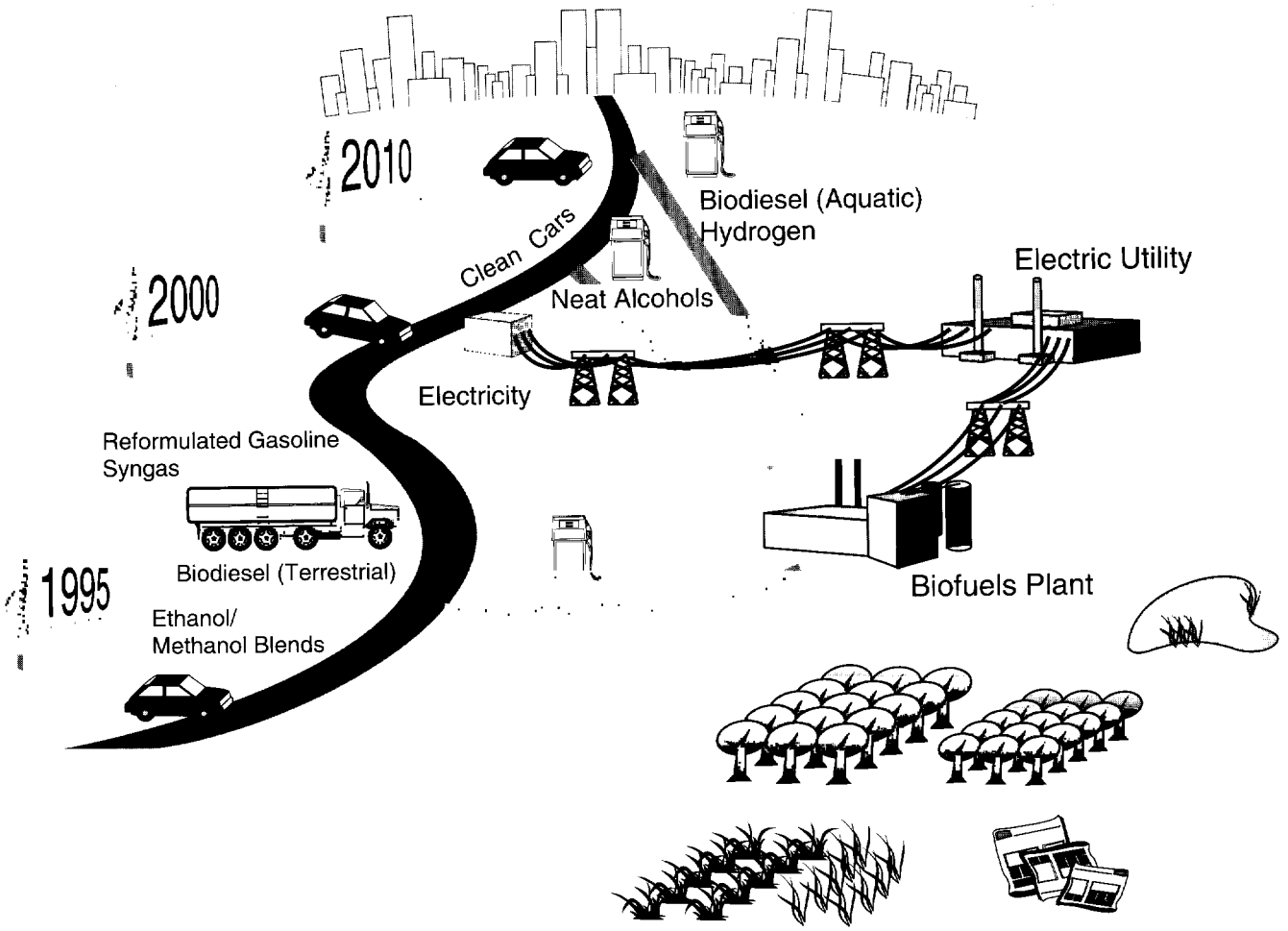
Biofuels: At The Crossroads

Strategic Plan for the Biofuels Systems Program

United States
Department of Energy



THE BIOFUELS COMPONENT OF TOMORROW'S TRANSPORTATION SYSTEM

The transportation network of tomorrow will utilize many resources, both conventional and renewable. New fuel efficient vehicles and smart highways will improve the efficiency of conventional use. Almost any type of current and future vehicle can be fueled from biomass. The flexibility of this important, domestic and renewable resource could provide liquid fuels for internal combustion engines (e.g., flexible and dedicated alternative fuel vehicles), electric and hybrid vehicles (e.g., electricity and liquid fuel), and fuel cell vehicles (e.g., hydrogen from ethanol or methanol technologies).

TO OUR STAKEHOLDERS

At the Crossroads of a Sustainable Energy Future

The Department of Energy (DOE) Biofuels Systems Program (BSP) is conducting research, development, demonstration, and commercialization activities to encourage the use of biofuels for transportation. The Program is managed by the Biofuels Systems Division (BSD) within the DOE Office of Transportation Technologies (OTT). The Division and Program organization are shown in Figures 1 and 2.

WHAT ARE BIOFUELS?

"Biofuels" are alcohols, ethers, and other chemicals made from cellulosic biomass - renewable resources such as fast growing trees, grasses, aquatic plants (microalgae), and waste products, such as agricultural and forestry residues, and municipal and industrial wastes. With further advances in technology, these domestically produced, biomass resources could provide over 50% of future U.S. light duty vehicle (LDV) fuel requirements. Some of the biofuels used to fuel cars and trucks include ethanol and biodiesel. Other alcohol fuels such as methanol, which currently are produced from fossil fuels, can also be produced from renewable biomass and be classified as biofuels.

Many exciting developments are currently underway here at the Biofuels Systems Program. We recently undertook a strategic process to inventory our current situation as well as examine potential future trends. **What we found was that the BSP is at a unique crossroads, positioned to advance biofuels science and technologies into a ready marketplace to fuel an economically competitive transportation sector with secure, clean, and renewable energy resources.** We are examining a number of ways that biofuel products and technologies can capitalize on the massive markets at home and abroad for sustainable energy technologies. Many of our goals involve a new way of doing business, one that is more responsive to our stakeholders, as described in *Fueling A Competitive Economy*, the DOE Strategic Plan. In support of our goals, we are working with a number of industries to deploy bioconversion and thermoconversion technologies to produce ethanol, methanol, biodiesel, and fuel additives for transportation. In FY 1995, the program will focus on pilot-plant operations in partnership with Amoco Oil Company and the New Energy Corporation of South Bend, Indiana, leading to collaborative ethanol production demonstrations based on low-cost feedstocks. A second element of the BSP is the terrestrial feedstock development program where we are collaborating with industry partners, such as Boise Cascade, on opportunities to develop low-cost/high-yield feedstocks such as fast-growing trees (e.g., hybrid poplars) and herbaceous species (e.g., switchgrass). We are also working with several environmental organizations who are interested in sustainable agriculture for energy while enhancing habitats for wildlife.

The BSP's Vision, Mission, Goals, Objectives, and Strategies that have emerged from this process are detailed in this strategic plan. As the plan evolves, it is our intent to continue to reach out and involve you, our stakeholders. We can achieve our vision only by your meaningful involvement. We are currently initiating a set of information, education, and outreach activities to make it easier for our stakeholders to access BSP technology, resources, and facilities. Furthermore, we invite you to contact us either directly or through the National Alternative Fuels Hotline to express your opinion on this plan which we view as an ongoing process and living document.

"We need the advice and thinking of our customers and stakeholders. We need new partnerships with communities, other Federal agencies, academia, State, and local governments, and industry."

