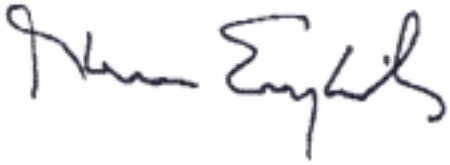
Vision

for Bioenergy & Biobased Products in the United States

October 2002

Foreword

The Vision for Bioenergy and Biobased Products in the United States establishes far-reaching goals for increasing the role of biobased energy and products in our nation's economy. It represents the collective vision of the Biomass Technical Advisory Committee established by the Biomass R&D Act of 2000. The Advisory Committee is a group of 26 individuals from industry, academia, non-profits, and the agricultural and forestry sectors who are experts in their fields. The Committee believes that the Vision goals are technically feasible given future advances in research and development and an appropriate mix of market incentives and public policies. The Committee recognizes that economic, international, and many other factors can impact the future demand for and development of biomass technologies, and thus the ability to achieve these Vision goals. The Committee believes, however, it is appropriate that long-term goals be challenging. This Vision puts forth the challenge of pursuing the opportunities that biomass technologies hold for the United States.



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By 2030, a well-established, economically viable, bioenergy and biobased products industry will create new economic opportunities for rural America, protect and enhance our environment, strengthen U.S. energy independence, provide economic security, and deliver improved products to consumers.

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1. INTRODUCTION

The United States is approaching a biobased revolution that will fundamentally change the way we produce and consume energy and industrial products. From biological resources we can derive products as diverse as fuels and lubricants, heat and electricity, chemicals, food, feed, building materials, paper, clothing, and much more.

The United States imports 11 barrels of oil for every 10 barrels produced domestically. Imported petroleum supplies transportation fuels, heating oil, chemical feedstocks, and many other products used throughout our economy. A primary goal of the *National Energy Policy* s to ncrease our energy supplies by using a more diverse mix of domestic resources and to reduce our dependence on imported oil. Biomass technologies — some currently in use or in the early stages of development and others not yet imagined — can contribute to the new mix of resources for energy and value-added chemicals and materials.

Bioenergy and biobased products – produced from resources such as crops, trees, and agricultural, industrial, municipal, and forestry wastes – hold great promise for our economy. We can harness the molecular building blocks and components of plants to heat our homes, run our cars, light our buildings, and provide industrial and consumer products for everyday use. Efficient use of biomass can help the United States utilize its domestic energy resources more wisely.

As a renewable and domestic resource, biomass can substantially improve our economy, national security, and environment. The agricultural and silvicultural communities will have new and more diverse markets for their crops. The biobased revolution could present new business opportunities for farmers and others, allowing them to participate and profit from the production of bioenergy and biobased products. New concepts in ntegrated biorefineries that produce a wide variety of fuels, power, and value-added chemicals and materials can revitalize rural economies. Biomass systems offer a range of opportunities that can be scaled to meet specific needs. Large-scale systems can be developed for fuels and commodity chemicals, for example, while small-scale systems can be developed for distributed applications such as off-grid power.

Achieving the goals set forth in this A *Vision for Bioenergy and Biobased Products in the United States* will have benefits that reach beyond the U.S. biomass industries:

- **National Security** – Domestic bioenergy sources could help our nation to substantially reduce dependence on petroleum.
- **Environmental Protection** – By offsetting fossil fuel use and related emissions of nitrogen oxides, sulfur dioxides, and other pollutants, bioenergy and biobased products will contribute to cleaner air and water. Further more, increased cultivation of carbon-fixing plants will help mitigate greenhouse gas emissions that contribute to global climate change. It will also provide a productive avenue for using agricultural, industrial, commercial, municipal, and forestry wastes.
- **Rural Economic Growth** – Growth in biobased products and bioenergy will stimulate rural development efforts in farming, forestry, and associated service industries.

In the future, biomass also could play a key role in the “hydrogen economy” The Department of Energy, in conjunction with industry and academia, has developed a *National Vision of America’s Transition to a Hydrogen Economy* That Vision highlighted the important role that biomass resources can play in facilitating the hydrogen economy With advances in research and development, biomass can play a key role in that new economy and can increase U.S. energy independence. New processes for the biological extraction of hydrogen from plant materials could provide hydrogen energy for use in stationary power systems, transportation, or other applications. Using agricultural residues and wastes or biomass specifically grown for energy uses, hydrogen can be produced via pyrolysis, gasification, or fermentation processes.

