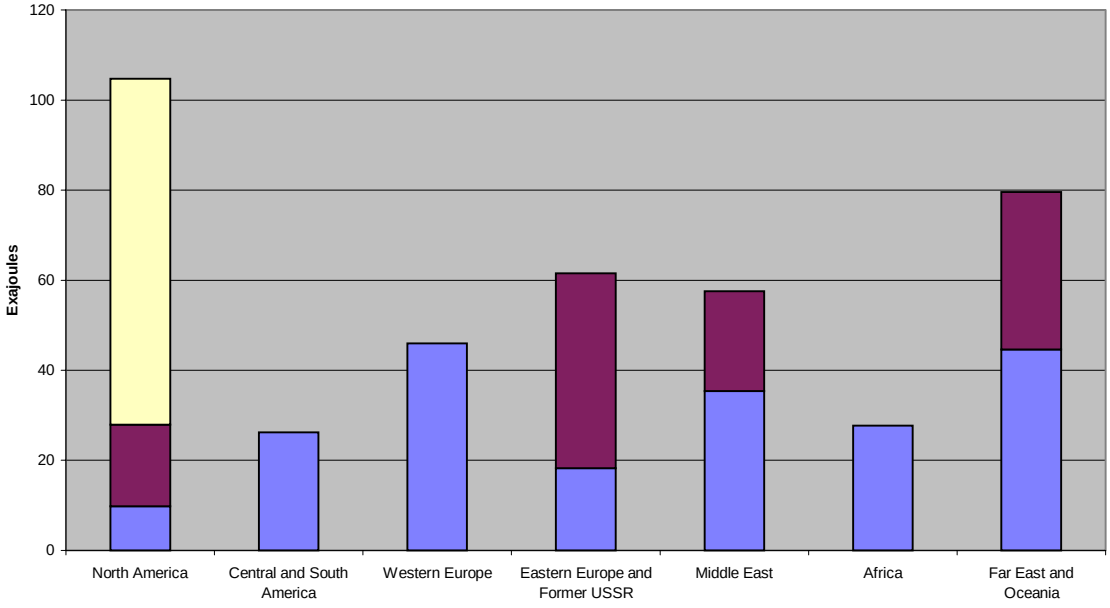


**Figure 2. Production of primary energy in 1998 (EIA, 1999).** Large producers shown individually: North America (yellow = U.S., red = Canada, blue = other); Eastern Europe (red = Russia, blue = other); Middle East (red = Saudi Arabia, blue = other); Far East (red = China, blue