Hazel R. O'Leary
Secretary of Energy
DOE Strategic Plan

Figure 1
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy

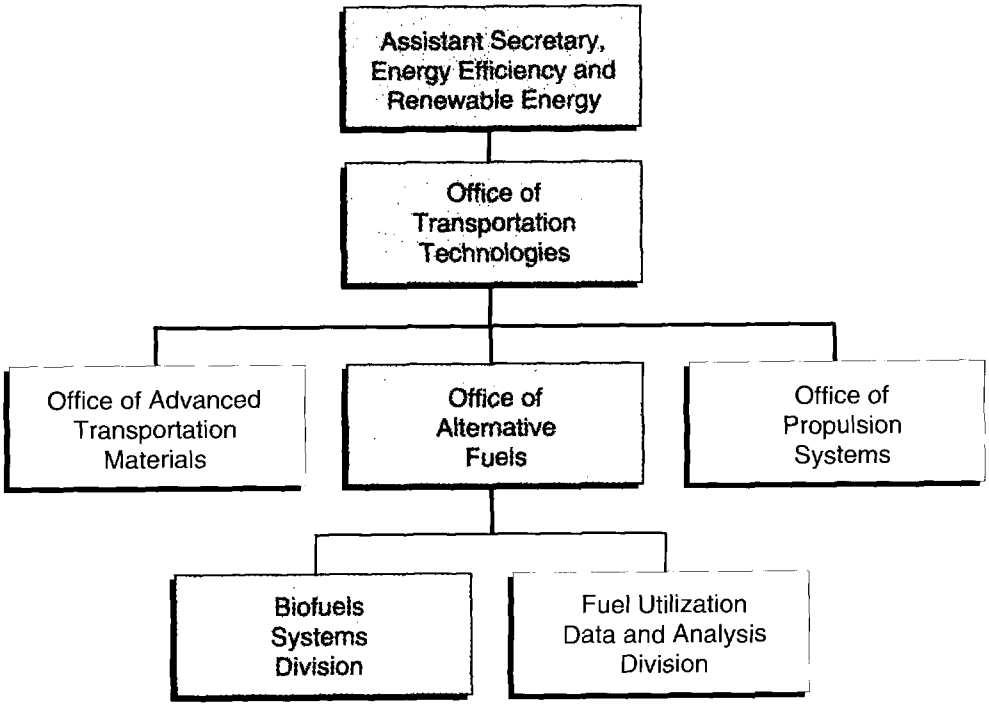
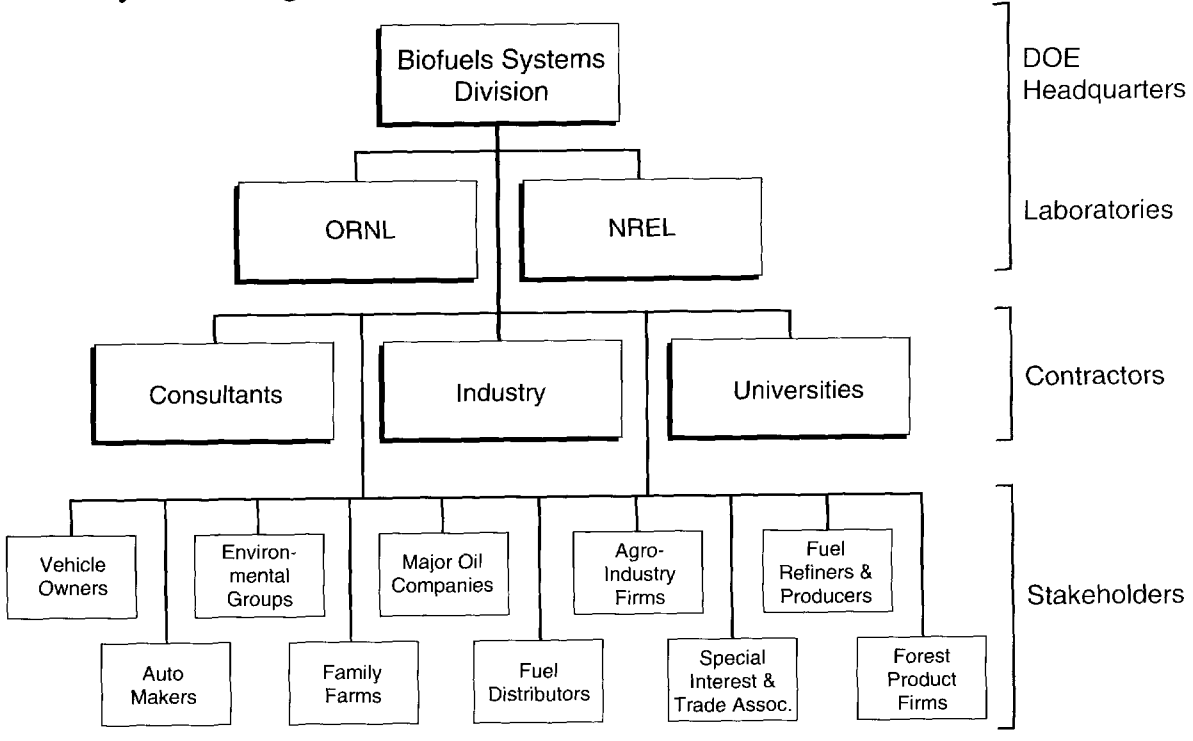


Figure 2
Biofuels Systems Program (BSP) Organization



PROGRAM VISION AND MISSION

Program Vision

To realize the large-scale use of environmentally-sound, cost-competitive, biomass-based transportation fuels through the adoption and commercialization of the best technologies.

Program Mission

We will research, develop, demonstrate, and facilitate the commercialization of biomass-based, environmentally-sound, cost-competitive, U.S. technologies to develop clean fuels for transportation, leading to the establishment of a major biofuels industry.

We will use biomass sources, such as waste paper and wood residues, to serve near-term niche markets as a bridging strategy to position the biofuels industry for the long-term bulk fuel markets. To meet these ends, we are focusing on: the research and development of integrated biofuels systems; the creation of strategic partnerships with U.S. industry and other stakeholders; and improving the operations of our program through well-defined metrics, communication, and coordination with our stakeholders and customers.

WHY BIOFUELS?

Sustainable Transportation Systems

Our country's transportation system is critical to the economic well-being of our nation. Safe and efficient delivery of goods and services is of paramount importance. Increasingly, it is being realized that a sound, well-planned transportation system is a key element of sustainable development. Biofuels can contribute to an energy mix of environmentally-sound, domestic fuels.

New partnership programs such as Clean Cities are helping to bring together federal government agencies, such as the Department of Commerce and the Department of Energy, local government, and private sector suppliers to put more alternative-fueled vehicles (AFVs) on the road and, by creating a stronger demand, encourage the building of fueling stations, maintenance facilities, and other convenient local infrastructure to support them. It is estimated that the Clean Cities effort will result in 250,000 AFVs and 1,000 additional refueling stations throughout the United States - all by 1996.

Moreover, requirements in the Energy Policy Act of 1992 and other legislation, such as the Alternative Motor Fuels Act of 1988, should, by the end of the 1990s, draw significant numbers of vehicles that are capable of using nonpetroleum fuels (over 100,000 units annually) into Federal, state, and private fleets. It is the Program's intent to supply as many of these AFVs as possible with biomass-based transportation fuels.

LEGISLATIVE AND EXECUTIVE ACTIONS TO INCREASE THE USE OF ALTERNATIVE FUELS

- Alternative Motor Fuels Act of 1988 (AMFA)
- Clean Air Act Amendments of 1990 (CAAA)
- 1991 Executive Order 12759 - Federal Energy Management
- The Energy Policy Act of 1992 (EPAct)
- 1993 Executive Order 12844 - Federal Use of Alternative Fueled Vehicles

The aggressive development and deployment of transportation fuels derived from biomass offer the following benefits highlighted below.

Fueling Sustainable Transportation Systems: Creating Jobs and New Markets

The development of a major biofuels industry will create many domestic jobs in agribusiness, engineering, lending institutions, construction, fuel production and distribution. Biofuels technologies also provide the potential of exports to other countries, where new markets exist for alternative fuels, either as a fuel extender or to address growing concerns about mobile source emissions.

Advances in genetic engineering and the growth and harvesting of feedstocks will generate thousands of jobs and improve efficiencies in agriculture and in the lumber, pulp, and paper products industries. The production of high-valued chemicals including ethers, solvents, and pharmaceuticals will also create high-paying jobs.

Biofuels will also revitalize the nation's rural economies by providing more farm jobs, increased equipment sales, fuel plant employment, and other indirect employment and income benefits.