Biomass technologies will lead to cleaner air and water for our communities by offsetting fossil fuel consumption and related emissions. Furthermore, by increasing the cultivation of carbon-fixing plants, a strong bioenergy and biobased products industry will help to stabilize or reduce greenhouse gas emissions. This industry will also provide avenues for productive uses of agricultural, industrial, commercial, municipal, and forestry wastes.

The use of domestic biomass resources to diversify our energy supply and increase our energy and economic security is widely recognized in national policy and federal regulations:

- Research to advance biomass technologies will respond directly to goals outlined by the Administration in the *National Energy Policy,* including:

    - **Modernize Energy Conservation.** Advanced biomass technologies and improved efficiencies in existing biomass technologies will enable higher energy output per unit of biomass consumed, enable the United States to more efficiently utilize biomass resources, and enhance the economic competitiveness of biomass technologies.

    - **Modernize Our Energy Infrastructure.** The industrial biorefinery represents a new model for providing biobased fuel, power, and products from sustainable, local resources. It offers the opportunity to revitalize rural economies and diversify energy supply in areas of the country with large biomass resources.

    - **Increase Energy Supplies and U.S. Energy Security.** Development and deployment of economically competitive biobased technologies will significantly contribute to U.S. energy security by offsetting the demand for petroleum.

- In June 2000, Congress passed the *Biomass Research and Development Act of 2000* (Title III of the Agricultural Risk Protection Act of 2000), which created a research initiative focused on producing fuels, power, chemicals, and materials from a wide variety of biomass. The Act called for the formation of an interagency Biomass Research and Development Board, and a Biomass Research and Development Technical Advisory Committee.

- In December 1999, a Committee of the National Research Council published *Biobased Industrial Products*, which concluded that “biobased products have the potential to mprove sustainability of natural resources, environmental quality, and national security while competing economically”

Looking to the Future

This document sets forth a national *Vision* as identified by the Biomass Research and Development Technical Advisory Committee for bioenergy and biobased products in the United States. It provides specific quantitative goals for integrating sustainable, competitive; biomass technologies into our Nation's economy Achieving this V sion will require advanced research to increase crop yield, mprove conversion efficiencies, and many other technical advances. It will require educating the public and identifying an appropriate mix of market incentives and public policies to remove the barriers facing biomass technologies. It will require continued growth in our nation's agriculture, natural fibers, pulp and paper, and other biomass-related industries. These measures will help make bioenergy and biobased products part of the everyday lives of Americans and contribute to farm profitability and rural development.

As with any *Vision*, barriers to achieving our goals exists. The primary concern with the advancement of biomass technologies lies in the extensive training, education, and research that is necessary to achieve far-reaching goals. The support needed must come from collaborative efforts among industry, as well as between industry and local, state, and federal government. Communication and cooperation will be required to overcome the technical, market, and policy challenges impeding biomass technologies.

This *Vision* supports the spirit of both the *National Energy Policy* and the *Biomass Research and Development Act of 2000,* which call for cooperative approaches to expanding the use of domestic renewable resources to run our economy and protect our environment. This *Vision* calls for a strong mix of research, policy, and market-based solutions. Finally, this *Vision* affirms that biobased products and bioenergy can offer great opportunities for contributing to this Nation's energy and chemical product needs.

2. Current status of biomass technologies

Traditional biomass resources include agricultural crops, crop residues, forest resources and residues, dedicated energy crops, animal wastes, and segregated solid waste. These resources come from our nation's farms, forests, pulp and paper mills, and landfills. Unlike other forms of energy, substantial biomass resources exist and are currently used in nearly every state in the country. Biomass helps meet the demand for heat, electric power, and clean-burning transportation fuels. Biomass is increasingly recognized as a resource to replace petroleum-based chemicals for the manufacture of lubricants, plastics, clothing, and a wide range of other industrial and consumer-based products. The land used to produce resources for bioenergy and biobased products is also used to produce food and feed, lumber, paper, textiles, and many other products. Examples are shown in Exhibit 1. Achieving the goals set forth in this *Vision* will require expanding our biomass resources to meet new needs for bioenergy and biobased products