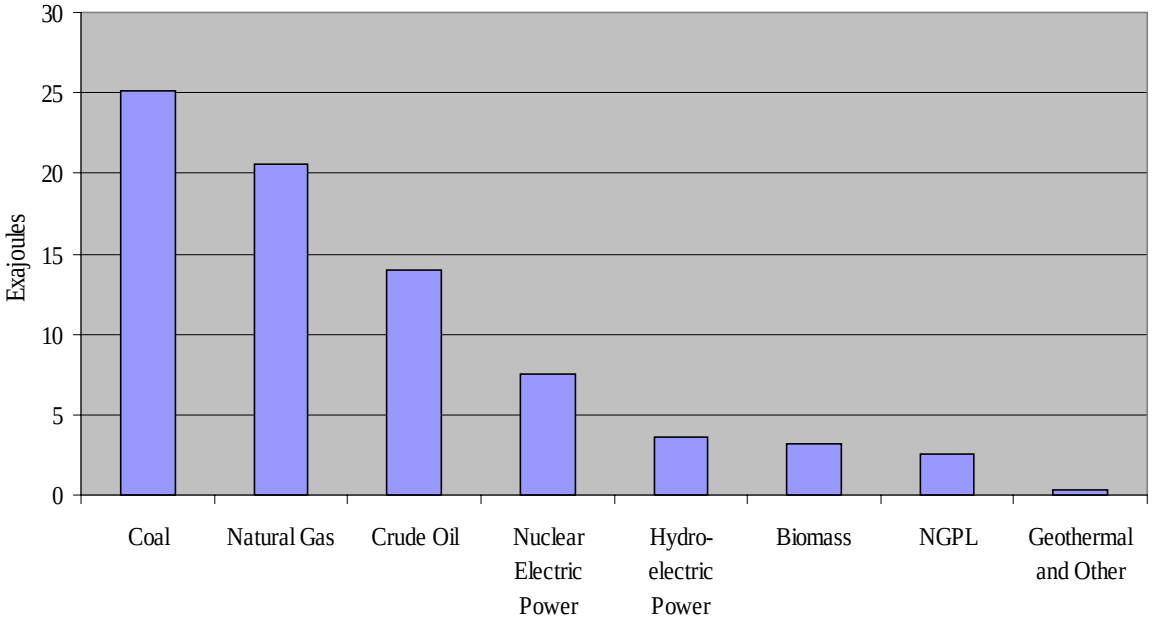


**Fig. 3. Energy production by source in 1998** (EIA 1999)**.** Crude oil includes lease condensate, Hydo-electric power includes conventional and pumped-storage, Biomass includes wood, wood waste, peat, wood liquors, railroad ties, pitch, wood sludge, municipal solid waste, agricultural waste, straw, tires, landfill gases, fish oil and/or other wastes.

Non-industrial Electricity generation from biomass residues and ethanol production from corn are both partially subsidized by some form of tax incentive or localized price supports. The only conditions under which biomass energy is economically competitive (without subsidy) in the U.S. at present is where it provides a waste disposal service for biomass wastes and residues that otherwise would be hauled to landfills. States or cities with tipping fees for landfill waste disposal clearly create the best opportunities for economically competitive biomass energy. This picture is expected to change if the current bioenergy initiatives being supported by the President and congress are successful.

**Bioenergy Initiatives in the United States**

The development of alternatives to traditional, fossil-based fuels for power and transportation as well as development of biobased products has received an unprecedented level of attention in the executive and legislative branches of the United States government.

*Actions in the Executive Branch of the U.S. Government*

On August 12, 1999, President Clinton signed Executive Order 13134 *Developing and Promoting Biobased Products and Bioenergy*. Executive orders are official documents, through which the President of the United States manages the operations of the Federal Government. The order outlines the administration=s means to achieve a goal of tripling the use of biobased products and bioenergy in the U.S. by 2010. As stated in a memorandum from President Clinton to the Secretaries of Agriculture, Energy, Treasury and Administrator of the Environmental Protection Agency, reaching that goal will require that the U.S. Afurther the development of a comprehensive

national strategy that includes research, development, and private sector incentives to simulate the creation and early adoption of technologies needed to make biobased products and bioenergy cost-competitive in national and international markets.@

The Executive Order establishes three entities (1) an Interagency Council, (2) an Advisory Committee, and (3) a National Coordination Office. The Council is asked to develop an annual strategic plan that defines national goals in the development and use of biobased products and bioenergy, promotes national economic growth (especially rural), provides energy security, and is sustainable and provides for environmental protection. It does not provide for additional Federal programs of offices, rather it requires that the goals be achieved through existing Federal programs. The first plan is due April 2000.

President Clinton's FY 2001 Budget includes $976 million in tax incentives over 5 years and $2.1 billion over ten years to accelerate the development and use of bio-based technologies, This package of credits would:

- Extend current "closed-loop" biomass credit. This proposal, which includes plants and trees specifically grown for use as biomass, extends for 2.5 years the current 1.5 cent per kilowatt hour tax credit (adjusted for inflation after 1992), which covers facilities placed in service before January 1, 2002.
- Provide credits for "open loop" biomass facilities. This proposal expands the definition of biomass eligible for the 1.5 cent tax credit to include certain forest-related resources and agricultural and other sources for facilities placed in service from 2001 through 2005, and provides a 1.0 cent credit for electricity produced from 2001 through 2003 from facilities placed in service prior to July 1, 1999.
- Provide a credit for co-firing biomass and coal. This proposal adds a 0.5 cent per kilowatt hour tax credit for electricity produced by co-firing biomass in coal plants from 2001 through 2005.
- Provide credit for methane from landfills. This proposal adds a 1.5 cent per kilowatt hour credit for electricity produced from landfills not subject to EPA's 1996 New Source Performance Standards/Emissions Guidelines (NSPS/EG) and 1.0 cent per kilowatt hour for landfills subject to NSPS/EG. Qualified facilities would be facilities placed in service after December 31, 2000 and before January 1, 2006.