Fueling Sustainable Transportation Systems: Protecting and Enhancing Environmental Resources

An estimated 82% of the carbon monoxide, 43% of the reactive organic gases (precursors to ozone), and 57% of the nitrogen oxides in domestic cities are emitted from the use of petroleum-based transportation fuels. Because biofuels burn cleanly, they are an excellent method for reducing emissions from the transportation sector. In fact, ethanol and methanol are listed as "clean alternative fuels" in both the 1990 Clean Air Act Amendments and the 1992 Energy Policy Act. Furthermore, the carbon dioxide (CO_2) advantage of biofuels is of particular importance. The threat of global climate change resulting from buildup

of CO_2 and other greenhouse gases may make it necessary for the world to move away from fossil fuels and towards energy forms, such as biomass, that result in little or no net additions of CO_2 to the atmosphere. In addition, biofuels can alleviate waste disposal problems in many parts of the country, due to landfill closings and more stringent wastewater regulations, because they can be produced from a wide variety of wastes.

Fueling Sustainable Transportation Systems: Energy Security

The transportation sector depends on petroleum for 97% of its energy needs. The largest contributor to the U.S. balance of trade/balance of payments problem is imported oil. In 1995, the oil trade deficit is expected to be $66 billion. Nearly half of our oil is being imported, and the expectation is that this fraction will continue to increase in the future. Estimates by DOE indicate that by 2020, up to 74% of the oil we use will be supplied by imports. In that same time frame, our oil trade deficit is projected to be $173 billion.

Numerous studies have concluded that our heavy reliance on imported oil is becoming a serious energy security issue, and it is clear that our vulnerability will get worse with time. Key among the reasons for rising oil imports is the limited domestic resource base of crude oil. Additionally, global oil resources are finite and not renewable, oil quality is deteriorating (becoming heavier and with more sulfur), while costs are expected to increase. An important way to stem the tide of imports is to substitute plentiful domestic energy resources, such as biofuels, for petroleum fuels in the transportation sector.

The cost to the nation's economy of importing oil is substantial. First, there are the military expenses associated with energy security. Although experts do not agree on what portion of our military costs should be allocated to energy security, the average value from four recent estimates is $35 billion per year. Maintaining the Strategic Petroleum Reserve is another cost element associated with energy security. From 1976 to 1990, the nation spent $40 billion on this reserve. Currently, we spend about $300 million per year. Aside from energy security, oil imports cost us in other ways. A recent Oak Ridge National Laboratory study estimates that the real cost to the U.S. economy of oil imports from 1972 to 1991 averaged $60 to $95 billion per year.

The production of alternatives to oil from domestic resources, such as biomass, would create manufacturing jobs, help American farmers, and keep more of our investment dollars at home supporting a sustainable energy future.

Potential Benefits of Biofuels

Time Horizon	Biomass Resources		Biofuels		Displacement of Transportation Fossil Fuel Use		Oil Import Savings ($Billions)	CO_2 Reductions (MM tons)
	BTUx10^{15}	MMTons	BTUx10^{15}	MMBOE	LDV (%)	All (%)		
Near-Term (1994-2000)	3.5	219	1.5	259	11.6%	5.8%	$5.9	146
Mid-Term (2000-2010)	6.0	375	3.0	518	21.4%	10.4%	$15.2	292
Long-Term (2010-2030)	16.0	1,000	9.0	1,554	52.6%	21.4%	$47.9	875

Note: MM = million BTU = British Thermal Unit
BOE = Barrel of oil equivalent

WHERE WE STAND

Moving "Biofuels" into the Mainstream

As depicted in Figure 3, the Biofuels Systems Program is conducting research on numerous feedstocks and conversion processes to produce a wide menu of biofuel options for the future, including -- ethanol, methanol, biodiesel, additives for reformulated gasoline (RFG), electricity, and hydrogen. While all of these options offer their own unique advantages and opportunities, BSP is working to accelerate the application of certain biomass technologies based on the near-term, mid-term, and long-term components of this strategic plan.

In the near-term, BSP is primarily focusing on those biofuels that can be deployed in niche markets using existing infrastructure, such as ethanol from waste biomass, fuel additives for reformulated gasoline, and biodiesel from plant oils. In the mid- and long-term, commercially produced energy crops will provide fuels for dedicated vehicles and a new infrastructure. Biofuels, such as ethanol and methanol, show promise for their mid- and long-term potential as bulk fuels. Renewable hydrogen and aquatic-based biodiesel also have long-term potential.

This is not to say that we are automatically ruling out the other fuel options; if and when new alternatives appear to be as or more promising, based on market/ stakeholder demand and the type of vehicles or research coming out of industry, there will be flexibility to shift our focus.

The Biofuels Program has traditionally encompassed two major areas of research and development (R&D). These areas are: (1) the production of biomass feedstocks and (2) the conversion of the feedstocks to transportation fuels and high-value chemicals. The Biofuels Systems Division has assigned feedstock R&D responsibility to the Oak Ridge National Laboratory (ORNL) while conversion R&D is centered at the National Renewable Energy Laboratory (NREL).

As part of a fundamental reorientation of our program to accelerate the application of biofuels, the research at these laboratories is being further integrated to link numerous feedstocks to various conversion technologies. BSP is also strengthening its ties to industry and other stakeholders. The BSP research program and collaboration with industry participants are discussed below.

Feedstock Production

Most current ethanol production is based on corn and other starch crops. The first facilities producing ethanol from cellulosic biomass will use low-cost wastes as feedstocks. The large-scale use of biomass-based transportation fuels, however, will require crops grown specifically for energy purposes. The emphasis on BSP's feedstock R&D program is on developing fast-growing trees and grasses as energy crops. Screening trials have been conducted on over 100 species of trees and 20 species of grasses. Of the trees identified as promising for energy crops, hybrid poplars are receiving the most research attention. Research efforts also emphasize switchgrass, a grass found to be promising over a wide area of the United States.

Sustainable energy crop yields achievable today appear to be in the range of 3 to 8 dry tons per acre per year. Indications are that yields up to 12 dry tons per acre may be achievable through the development of better varieties and improved cropping methods.

With current knowledge and technologies, it is estimated that energy crops could be produced, harvested, and delivered for about $3.00 per million BTUs. A reasonable goal for the future is $2.00 per million BTUs.

Conversion to Transportation Fuels

Three different R&D approaches are being pursued to develop commercial technologies for converting the raw materials in trees, grasses, and other plants -- or plant wastes -- to transportation fuels. These approaches are:

- Biochemical conversion of lignocellulosic materials from trees, grasses, and wastes to ethanol. In the near-term, the ethanol, or products derived from ethanol, would be used as an additive to gasoline. In the long-term, the ethanol would be used as the primary component in an ethanol-gasoline blend.

- Thermochemical conversion of biomass through gasification or pyrolysis-to-methanol, RFG components, biocrude derivatives, or hydrogen.

- Physical/chemical conversion of biomass such as vegetables oils, animal fats, and/or microalgal oils to produce biodiesel, an alternative fuel that can be used in diesel engines.

Each of these research areas is discussed briefly:

Ethanol. The basic processes for converting lignocellulosic feedstock to ethanol are (1) conversion of the cellulose and hemicellulose to sugars (hydrolysis) and (2) fermentation of the sugars to ethanol. R&D work is progressing on both of these basic steps. Emphases are on increasing the yield of sugars from hydrolysis, decreasing the production of fermentation inhibitors, and speeding up the fermentation process. A significant benefit of the biochemical process being developed by BSP is the generation of surplus electricity.

Thus far, process testing has been limited to bench-scale with some integration of process steps. A larger scale, process development unit (PDU) is under construction and will be ready for testing in mid-1994. Two cooperative research and development agreements (CRADAs) have been implemented with industrial partners capable of commercializing the technology.

As shown in Figure 4, using present BSP technologies, it is estimated that ethanol could be produced for $1.22 per gallon. Projected costs of energy crops will result in ethanol costs under $1.00 per gallon by 2005 and under $.70 per gallon by 2010. Waste feedstocks look even more attractive. For wastes with zero feedstock costs (e.g., municipal solid wastes [MSW]), near-term technology results in costs around $1.00 per gallon. By 2005, ethanol cost is predicted to drop as low as $.50 per gallon and to $.34 per gallon by 2010.