Exhibit 1
1997 Production of Selected Agriculture and Forest Products
(billion pounds)

Corn	480.0
Wheat	132.2
Soybeans	150.2
Pulp & Paper Board	186.2
Lumber Production	114.2

Sources: U.S. Department of Agriculture, American Forest and Paper Association

Bioenergy

The total consumption of *biomass for energy* n the United States was 3.34 quadrillion Btu (quads) in 2001 or approximately three percent of total U.S. energy consumption. As shown in Exhibit 2, biomass consumption increased 25 percent between 1990 and 2001 — an average annual rate of 2.1 percent.

- The industrial sector accounted for 81 percent of biomass energy use in the United States, or 2.7 quads in 2001.[1] This was primarily in the form of wood and waste (2.0 quads) for on-site energy requirements such as process heat; as well as 0.7 quads of biomass consumed by industrial companies classified as non-utility power producers to produce electricity for on-site needs and sale to the grid. Biomass energy used in the industrial sector offsets demand for fossil fuels to meet thermal energy requirements as well as demand for purchased electricity For example, the U.S. forest products industry obtains 56 percent of its own energy from its woody waste products and other renewable sources for fuel (bark, wood, and pulping liquor).[2] In addition, n the food, agriculture, and other ndustries, fats and oils are burned in boilers for heating and electricity generation.

- Biomass consumed to produce electricity n the electric utility sector is 0.019 quads.[3] This includes dedicated plants for energy, co-firing, and waste energy

[1] DOE/EIA, *Monthly Energy Review*, July 2002, Table 10.2.
[2] Energy Information Administration.
[3] DOE/EIA, *Monthly Energy Review*, July 2002, Table 10.3b.

- Transportation fuels from biomass are primarily fuel ethanol (a motor gasoline blend fuel) and biodiesel. Fuel ethanol accounted for 0.147 quads or less than one percent of U.S. transportation energy demand in 2001.[4] Demand for ethanol more than doubled between 1990 and 2001. In physical units, fuel ethanol production from corn and other biomass material is estimated at 1.76 billion gallons.[5] Ethanol production capacity is approximately 2.9 billion gallons per year n more than 20 states. Demand for ethanol is expected to increase and new plants and expansions are currently under construction. In addition, biodiesel production was estimated at 20 million gallons in 2001. Biodiesel capacity is between 60 and 80 million gallons per year [6]

- Biomass used in the residential and commercial sectors is primarily for space heating and represents approximately 14 percent of the biomass consumed for energy in the United States.

The Energy Information Administration (EIA) projects that total U.S. energy demand will increase at an average annual rate of 1.4 percent between 2000 and 2020, reaching 115 quads in 2010 and 130 quads in 2020. Overall renewable energy demand is projected to increase at an average annual rate of 1.7 percent through 2020, primarily due to state mandates for renewable electricity generation.[7]

Exhibit 2
Recent Trends in U.S. Biomass Energy Consumption
1990 – 2001 (Quadrillion Btu)

Sector	Source	1990	2001	% Change '90-'01
Residential	Wood (a)	0.581	0.433	-25%
Commercial	Wood (a)	0.037	0.052	40%
Industrial	Wood (b)	1.254	1.702	36%
Industrial	Waste (c)	0.271	0.287	6%
Transportation	Alcohol Fuels (d)	0.063	0.147	133%
Electric Utilities	Wood (b)	0.008	0.006	-25%
Electric Utilities	Waste (c)	0.013	0.013	—
Non-Utility Power Producers (e)	Wood (a)	0.308	0.379	23%
Non-Utility Power Producers (e)	Waste (c)	0.124	0.324	161%
Total		**2.659**	**3.343**	**25%**

Source: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review,* July 2002 (Tables 10.2, 10.3a, 10.3b)
Notes:
(a) Wood only
(b) Wood, wood waste, black liquor, red liquor, spent sulfite liquor, wood sludge, peat, railroad ties, and utility poles
(c) Municipal solid waste, landfill gas, methane, digester gas, liquid acetonitrile waste, tall oil, waste alcohol, medical waste, paper pellets, sludge waste, solid byproducts, tires, agricultural byproducts, closed loop biomass, fish oil, and straw
(d) Ethanol blended into gasoline
(e) Includes the portion of non-utility power producers' use of renewable energy to produce electricity; excludes the portion used to produce useful thermal output, which is included in "industrial"