*Actions in the Legislative Branch of U.S. Government*

Because an executive order is non-binding on the legislative branch of the U.S. government, senators (members of the U.S. Senate) and representatives (members of the U.S. House of Representatives) must introduce bills, which if approved could result in the appropriation of U.S. funds for initiatives such as the one outlined in the executive order. In addition, incentives (tax savings or credits) to produce and use biomass or biofuels take the form of introduced bills. The passage of such bills is vital for increasing the ability of biomass/biofuels to compete in the near-term with sources of power or fuel such as coal, petroleum and natural gas.

During 1999, approximately 26 bills related to bioenergy were introduced during the 106$^{th}$ congress. Only one of the bills has been acted upon. This bill is the National Sustainable Fuels and Chemicals Act of 1999 introduced by Senator Richard Lugar (Indiana) and cosponsored by thirteen additional senators. Two similar bills were introduced in the House of Representatives. The Senate bill and the two House bills include provisions for increased funding for biomass conversion research and development and biobased industrial product technology. The bills also direct the Secretaries of Energy and Agriculture to cooperate in promoting biomass research, development and demonstration, and to authorize additional funding for biomass.

Numerous bills have also been introduced in the House and Senate that provide for tax incentives related to bioenergy, affect agricultural or forestry policies that relate to, contain provisions for ensuring that renewable energy is part of the electric power restructuring that is ongoing in the U.S., and proposals that provide for credit for early actions or voluntary reductions in greenhouse gases. Subcommittee hearings were held on a tax credit bill (S1429), one proposal impacting carbon sequestration (S1457) and one concerning electric power restructuring (S1047). Of these, the tax credit bill is the only one that has been acted upon.

The tax credit of 1.5 cent per kilowatt hour for electricity produced from qualifying wind and biomass facilities was extended to cover facilities placed in service by December 31, 2001. The only change was that poultry waste was added as a form of qualifying biomass. Otherwise the biomass facilities must be supplied with "closed loop" biomass, which is defined to include only dedicated energy crops grown exclusively to generate power. It had been hoped that qualifying biomass would be expanded to include crop residues, mill residues and other forms of clean, segregated biomass residues. Although the tax credit has been available for a number of years, no biomass facilities have managed to qualify.

*Actions at the U.S. Department of Energy*

In 1998, independent of the actions in the legislative branch, DOE initiated a focused national effort to (1) boost economic opportunities in rural America, (2) provide new revenue streams for foresters, farmers, and other agricultural producers, (3) expand possibilities for sustainable energy use in power production, transportation, and manufacturing processes, and (4) lead to less dependence by U.S. consumers on foreign energy sources. The ABioenergy Initiative@ is building upon DOE=s Office of Energy Efficiency and Renewable Energy nearly 20 years of conducting programs aimed at increasing the development and deployment of biomass energy resources and technologies. The primary goal of the initiative is to accelerate the use of bioenergy technologies, fuels, energy crops, and feedstocks in power generation, industrial processing, and manufacturing and transportation applications. This is to be accomplished through partnerships with industry, national laboratories, and universities. DOE has developed a ten point action plan which includes (1) establishing a partnership vision, (2) developing roadmaps, (3) creating an effective policy framework, (4) expanding biomass markets, (5) conducting supporting analysis, (6) promoting advanced technologies, (7) expanding federal-state coordination, (8) pursuing outreach and showcasing successes, (9) holding quarterly progress meetings, and (10) maintaining effective partnerships. DOE has held several meetings with industry, national laboratories, and other government agencies to develop an integrated vision for the national bioenergy initiative. The vision document is close to being released for public review and comment.