Figure 3
Biofuels Pathways for Transportation Fuels

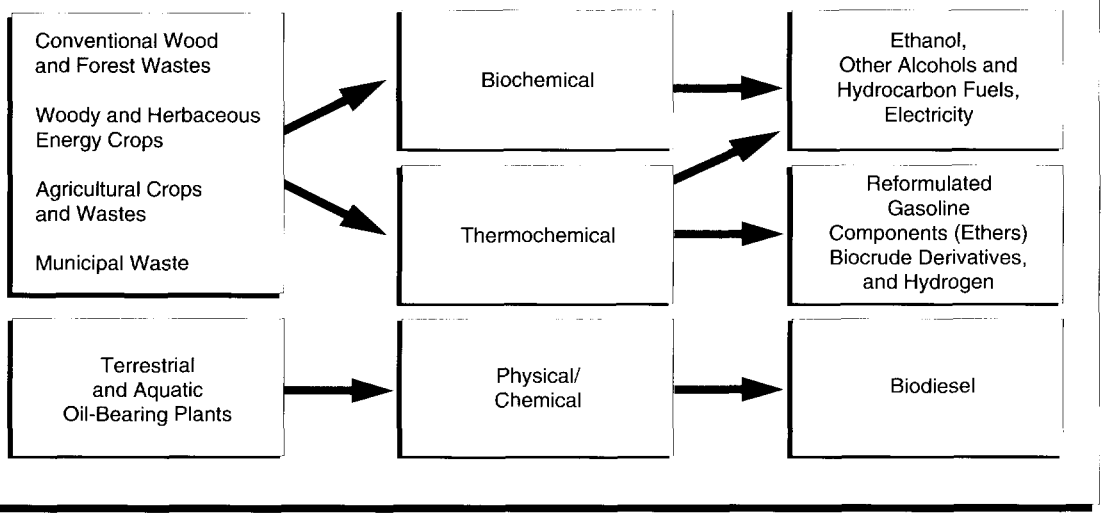
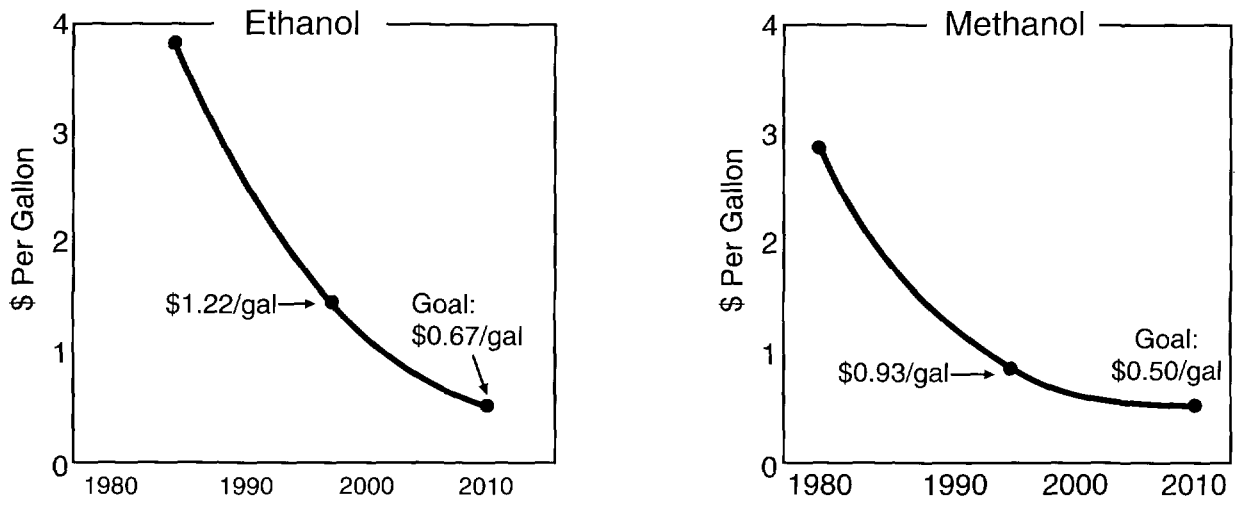


Figure 4
Biofuels Research Progress: Current Costs and Goals*



* Based on feedstock costs of $2/MMBTU (i.e., dedicated energy crops)

Alcohols and Hydrocarbon Fuels. Alcohols can also be produced from thermochemical processes. This approach uses gasification, a thermochemical process to convert biomass to synthesis gas (syngas) - a mixture of carbon monoxide, hydrogen, and low molecular weight hydrocarbons. The synthesis gas is then cleaned and conditioned to prepare it for the particular liquid fuel synthesis step of interest. This is followed by fuel cracking and/or purification, if necessary. The most promising fuel products are methanol; mixed higher alcohols such as butanol; and gasoline, diesel, and jet fuels. The biomass gasification, clean up and conditioning steps have been demonstrated at the pilot scale for methanol production. The fuel synthesis, cracking, and purification steps are currently commercially available for converting fossil fuels to all of the products listed. The sulfur-free nature of these fuels, when produced from biomass, gives them added value over their fossil-derived counterparts, especially if the projected cost goals are achieved. Using present BSP technologies, it is estimated that methanol could be produced for about $0.93 per gallon. A reasonable R&D cost goal is $0.50 per gallon.

Ethers and Biocrude through Pyrolysis. Pyrolysis, another thermochemical process for biomass, is an alternative approach to gasification. Pyrolysis produces a mixture of oils, char, and non-condensible gases which can be further processed to derive a variety of products. If a liquid refiner feedstock is desired, the oils are condensed to form biocrude which can then be deoxygenated and hydrogenated for compatibility with petroleum process streams. If hydrogen is desired, then the biocrude is reformed. Alternatively, iso-olefins can be produced from the pyrolysis mixture through a series of catalyzed reactions. The iso-olefins are then reacted with alcohols to produce ethers. Biomass pyrolysis technology is currently being scaled up to 35 tons per day which is considered near-commercial. Reforming is a standard petroleum refining technology, and ethers are commercially produced, using fossil fuel feedstocks. The other processes are being developed at the bench scale. As with the alcohol and hydrocarbon fuels, the products obtained by pyrolysis are sulfur-free.

Biodiesel. The production of biodiesel fuel from existing sources of plant oils -- e.g., vegetable oils and restaurant waste oils -- is already commercial technology in Europe and Japan. Some commercial demonstration-scale work is now underway in the United States for soybean-derived biodiesel. The Biofuels Systems Program is looking into near-term deployment of biodiesel from plant oils, while developing long-term concepts for obtaining biodiesel from microalgae.

BSP Collaboration With Industry A Primary Focus

The BSP is collaborating with industry, university, national laboratories, and other researchers, to accelerate the application of biomass technologies and their associated fuels, based on the near-term, mid-term and long-term components of the strategic plan. All three components are being pursued ***today***. Some examples of collaboration are discussed below.

Near-Term Commercialization

The near-term focus of the BSP is on processes that will lead to the commercial production of ethanol from waste and cellulosic biomass, fuel additives for RFG, and biodiesel from plant oils. To meet these objectives, BSP has extended its efforts with a new emphasis on scale-up (transferring technology from the laboratory to the marketplace) and partnering with industry. This is best exemplified by the Program's CRADAs with Amoco Corporation and New Energy Company of Indiana. The Amoco partnership involves converting wastes into ethanol for immediate application. This partnership is exciting because oil companies, such as Amoco, would have the ability to produce ethanol's ether derivative ETBE, a high-value RFG component, which can be used to control base gasoline's vapor pressure.

BSP's partnership with the New Energy Company of Indiana is developing technology for ethanol production from the residual starch and cellulosic components in corn to enhance ethanol yields and decrease production costs for corn dry-milling operations. New Energy provides an existing facility in which to integrate biomass-ethanol production technology rapidly; their pilot plant is now providing data at an industrial site to support large-scale implementation in the immediate future. In 1993, the New Energy CRADA received an *R&D 100* award as one of the most important inventions of the year.