[4] DOE/EIA, *Monthly Energy Review*, July 2002, Table 2.5.
[5] DOE/EIA, *Petroleum Supply Monthly*, January 2002, page 135.
[6] National Biodiesel Board.
[7] Nearly 55 percent of projected demand for renewables in 2020 is for electricity generation. Renewable electricity generation is projected to grow slowly because of the relatively low cost of fossil-fired generation and because competitive electricity markets favor less capital-intensive natural gas technologies over coal and baseload renewables. Where enacted, state renewable portfolio standards, which specify a minimum share of generation or sales from renewable sources, contribute to the growth of renewables. (DOE/EIA, A*nnual Energy Outlook*, 2002.)

EIA projects that biomass energy consumption will increase at an average annual rate of 1.8 percent over the 2000 to 2020 time period — from the current 3.3 quads to 4.7 quads n 2020. In 2020, biomass will meet about 3.6 percent of U.S. energy demand – a slightly higher share than the current three percent.[8] As shown in Exhibit 3, EIA projects that biomass will continue to account for a significant share of energy consumption in the industrial sector, reaching 8.2 percent of total industrial energy consumption in 2020. Biomass will continue to play a relatively small role in electric utility generators and in transportation accounting for 0.4 percent and 0.7 percent of energy demand in those sectors respectively

Exhibit 3
Energy Information Administration Projections for
Transportation, Industrial, and Electric Generator Energy Consumption
(Quadrillion Btu per year)

	2010			2020		
	Total Energy Consumption	Biomass Energy Consumption	Biomass % of Total	Total Energy Consumption	Biomass Energy Consumption	Biomass % of Total
- Industrial	35.5	2.7	7.6%	38.9	3.2	8.2%
- Electric Generators	42.7	0.2	0.5%	48.3	0.2	0.4%
Subtotal Power	78.2	2.9	3.7%	87.2	3.4	3.9%
Transportation	33.6	0.24	0.7%	39.5	0.28	0.7%

Source: DOE/EIA, *Annual Energy Outlook*, 2002 , Tables A2, A18

[8] DOE/EIA, *Annual Energy Outlook* 2002.

Biobased Products

Currently, petroleum is refined to make the chemical feedstocks used in thousands of products Many of these petroleum-based feedstocks could be replaced with value-added chemicals produced from biomass resources.

The area of *biobased products* represents a major new market opportunity for domestically grown biomass resources. It will be a new source of revenue for not only those who produce the feedstocks, but also for the farmers and others who are involved in the production of biobased products themselves. Continued research can significantly increase opportunities for biobased products, expand existing markets, and open entirely new markets

Currently, production of biobased textile fibers, polymers, adhesives, lubricants, soy-based inks, and other products is estimated at 12.4 billion pounds per year as shown in Exhibit 4. Total production (biobased and non-biobased), however, is in the hundreds of billions of pounds. The growth opportunities for biobased products are, therefore, enormous. Exhibit 5 lists estimated production for several products that are potential growth markets for the biobased industry [9]

Exhibit 4
Estimated Production of Biobased Products
(million pounds)

Organic acids (lactic, citric, levulinic)	208
Ethanol for industrial use	1,757
Starch	3,000
Sorbitol	515
Glycerol/glycerine	410
Alkyd resins	550
Soy-based products	654
Specialty oils (spearmint, peppermint)	9
Forest chemicals (crude sulfate turpentine, tall oil, pine rosin)	2,826
Cellulose polymers	2,500
Total	**12,429**

Multiple data sources including: Chemical Market Reporter, ChemExpo "Chemical Profiles", USDA, United Soybean Board, *Chemical Economics Handbook.*

Biobased feedstocks can be used to produce a larger share of these products, offset petroleum-based chemical feedstocks, and create economic growth in rural America. Recent developments in the efficient enzymatic conversion of corn carbohydrates to polylactic acid (PLA) and other polymers provide a glimpse of the future potential for biomass.