**Bioenergy Program Goals in the U.S.**

The bioenergy research and development in the U.S. is following two separate pathways as lead by two separate programs within DOE. While the programs may combine in the near future as a result of the Bioenergy initiative, the program managers of the Biomass Power Program and the Alternative Fuels Program are currently expressing needs for different biomass feedstock research. Oak Ridge National Laboratory manages the feedstock research for both of the programs. The following sections describe stated goals and metrics and feedstock research needs of both programs followed by a brief description of the feedstock research approach of the BFDP.

*Biomass Power Program Goals and Feedstock Needs*

The mission of the U.S. DOE Biomass Power Systems Program is to develop and validate clean, efficient, renewable, biomass-based electricity generation technologies and operational systems with sustainable biomass supplies. Cost-competitive feedstock development and resource assessment are seen as indispensable components of an integrated biomass strategy.

Near-term (2000-2005)

The near-term goal of the Biomass Power program is to facilitate increased use of biomass power primarily by collaborating with utilities, independent power producers, and small power users such as schools and hospitals to encourage co-firing of biomass with coal, oil, or natural gas.

Wood wastes and residues including urban wood wastes, wood products wastes (from sawdust to furniture manufacturing wastes) and limited amounts of forestry residues (bark, tops and limbs) are the most likely feedstocks to be economically available in the near-term. However, policy changes appear to be needed for biomass power expansion using these resources. Feedstock research and development activities needed to support near-term biomass power generation includes:

(1) Analysis to better define location, cost, and availability of biomass resources;
(2) Analysis of supply logistics to better define complete systems costs;
(3) Improvement of residue collection, handling, storage, and feeding technologies to improve system economics;
(4) Analysis of environmental effects of wood waste and residue use;
(5) Analysis to support evaluation of policy options and regulations;
(6) Outreach activities to all types of stakeholders of biomass power systems; and
(7) Improvement of information on feedstock characteristics relevant to biomass power.

Mid-term (2005-2010)

The Biomass Power Program metric for 2010 (published prior to the summer 1999 Executive Order) is to displace as much as 0.42 Quadrillion Btu (Quads) or 0.44 EJ of fossil energy. These goals will likely be expanded as a result of the Executive Order. The best alternative for meeting expanded goals is to obtain a significant increase in co-firing and some use of small modular systems.

Biomass power demonstration projects already underway in the U.S. are designed to demonstrate that a combination of residue and crop resources can provide reliable, year-round supplies for biomass power production. The projects in progress include the following. In New York, utilities are testing co-firing of forestry residues with coal and farmers are being recruited to grow willows for future supplies. Projects in Iowa and Alabama are evaluating the potential of switchgrass as a reliable feedstock supply system for co-firing with coal. A new 25 MW Biomass Power facility project in Minnesota is planning to supply the plant with hybrid poplars. An alfalfa residue supply system was recently also under investigation for supplying a gasifer, but the project was discontinued for several non-technical reasons. The hybrid poplar, willow, and switchgrass supply system demonstrations provide an opportunity to test concepts and technologies under development by energy crop researchers and to provide feedback to the core crop development activities. They also provide the opportunity to investigate environmental effects under operational conditions.

Feedstock R&D needs for meeting mid-term objectives include those described above for near-term and additional activities associated with the ongoing demonstration projects such as:

(1) Technical support and monitoring of the ongoing projects;
(2) Evaluation of the environmental and economic effects of the projects;
(3) Communication of the environmental and net economic benefits to stakeholders and decision makers who can affect the rate of commercialization of biomass power;
(4) Improvement in collection, harvesting, handling, storage and feeding technologies for switchgrass, woody crops, and a variety of wood and agricultural residues; and
(8) Additional yield improvement of biomass crops through breeding, species/site matching, and optimization of management approaches.

Long-term (2020)

The Biomass Power Program metric for 2020 (published prior to the summer 1999 Executive Order) is to supply as much as 0.53 Quads/yr (0.56 EJ/yr) of power. This metric will likely be significantly increased in FY 2000. It is anticipated that gasification and advanced direct combustion technologies which operate most efficiently at scales of 50MW or larger will be major contributors to biomass power production by 2020 in addition to maximal use of co-firing opportunities.