In addition, the Program has cost-shared arrangements for fuel production with five different consortia of industrial companies located in various states including California, New York, Florida, Hawaii, and West Virginia. It is expected that these consortia will lead to the first commercial fuel production plants in 1995 to 1996. These first plants will utilize low-value waste materials such as waste paper, rice straw, sawdust, and paper sludge. The utilization of these materials for the production of transportation fuels will also help solve serious waste disposal problems.

Additional partnerships are being arranged with the National SoyDiesel Development Board for the near-term commercialization of biodiesel. Biodiesel could contribute to reducing particulate emissions from urban buses as required under the Clean Air Act Amendments of 1990 (CAAA). Preliminary results of tests conducted by engine manufacturers suggest that biodiesel may significantly lower several key exhaust emissions, especially those of problematic particulate matter. DOE's Office of Alternative Fuels plans to conduct several biodiesel emissions and engine testing projects with the expectation that the fuel will meet CAAA requirements.

In addition, BSP is funding a new Alternative Fuels Users Facility (AFUF) which is considered critical for determining the commercial potential of a major new biofuels industry in the United States. During 1994, NREL will begin operating the multimillion dollar facility at its Golden, Colorado site. NREL engineers and their industry partners will use the AFUF for initial scale-up and integration of ethanol production that shows great promise in the laboratory. Researchers and engineers from industry and academia, as well as from NREL and other national laboratories, will be able to test promising biomass conversion technologies at the pilot-plant scale.

Mid-Term Commercialization

The mid-term focus of the BSP is to continue improving the basic technology for the production of biofuels from wastes, as well as begin deploying commercially-produced dedicated energy crops for the production of alcohols, hydrocarbons, electricity and biodiesel.

It is anticipated that commercial production of fuels from energy crops will be initiated in the late 1990s or early 2000. Currently, a CRADA is being arranged with Boise Cascade and ORNL to analyze the potential of using osmotically-active compounds as a molecular selection criteria for choosing poplars. This technique will allow Boise Cascade to select for drought tolerant species and save considerable irrigation costs while reducing related environmental impacts.

Thermoconversion R&D program activities include interacting with potential stakeholders to determine which fuels and chemicals are of most interest to industry.

Long-Term Commercialization

The major long-term foci of the program are: the widespread use of energy crops for the production of biofuels for bulk transportation fuel markets; the development of aquatic microalgae, capable of rapid growth and high lipid (oil) content for processing as a diesel fuel; and the economic production of biomass-derived fuels and chemicals, such as hydrogen.

Currently, the BSP is setting up several feedstock R&D centers for the development of a greater variety of energy crops to be able to support the widespread use of biofuels. DOE's Office of Alternative Fuels, building on biofuels technologies, is currently supporting research into renewable sources of hydrogen, including steam reformation and thermochemical gasification of biomass. Finally, the BSP program is collaborating with pharmaceutical and biotechnology companies to develop strains of microalgae capable of fast reproduction and high levels of lipid production.

"To help U.S. industries to be more competitive, we need to make it easier for them to access our national laboratory system and the work our labs are doing on pollution prevention, energy efficiency, and renewable fuels. We need to increase the number of significant long-term partnerships between industries and DOE's programs for creating and commercializing these new technologies."

Christine A. Ervin
Assistant Secretary
Energy Efficiency
and Renewable Energy

Examples of BSP Collaboration with Industry and Other Stakeholders

NEAR-TERM

Waste to Ethanol (Biochemical Conversion)

- Amoco/NREL CRADA - Waste to Ethanol
- New Energy/NREL CRADA - Corn Waste to Ethanol
- South Point Ethanol - West Virginia Saw Mill Waste to Ethanol
- Wood Industry Company (WICO) Southern California Ethanol Initiative - Agricultural Residues to Ethanol
- Stone Webster/NYSERDA New York Initiative - MSW to Ethanol
- Northern California - Rice Straw to Ethanol
- PICHTR/Cargill - Hawaiian Sugar Cane Residue to Ethanol
- Weyerhauser/Carolina Power - Wood Waste to Ethanol Evaluation

Waste to Reformulated Gasoline Components (Thermochemical Conversion)

- Interchem/NREL - Refused Derived Fuel (RDF) to Olefinic Compounds/Ethers
- 24 Industry Proposals received - Integration of Biomass Gasification Technologies for Biofuels and Electric Power (in cooperation) with DOE Solar Thermal and Biomass Power Division - Several contracts being negotiated.
- Pittsburgh Energy Technology Center - Coal/Biomass Fuels Technology Development

Biodiesel

- National SoyDiesel Development Board (NSDB)
- Alternative Fuels Data Center (AFDC) Support of Engine Testing for Biodiesel
- Fats and Protein Research Foundation
- Joint Industry/USDA/DOE Total Fuel Cycle Analysis

MID-TERM

Energy Crops to Ethanol

- Alabama Biomass to Ethanol Committee - Dedicated Feedstocks for Conversion to Ethanol
- University of Florida/Bartow Ethanol Energy Crop Development - Dedicated Feedstocks for Conversion to Ethanol
- Biofuels National Roundtable - Developing Guidelines for Sustainable Biomass Production
- Boise Cascade/ORNL CRADA (in process) - Technique to Select Drought Tolerant Feedstock Poplar Species

Biodiesel

- Public Service Company of New Mexico
- Marine Polymer Technologies, Inc. (Biotechnology Company)

LONG-TERM

Biodiesel

- Sterling Winthrop (Pharmaceutical Company)
- Agracetus (Plant Genetics Company)

THE MAJOR ISSUES

Moving Biofuels from Research to Market

As the Biofuels Systems Program's technologies mature, the program is shifting its focus from lab-oriented R&D to market-oriented research, analysis, and technology transfer activities. As part of our strategic planning process, we have examined some of the priorities and challenges involved in marketing biofuels to meet their potential.

In the transportation sector, passenger cars and other light duty vehicles provide the best markets for alternative liquid fuels from biomass. In the last several years, as a niche market for blends, the demand for biofuels has been roughly one billion gallons. This demand is expected to increase to 4.7 billion gallons by 1995 due to the Clean Air Act oxygenated fuel and reformulated gasoline programs. Biofuels, in the near-term, will be used primarily as an oxygenate for gasoline, either directly or as an ether derivative. By 2000, biofuels could supply 100% of the oxygenate market, while providing additional neat fuel for a growing flexible and dedicated alternative fuel fleet. By 2030, biofuels could provide over 50% of the light duty vehicle fleet requirement, primarily by using biofuels in dedicated systems, as opposed to an oxygenate for gasoline.

Several issues described below will affect whether biomass fuels attain their market potential, including: 1) the economics of biofuels; 2) environmental and availability issues regarding the resource base; and 3) sustaining the momentum of a growing, but fledgling, biofuels industry.

The BSP is addressing these concerns through a series of targeted strategic goals (elaborated upon in the second half of this document). These revolve around improving the program's participation with industry as well as advancing grass roots coordination and outreach, in order to transfer biofuels technology. BSP is also focusing on improving its internal operating modes by emphasizing total quality management practices and tailoring its analytical processes to more closely integrate feedstock and conversion research with end-use requirements. In a first step of achieving better integration, the Biofuels Systems Program is collaborating closely with its

Biofuels Options for the Marketplace

Time Frame	Biofuels	Market Applications
Near-Term (1994-2000)	Oxygenates Octane derivatives Fuel extenders Biodiesel (Terrestrial) Electricity	Passenger cars and light duty vehicles Urban buses - 1990 CAAA requires 25% reduction in particulates
Mid-Term (2000-2010)	Ethanol Methanol Biodiesel (Terrestrial) Electricity	Flexible/dedicated vehicles Electric and hybrid vehicles Expanded use of biofuels in mass transit
Long-Term (2010-2030)	Ethanol Methanol Biodiesel (Aquatic) Electricity Hydrogen from ethanol and methanol technologies	Flexible/dedicated vehicles Electric and hybrid vehicles Full gamut of heavy, middle, light duty vehicles Fuel cell vehicles

parent organization, the Office of Transportation Technologies, in the areas of heavy duty, advanced hybrid vehicle, and fuel cell technologies which can be fueled by all biomass-based fuels. BSP is also working to enhance internal communications among DOE headquarters, the laboratories, and program contractors.