Exhibit 5
Estimated Production of Selected Chemicals and Lubricants Representing Target Market for Biobased Products
(million pounds)

Organic Chemical Intermediates	203,575
Lubricants & Greases	20,174
Total	**223,749**

Sources: U.S. International Trade Commission and American Chemistry Council Estimates; *EIA Petroleum Supply Monthly*

Advances in biotechnology could enable the engineering of valuable types of plant-based materials for production of a wide range of biobased products Through advanced research, new concepts in the industrial biorefinery could become a reality In the industrial biorefinery, any combination of biofuels, electric power, materials, chemicals, and other products could be produced from local biomass resources.

[9] Estimates based on Bureau of Commerce, 1997 Economic Census, data and industry estimates.

3. THE NATIONAL VISION FOR BIOMASS TECHNOLOGIES

By 2030, a well-established, economically viable, bioenergy and biobased products industry will create new economic opportunities for rural America, protect and enhance our environment, strengthen U.S. energy independence, provide economic security, and deliver improved products to consumers.

VISION GOALS

Through a combination of technical research and market-based and public policy efforts, competitive biomass technologies will provide sustainable energy and materials. Biomass by nature is widely dispersed. The technologies will include large, central systems as well as small systems for local conversion.

The Biomass Research and Development Technical Advisory Committee has established long-term goals that will dramatically transform the role of biomass in the everyday lives of Americans. These are:

- **Biopower** – Biomass consumption in the industrial sector will increase at an annual rate of two percent through 2030, ncreasing from 2.7 quads in 2001 to 3.2 quads in 2010, 3.9 quads in 2020, and 4.8 quads in 2030. Moreover, biomass consumption in electric utilities will double every 10 years through 2030. Combined, biopower will meet four percent of total industrial and electric generator energy demand in 2010 and five percent in 2020.

- **Biobased Transportation Fuels** - Transportation fuels from biomass will increase significantly from 0.5 percent of U.S. transportation fuel consumption in 2001 (0.147 quads) to four percent of transportation fuel consumption in 2010 (1.3 quads), 10 percent in 2020 (4.0 quads), and 20 percent in 2030.

- **Biobased Products** - Production of chemicals and materials from biobased products w ll increase substantially from approximately 12.5 billion pounds, or five percent of the current production of target U.S. chemical commodities in 2001, to 12 percent in 2010, 18 percent in 2020, and 25 percent in 2030.

The strategy for achieving these goals will require significant developments in technical R&D and an appropriate mix of market and public policies to remove the barriers to growth in biomass technologies. Significant opportunities exist to increase crop yield and industry-friendly materials. Similarly, conversion efficiencies can be dramatically improved thereby achieving higher rates of useful energy and value-added chemicals from biomass feedstocks. In its vision for the future, the Technical Advisory Committee believes that continued advances in science and technology will enable biomass to make an even greater contribution to bioenergy and biobased products Advances in research will facilitate integrated production of biobased fuels, electric power, and products in the integrated biorefinery Biomass will become a significant supplier of our Nation's energy and chemical products supplies and will help the United States offset demand for petroleum. Biomass can also be a key resource for hydrogen production, which will further increase opportunities for U.S. energy ndependence.

This *Vision* s developed as a challenge to industry and policymakers to realize the true potential of biomass technologies. It is a starting point from which to measure future progress in meeting far-reaching goals established by the industry

Vision Goals for
BioEnergy and Biobased Products

	2010	2020	2030
BioPower Biomass share of electricity & heat demand in utilities & industry.	4% (3.3 quads)	5% (4.0 quads)	5% (5.0 quads)
BioFuels Biomass share of demand for transportation fuels.	4% (1.3 quads)	10% (4.0 quads)	20% (9.5 quads)
BioProducts Share of target chemicals that are biobased.	12%	18%	25%

4. NEXT STEPS

The revolution that biomass systems can achieve for our national economy can become a reality. The appropriate mix of technology R&D, in combination with market and public policies, can develop and demonstrate critical integrated biobased products and bioenergy systems for fuels, heat, power, chemicals, and materials so these systems may contribute to market goals over the next 30 years.

This *Vision* provides a framework for action. Its challenging, yet realistic, goals have set the destination. The roadmap that follows will chart the technical research, development, and demonstrations needed to achieve technical advances in biomass systems. The roadmap will also outline the institutional and policy changes needed to remove the barriers to economically and environmentally sound development of sustainable biomass systems.

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