Production of significant amounts of new biomass power by these relatively large-scale facilities will require widely available, abundant, competitively priced, sustainable, dedicated feedstock supply systems. Additionally, it would be desirable to develop biomass power crops that contain low levels of ash and alkali and high Btu values. There is public concern that unsustainable harvesting of natural forest stands will occur to supply feedstocks to bioenergy systems. Thus it may be necessary for utilities or power producers to collaborate with the wood products industry in the establishment and harvesting of farm-grown trees to supply both fiber and power needs.

Feedstock research and development activities needed to support the long-term goals of the Biomass Power industry include the following:

(1) Genetic improvement of model fast growing species to further improve yields in order to reduce production costs and improve reliability of feedstock supplies;
(2) Selection and development of new species to increase diversity in feedstock supply systems and optimize use of the available landscape;
(3) Improvement of feedstock characteristics through either genetic modification of existing fast growing species or selection of new species with preferable characteristics;
(4) Development of the basic understanding and tools needed to allow environmentally acceptable modification of the traits and characteristics of desirable species;
(5) Improvement in our understanding of the environmental effects of deployment of new crops in the landscape at large scales of operation;
(6) Improvement in management approaches for optimizing growth, disease resistance, ease of harvest, feedstock characteristics and environmental benefits from energy crop production; and
(7) Further improvement in harvesting, handling, storage and transportation technologies.

*Alternative Fuels Program Goals and Feedstock Needs*

Ethanol is the primary alternative fuel being developed by the Alternative Fuels Program of DOE. The DOE goal for ethanol research is to facilitate the development of a robust biomass ethanol fuel market, thereby helping to meet the Nation’s energy policy goals.

Near-term (2000-2005)

The near-term objective is to demonstrate commercial-scale production of ethanol from cellulosic material using one or more low-value waste feedstocks. A few projects are already underway which expect to be commercial and cost-competitive by 2005 under current policy conditions. These projects propose to use rice straw, sugarcane bagasse, and selected portions of municipal solid waste. Little to no feedstock research is needed to assist these near-term projects.

Midterm (2005-2010)

The midterm (2005-2010) objective is to facilitate achievement of industry-scale ethanol production using a variety of cellulosic materials generated by U.S. farmers. Feedstocks are anticipated to be agricultural residues such as corn stover and wheat stover, supplemented with dedicated crops such as switchgrass. The 2010 metric published in early 1999 by the Alternative Fuels Program is to displace 0.36 Quads (0.38 EJ) of imported oil, equivalent to four billion gallons of ethanol.

Feedstock research and development needed to support the mid-term ethanol goals are as follows:

(1) Identification of environmental concerns of the public and policy makers relative to use of agriculture residues and switchgrass and research to address those issues;
(2) Definition of conditions under which agriculture residues can be removed without negative environmental effects;
(3) Improvement of collection, handling, and storage methods for agricultural residues and switchgrass;
(4) Additional yield improvement of switchgrass through breeding, species/site matching, and optimization of management approaches; and
(5) Outreach and communication with key ethanol stakeholders.

Long-term (2010-2020)

The long term objective is to demonstrate that ethanol production from dedicated energy crops is cost-competitive with gasoline and to facilitate the development of a significant cellulosic industry. The metric of the Alternative Fuels Program published in early 1999 is to displace 1.0 Quads (1.1 EJ) of imported oil, equivalent to 11 billion gallons/year (41.6 billion liters) of ethanol.

Feedstock research and development needed to support the long-term ethanol goals are essentially the same as those needed for Biomass Power but there are some major differences. Optimization of feedstocks for ethanol conversion includes modifying the cellulose to lignin ratios to favor higher cellulose levels. This is likely to also reduce the Btu value, losing some of the value on a per ton basis for biomass power conversion. Characteristics such as low ash content and low levels of alkalies should benefit both technology pathways. Another research approach, that is unique to ethanol, is to optimize crop genetic characteristics for production of a suite of higher value co-products along with ethanol. In either case, advancement of basic plant science is needed to provide capability for tailoring plant characteristics for single or multiple end-products while continuing to increase the yield and reduce crop risks.