Economics of Biofuels

Using present technologies and under current market conditions, transportation fuels from biomass are competitive with petroleum-based fuels in only very special circumstances (tax credits, facility add-ons for conversion, plant site, negative value waste feedstocks, etc.). One, or a combination, of three things must happen to make biofuels reach its market potential:

- Improvements in the technologies for both growing biomass and converting it to transportation fuels;
- Price increases in petroleum-based transportation fuels; and/or
- Internalization of the true benefits from biomass fuels. The benefits that are not currently reflected in market prices are (1) the environmental benefits, especially those related to CO_2 and (2) the benefits from reduced oil imports.

Regarding technology improvements, the prospects are excellent that the research directions presently being pursued will result in transportation fuels from biomass at a cost competitive with petroleum-based fuels from oil at $20-25/barrel. Although the future of world oil prices is very uncertain, most projections point to $20-25/barrel oil very early in the 21st century. The question of internalizing costs is a public policy matter that the Biofuels Program cannot address, but it does seem clear that neither the global climate change issue nor the oil-import issue are going to be addressed effectively without explicit recognition of externalities. Studies are currently underway in the U.S. to examine the external costs of petroleum fuel use -- pollution, trade imbalances, subsidies, and the greenhouse effect -- to determine how they differ from the likely costs of other transportation fuels.

The Resource Base

As indicated in the Vision and Mission statements, the Program's aspiration is to foster the creation of a major biofuels industry, an industry that provides a significant fraction of the nation's transportation fuels. Although there is not a precise quantity of fuel associated with "significant fraction," the intent of the Biofuels Program is to develop the technologies that can be major contributors to achieving or exceeding EPAct requirements (Section 502) of producing sufficient domestic replacement fuels to substitute, on an energy equivalent basis, 10% by 2000 and 30% by 2010, of the projected consumption of motor fuel by light duty vehicles in the U.S. This suggests an eventual capability of producing between 224 and 727 million barrels of oil equivalent per annum of transportation fuels. This level of refined fuels will require a feedstock supply of between 190 and 527 million tons per year of raw biomass, taking into account the efficiency of converting the feedstock to transportation fuels. It should be noted that in the long-term, we expect a biofuels industry to be capable of producing as much as 1 billion tons of raw biomass per year which, given improved conversion efficiencies, could satisfy over half of future light duty vehicle fuel requirements. Thus, achieving the Program's vision will ultimately require a substantial amount of biomass energy.

Waste Feedstocks

The initial step to establishing a biofuels industry will emphasize the production of additives for conventional fuels with the production being based on waste materials. These wastes may come from a variety of sources including agriculture, the wood products industry, and municipal refuse. It is estimated that economically recoverable wastes are about 375 million tons per year, with about 156 million tons already being used -- mostly for steam and electric power production. The remaining 219 million tons of wastes would yield nearly 259 million barrels of oil equivalent transportation fuels, if it were all available for conversion to biofuels. Realistically, a portion of the economically recoverable wastes will be used for steam and power production. Thus, the ultimate production of transportation fuels from wastes

will probably be no more than approximately 172 million barrels of oil equivalent per year, or less than 9% of our present consumption rate for light duty vehicle fuels. Wastes could, therefore, provide the feedstock for a reasonable start, but this resource could not support a large-scale industry. Consequently, energy crops will be needed to achieve the Program Vision of a major biofuels industry.

Energy Crops

The most likely land resource base for biomass production is the nation's excess cropland. The U.S. Department of Agriculture's intermediate estimate for excess cropland by 2030 is 129 million acres. It appears that 40 million of these acres could provide high yields without irrigation. The remaining 89 million acres would require either irrigation or the development of crops for dry land farming. If the Program goal of 10 dry tons per acre per year is achieved, the 40 million acres would yield about 400 million tons per year of primary energy. If converted to biofuels, using mid- to long-term conversion efficiencies, this feedstock would provide between 550 and 620 million barrels per year of oil equivalent transportation fuels.

BIOFUELS FROM WASTE

The paper and organic fractions of MSW comprise over 65 percent by volume of the waste stream. These "cellulosic" fractions provide an excellent feedstock for conversion to biomass fuels. Furthermore, significant amounts of cellulose are presently being landfilled due to the lack of demand for recycled paper. The utilization of cellulosic waste streams would reduce the demand for land resources needed for landfilling and their associated environmental impacts by reducing the amount of MSW, while at the same time producing much needed cleaner transportation fuels. Many municipalities spend anywhere from $10 to $100 per ton in tipping fees just to dispose of MSW or collect it for recycling. Alternatively, these waste feedstocks could be supplied to a biofuels facility at no or negative cost to the facility.

It should be noted that the excess cropland is distributed over several growing regions of the United States. Crops must be matched to growing regions, and this means that the crop research and development effort must include several plant species. It also means that the actual development work must take place over a wide geographical area corresponding to the growing regions. The above discussion indicates that the combination of wastes and energy crops from the nation's best excess cropland would provide between 722 and 792 million barrels per year of oil equivalent transportation fuels, or 25% to 30% of LDV fleet requirements in the mid-term. Going beyond this to achieve the Program Vision will require an expansion of the land resource base beyond the 40 million acres of relatively good land projected to be in excess of that needed for food and fiber. Therefore, in the long-term, energy crop techniques suitable for the drier excess cropland and for marginal lands will need to be developed.

Growing A New Industry

The current biofuels industry involves a broad spectrum of stakeholders ranging from the corn/grain-to-ethanol, pulp/paper, agricultural and forestry industries, as well as oil companies. In addition to the current participants, other stakeholders such as fermentation equipment producers, who manufacture the needed conversion equipment for biofuels, and wholesale fuel distributors, who will develop its accompanying infrastructure, will all play an important role. In general, the future industry will encompass those participants who have a technical and financial interest in the development of transportation fuels on an industrial scale.

This situation presents BSP with both a challenge in meeting the potential needs of a wide range of stakeholders, while providing the opportunity to work with and positively impact several industrial sectors of the nation. Currently, BSP collaboration with industry is undertaken through the following arrangements which include:

1) CRADAs;
2) Cost-sharing arrangements; and
3) Collaborative research.

In addition to these mechanisms, BSP believes that additional cross fertilization is required between industry stakeholders and the Program as the successful development of a biofuels industry will require a high level of coordination and collaboration

among several industrial groups, government agencies, and public interest groups.

As a result, the Program is facilitating the joint funding of roundtable discussions, conferences, and symposia to further industry/program communication and coordination. This is exemplified by BSP's collaboration with the National Biofuels Roundtable, an organization comprised of over 25 participants from industry, government agencies, environmental, and public interest groups.

Furthermore, the Biofuels Systems Program will increase its efforts to disseminate information on new technologies and involve additional potential industry participants through the establishment of an effective external communications, education, and coordination effort.

The following section highlights the strategic goals of the Biofuels Systems Program.

GUIDING THE DEVELOPMENT OF A SUSTAINABLE BIOMASS RESOURCE: THE NATIONAL BIOFUELS ROUNDTABLE

If large-scale development of biomass for liquid fuels or electricity production occurs, significant shifts in agricultural land could result. Additional pressure could be placed on forests and other natural resources, unless managed appropriately. Developing a biofuels industry in an environmentally conscious manner is critical to achieving the full environmental benefits of biomass (e.g., use of perennial energy crops to reduce erosion and runoff, selection of crop practices to reduce anthropogenic carbon emissions that may contribute to global climate change, and application of energy crops in ways that minimize the fragmentation of desirable habitats).

To address these concerns, the Biofuels Systems Program is working with some of our stakeholders under the National Biofuels Roundtable, a forum looking to mitigate any potential real or perceived negative effects as well as enhance ecological integrity and biological diversity.

The Roundtable is committed to reaching a consensus on guiding the development of a sustainable biomass energy resource. Seven principles have been established for developing biomass energy including the protection and enhancement of ecological and biological diversity. This organization promises to be a catalyst for applying good biomass practices at the local and regional levels.

SOURCE: "Principles and Guidelines for the Development of Biomass Energy Systems," A Report from the National Biofuels Roundtable, Draft Final Report, May 1994.

ROADMAP TO GOVERNMENT - INDUSTRY PARTNERSHIPS

Goals, Objectives, and Strategies

The BSP is positioned at a crossroads to provide the transportation sector with the scientific and technological base leading to the use of efficient renewable energy resources; industrial competitiveness; improved environmental quality; and enhanced national security. Achieving this potential will be a continuing challenge that, at the same time, will create opportunities for our stakeholders.

Our strategic planning efforts have resulted in a technology- and market-based roadmap that will most effectively use our unique scientific and technological assets and expertise to meet the needs of our industrial partners for the benefit of the nation. This technology- and market-based strategic plan benefits from the strengths, weaknesses, and other key factors identified in our situation analysis, such as our need to work cooperatively with industry and improve the internal operations of our program.

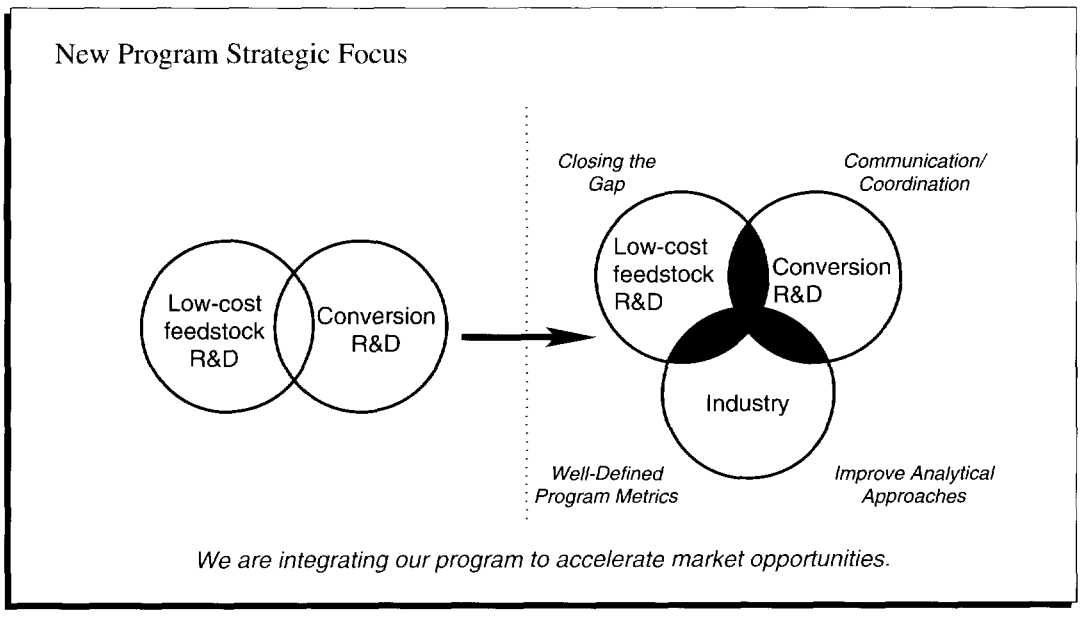
The four strategic goals developed as a part of this strategic plan are outlined below and discussed in additional detail in the following sections:

STRATEGIC GOAL #1: ***Close the gap between technology readiness and market opportunities.***

STRATEGIC GOAL #2: ***Enhance the Biofuels Program management structure and procedures to produce a coordinated program with well-defined metrics.***

STRATEGIC GOAL #3: ***Adopt an integrated, systematic, and comprehensive analytical process to guide program management.***

STRATEGIC GOAL #4: ***Establish an effective external and internal communications, education, and coordination effort.***



STRATEGIC GOAL 1

Close the Gap Between Technology Readiness and Market Opportunities

The BSP has a critical role to play in assisting the transportation sector's economic competitiveness as a result of its unique lines of business, laboratory system, and research and development capabilities. The BSP, its laboratories, and contractors have the expertise and facilities that are essential to major high technology transportation (and other) energy producers in reconciling their economic and environmental requirements.

To reach our strategic goal of closing the gap between technology readiness and market opportunities, *we are making fundamental changes in the way we are conducting R&D in feedstock and conversion processes and are working to increase industry-government partnerships.*

We are linking together our feedstock and conversion programs much more closely in an interactive mode so that industry will have the confidence that these technologies are available to support significant commercial enterprises, at each stage of market opportunity (e.g., use of waste resources for niche markets in the near-term vs. energy crops for bulk fuel markets in the future).

Objective: **Cost-share a biomass waste-to-fuels Engineering Demonstration Unit (EDU) with an industrial partner by 1996.**

Objective: **By 2005, demonstrate the technical ability for producing 518 million barrels of oil equivalent of cost-competitive transportation fuels from biomass wastes and energy crops.**

Objective: **By 2010, deploy the technologies necessary for producing biofuels at a scale of 518 million barrels of oil equivalent.**

Objective: **By 2020, demonstrate the technical capability of producing cost-competitive biofuels, in the range of 1,000 to 1,600 million barrels of oil equivalent per year.**

Objective: **By 2030, deploy the technologies necessary for producing biofuels at a scale of 1,600 million barrels of oil equivalent per year.**

To meet these objectives we will undertake the following strategies:

1) Quantify the availability, type, cost, location, and alternate uses of biomass waste to identify potential business opportunities.

2) Identify one or more industrial partners for executing an agreement to cooperatively build and operate a 50-100 tons per day biomass waste-to-fuels demonstration plant.

3) By the end of calendar year 1994, identify potential barriers and remedies to large-scale deployment of biofuels.

4) By 1997, increase the number of feedstock R&D centers from 3 to 8 to cover the crop production regions of the U.S., and thus, reduce the risks inherent in the energy crop deployment required to produce the oil equivalent of 518 million barrels of biofuels.

5) By 2000, and with assistance from U. S. Department of Agriculture, select at least 4 of the feedstock R&D centers to conduct fundamental research on productivity under various growing conditions.

6) By 2005, demonstrate the feasibility of large-scale feedstock production through expanded field trials and demonstrations of improved crops on typical cropland.

7) By 2005, carry out the necessary development and demonstrations at bench, PDU, and EDU scale.

8) By 2005, establish at least 16 fully integrated feedstock R&D centers to expand the geographic range of biofuels production capability and to develop information on new energy crops, as well as the limits of biomass supply, especially for more difficult site and climate conditions.

9) By 2005, establish close collaboration with the agricultural, fuels, and vehicle industries directly involved in deploying biofuels and with the financial sector from which investment capital will be needed.

10) By 2015, demonstrate the operational readiness and economic viability of converting the new energy crops to fuels.

11) By 2020, deploy new energy crops and systems throughout industry to support expanded biomass resource base utilization and production levels.

STRATEGIC GOAL 2

Enhance the Biofuels Program Management Structure and Procedures to Produce A Coordinated Program with Well-Defined Metrics

One of the major findings from the situation analysis conducted during our strategic planning process is the realization that the BSP has an urgent need to enhance its program management structure, processes and procedures, as well as its ability to measure progress. In order to attain a well-coordinated and integrated program, internally and externally, the BSP must embrace the best management practices to improve stakeholder satisfaction, prevent defects, and eliminate waste. As with the rest of the DOE, the BSP must be viewed as an organization with which its stakeholders *want* to do business. To assist in attaining this goal, the initial step of developing and introducing Total Quality Management (TQM) practices for the Biofuels Program is being taken in FY 1994. As the TQM principles are refined and adapted to our specific needs, this new phase of our management will begin to be implemented in FY 1995. Once fully implemented, we envision a management system that will lead to continuous, cost-effective improvement.

Objective: **By the end of FY 1994, initiate, at BSP, an Intra- and Inter-agency coordination effort for biofuels development.**

Objective: **Implement a strategic management process by FY 1995.**

Objective: **Implement TQM practices throughout the Biofuels Program by 1995.**

To meet these objectives we will undertake the following strategies:

1) Define a structured, strategic management process which entails incorporation of a strategic management charter, appointing a strategic management team, and establishing biannual meetings.

2) Identify, establish, classify, and maintain contacts at government agencies with mutual interests in the Biofuels Program. Keep them informed and seek their input through formal and informal meetings.

3) Implement the following four guidelines for BSP and its program participants:

   a) Document the Program requirements in a management plan;

   b) Perform management assessments to baseline the Biofuels management program and identify areas for improvements;

   c) Develop an implementation plan; and

   d) Measure progress.