**Biomass Feedstock Research in the U.S.**

The BFDP defines a mission to accomplish, through partnerships, the research, analysis, demonstrations, and infrastructure development needed to establish environmentally sustainable and economically competitive biomass supply systems with widespread availability at scales capable of supporting multiple bioenergy and bio-products industries. This mission statement

encompasses long-term crop development activities, together with near- and mid-term activities that involve much more than crop development.

The crop development activities aim to develop new plant materials and the basic plant science information needed to achieve yield increases, reduce the risk of crop loss from biological and climate factors, and genetically modify plants for specific end-uses. Since it's initiation in 1978, crop development research has evolved from evaluation of many species and production methods to a focused effort on improvement of poplars and switchgrass as model crops that are broadly adaptable to many regions of the U.S. Hybrid poplars serve as a vehicle for basic research on molecular genetics because of their ease of clonal propagation and the relatively large amount known about their genomics and physiology (compared to other energy crops).

Regional crop development "centers" exist as groups of interacting researchers in the North Central, Pacific Northwest, and South for poplars, in the Northeast for willows, and in the North Central, South Central and East for switchgrass. Hybrid poplars are most likely to be used as a source of energy by fiber companies that are primarily growing the crop for fiber but use the tops and limbs, bark and lignin to produce heat and electricity. Willows are being developed as a dedicated crop for biomass power. Switchgrass is of interest as a dedicated crop for both biomass power and ethanol.

The focal point of the crop development centers for each species is the crop breeding effort. Breeding incorporates both traditional and molecular genetics approaches and is linked to research on optimization of management approaches. Management research includes evaluating the lowest cost, most environmentally sound methods for obtaining high yields and increasing carbon sequestration. Several institutions may be involved in these virtual crop development centers within a region, but information and plant material exchanges are encouraged and facilitated. Research projects' range from bench scale to near-operational field scale trials. The small scale regional field trials are an extremely important interim step for making the connection between the breeding and the selection of the most appropriate genotypes for the region. It is also at this stage that several academic institutions and the private sector are brought in as collaborators in a regional crop development center.

In order to meet the long-term (2010-2020) objectives of both the Ethanol and Biomass Power Programs, the long-term crop development efforts on poplars, willows, and switchgrass must continue and be expanded through the addition of new species. Success would be best assured if government funding could be leveraged through partnerships and industry cost-share to amount to at least $1 million/year per crop for at least the next 5 to 10 years. The testing and plant material scale-up phase of crop development requires a minimum of 10-12 years. Thus, for either wood or grass crops, new but fully tested materials suitable for commercial establishment by 2015 should be identified in breeding and research nurseries by no later than 2005. While funding appears to be increasing, it is not yet at the level needed to assure meeting 2015 to 2020 goals, much less the 2010 goals. To adequately develop crops for all crop growing regions in the U.S., a program supported by government funding at the level of at least 20 million annually is needed together with strong partnerships with the private sector.

The near and mid-term activities of the BFDP include analysis, demonstration, evaluation, environmental research, and infrastructure development activities. All activities are aimed to facilitating the success of the first few integrated commercial projects for both biomass power and ethanol production. Research on agricultural residues is determining how much residue can be removed without affecting the sustainability of the agricultural crop production systems. The primary effort on urban and mill wastes is to determine how much may be available under various price conditions. Near-term project development efforts require facilitation of

infrastructure development for more efficient collection, delivery, handling, storage and processing of feedstocks. The U.S. bioenergy feedstock development program is adding staff and developing proposals to expand to cover that area while maintaining the long-term crop development effort.

*References*

EIA (Energy Information Administration). 1999. International Energy Annual 1998. DOE/EIA-0219 (98). Energy Information Administration, Washington DC. [Also available on EIA's Internet site at: http://www.eia.doe.gov/emeu/iea/contents.html.]