STRATEGIC GOAL 3

Adopt an Integrated, Systematic, and Comprehensive Analytical Process to Guide Program Management

Investments in energy-related R&D have a strong influence on economic productivity, jobs and income, environmental quality, and national security. Careful management and balancing of our R&D portfolio is particularly important in these days of limited funding, so that the proper pathways are followed, while avoiding duplicity, eliminating waste, and minimizing false starts. This "balancing act" requires the use of an interactive analytical process to provide the type of objective feedback that will assist program management and decision-making.

A coordinated analytical structure is of particular importance, since the Biofuels Systems Program encompasses and interacts with an extremely wide array of disciplines, topics, and issues relating to conventional and alternative fuels and modes of transportation, the environment, agriculture, fiscal policy, legislative and regulatory mandates, financial institutions, consumer behavior, and national security. Analyses of these issues require understanding and integration of extensive technical, economic, scientific, and institutional data, as well as the use of diverse and disparate methodologies, models, and other analytical tools. The challenge to the BSP is to be able to conduct first-class basic and applied analyses that will help the program and its stakeholders achieve near-term goals, objectives, and strategies while meeting their long-term needs. Furthermore, these analyses must be conducted in the context of providing the kind of program measurement, accountability, and responsibility expected by the public.

Objective: Develop and adopt standard methodologies and tools for use in analyses by the end of calendar 1994.

Objective: Establish an annual analysis review process to identify needs, provide quality control, and ensure feedback for Program management.

To meet these objectives we will undertake the following strategies:

1) The BSP's analytical team will develop integrated guidelines and methodologies that are based on commercial practices and that are valid for all facets of biofuels.

2) Examine and evaluate the analytical methodologies and tools used in the petroleum refining industry and by our parent organizations to ensure the standard(s) adopted by the Biofuels Systems Program are in the mainstream.

3) During the second quarter of each fiscal year, the BSP strategic management team will identify the analyses to be conducted, as well as review the results or progress of previously-approved analyses.

STRATEGIC GOAL 4

Establish an Effective External and Internal Communications, Education, and Coordination Effort

The BSP has a responsibility to establish and enhance relationships with its stakeholders, to increase knowledge about its mission and activities, and to increase the level of feedback for effective program management. In addition, the DOE's agency-wide transformation mandates a change in culture, emphasizing stakeholder orientation, openness, and public trust. It is the intent of the BSP to be responsive to its stakeholders -- internal and external -- by initiating an effective communications, education, and coordination effort, designed to reach industry and the research community, regulatory and legislative bodies at all government levels, educational institutions, interest groups, and the general public. Key to this communications goal will be the establishment of a working group to coordinate and guide these activities.

Objective: **By the first quarter of FY 1995, initiate a set of targeted outreach and information dissemination activities over time, with full implementation by the end of FY 1999.**

To meet these objectives we will undertake the following strategies:

1) By the end of FY 1994, establish guiding and coordinating working groups and identify the industrial firms and trade organizations that are key to the commercialization of biofuels.

2) Beginning in FY 1995, develop sets of outreach materials, including videos, presentations, brochures, factsheets, and other information packages aimed at satisfying general and targeted information needs.

3) Beginning in FY 1995, hold periodic workshops on especially important topics, such as the environmental aspects of biofuels.

4) Beginning in FY 1995, place at least two biofuels "stories" in high-profile public and science media.

5) By the end of FY 1995, establish an electronic network, such as through Internet, that will house Biofuels information and will link the Program to the research community, educational institutions, public interest groups, government agencies, and industry.

6) By the end of FY 1995, prepare a technology transfer plan.

7) By the end of FY 1996, assess the human resource needs for a biofuels industry and develop a list of education and training alternatives for meeting these needs. The most cost-effective of these will be selected and its implementation commenced by the end of FY 1998.

IN CLOSING

This strategic plan is the first of many steps toward realizing the potential of biomass. Through this document we have outlined our vision of the future and the general guidelines and principles we will incorporate to achieve that future. As has been stressed throughout the plan, industry's participation is critical to making the future a reality. As the Program proceeds to develop and deploy biofuels technologies, this plan will be updated to ensure it is current, given any new market, regulatory, or economic realities unforeseen at the time of publication. By making this plan a "living document," it will be used by BSP as guidance for its future activities. We encourage and welcome your comments.

WAYS TO COLLABORATE WITH THE BIOFUELS SYSTEMS PROGRAM (BSP)

A variety of mechanisms exist for industry and other stakeholders to collaborate with the Biofuels Systems Program as described below. We invite you to contact us about how to access BSP technologies, resources, and facilities.

Cooperative Opportunities

Cooperative Research and Development Agreements speed the commercialization of novel technologies. In these agreements, known as CRADAs, BSP and industrial partners like you share the results of the R&D as well as the costs.

Cost-Shared Subcontracts may work to your advantage by permitting you to accrue rights to intellectual property developed under the contract. In this type of arrangement, you contribute, usually in-kind, to R&D costs.

Sponsored Research calls on the unique experience and expertise available at BSP, as well as our state-of-the-art facilities. This type of agreement can include basic or applied research, developmental projects, and technical or economic analyses. If the study is proprietary, the sponsor retains all intellectual property rights.

Visiting Researchers from industry or universities can benefit from access to our specialized facilities under various exchange programs. We can negotiate with you on user fees and scheduling if you want to request the use of BSP facilities.

Collaborative Research allows us to cooperate with you, our counterparts in industry, to reach a common goal by sharing progress and results. The agreements are usually informal and noncontractual.

Additional Biofuels Information Sources

National Alternative Fuels Hotline

The Hotline assists the general public and interested organizations in improving their understanding of alternative transportation fuels. Information is available on alternative fuel legislation, fact sheets on alternative fuels and vehicles, major government programs, and points of contact in the public and private sectors. The National Alternative Fuels Hotline is 1-800-423-1DOE.

The Alternative Fuels Data Center

The AFDC is operated by the National Renewable Energy Laboratory through DOE's Office of Alternative Fuels. The AFDC provides unbiased, accurate information on alternative fuels and alternative-fueled vehicles to governmental agencies, private industry, research institutions, and other interested organizations. The Center can be contacted through the National Alternative Fuels Hotline.

DOE Biofuels Information Network

The DOE Biofuels Information Network (BIN) will soon be available on the Internet. BIN will allow stakeholders to obtain information about feedstocks and conversion technologies from Oak Ridge National Laboratory and the National Renewable Energy Laboratory directly at their desk top. The full text of fact sheets, newsletters and reports will be online as well as searchable bibliographic databases.

KEY PUBLICATIONS

Biofuels Program Plan: FY1992-FY1996
U.S. Department of Energy
January 1993
Available from NTIS
Order No. DOE/CH10093-186

Fuel Cycle Evaluations of Biomass-Ethanol and Reformulated Gasoline, Volume I
Produced for the U.S. Department of Energy by the National Renewable Energy Laboratory (Tyson, et al.)
November 1993
Available from NREL
Order No. NREL/TP-463-4050

Biofuels: Project Summaries Fiscal Year 1992
U.S. Department of Energy
May 1993
Available from NTIS
Order No. DOE/CH10093-213

The American Farm: Harnessing the Sun To Fuel the World
Produced for the U.S. Department of Energy by the National Renewable Energy Laboratory
March 1994
Available from NTIS
Order No. NREL/SP-420-5877 DE94000217

Energy Crops Forum
Produced for the U.S. Department of Energy by the Oak Ridge National Laboratory (ORNL)
Newsletter published three times per year
Available from ORNL Biofuels Feedstock Development Program

Biofuels UPDATE
Produced for the U.S. Department of Energy by the National Renewable Energy Laboratory (NREL)
Newsletter for the National Alternative Fuels Hotline at 1-800-423-1DOE

The Potential of Renewable Energy: An Interlaboratory White Paper
U.S. Department of Energy
November 1990
Available from NTIS
Order No. DOE/CH10093-84

Estimates of U.S. Biomass Energy Consumption 1992
U.S. Department of Energy/ Energy Information Administration
May 1994
Available from U.S. Government Printing Office
Order No. DOE/EIA-0548(92)

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