Office of Energy Efficiency and Renewable Energy

Office of the Biomass Program

Multiyear Plan
2004 and Beyond

DRAFT November 6, 2003

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Preface

This multiyear planning document provides the strategic five-year plan for the Office of the Biomass Program (OBP), one of eleven offices under the purview of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy (DOE/EERE). The OBP was formed to integrate and consolidate EERE activities in biomass energy research and development, and brings together technical components from several different offices within EERE. This document represents one of the first strategic planning effort undertaken by the newly integrated office.

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1.0 Introduction

1.1 Office of Energy Efficiency and Renewable Energy

The mission of the U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE) is to strengthen America's energy security, environmental quality and economic health. The Office accomplishes this mission through public-private partnerships that enhance energy efficiency and productivity, promote the development of clean, reliable, affordable energy technologies, and expand the energy choices available to Americans.

To focus its efforts on the Nation's most pressing energy problems and achieve the greatest possible benefits from its programs, EERE has established nine portfolio priorities. These priorities serve to guide the portfolio decision-making process and support EERE goals for a secure energy future.

The use of renewable energy resources is a key tenet of the EERE mission and a recurring theme in its priorities. Today, the U.S. economy is dominated by technologies that rely on fossil energy (petroleum, coal, natural gas) to produce fuels, power, and a wide range of chemicals. There are, however, many compelling reasons to expand our energy choices to include more renewable sources such as biomass, solar, wind, and geothermal energy. Our growing dependence on foreign oil, for example, exposes the economy to critical disruptions in supply and could potentially impact national security. Volatilities in the price and availability of fossil energy create economic and social uncertainties for businesses and individuals.

EERE Portfolio Priorities

- *Dramatically reduce or even end dependence on foreign oil*
- *Reduce burden of energy prices on the disadvantaged*
- *Increase the viability and deployment of renewable energy technologies*
- *Increase the reliability and efficiency of electricity generation, delivery and use*
- *Increase the efficiency of buildings and appliances*
- *Increase the efficiency/reduce the energy intensity of industry*
- *Create the new domestic bioindustry*
- *Lead by example through Government's own actions*

Biomass is an abundant natural and renewable domestic resource that has the potential to supplement our fossil energy supply and help create a more secure energy future. Within the continental U.S. we can grow and harvest several hundred million tons of additional plant matter per year on a sustainable basis. Many of the chemicals and fuels that are now created from petroleum could be produced from domestic biomass, and with fewer environmental impacts. A bioindustry could provide avenues for productive use of agricultural and forestry wastes, reducing the need for landfills and decreasing forest fire hazards.

1.2 Office of the Biomass Program

1.2.1 Background

EERE recognizes the significant potential of biomass as an energy resource, and the opportunities it represents to enhance energy security and support the national mission and priorities of DOE. To take advantage of this valuable resource, EERE has established the Office of the Biomass Program (OBP) to foster technology development and drive the growth of a new bioindustry.

The OBP emerged in July 2002 as part of the EERE effort to streamline its organization and improve delivery of energy-efficient and renewable technologies to the U.S. The drive to reorganize was a response to the President's Management Agenda for Fiscal Year 2002 as well as the DOE/EERE Strategic Program Review, which was completed early in 2002.

The OBP brings together three programs that previously conducted biomass R&D under separate EERE offices – biofuels, biopower, and the Agriculture Industries of the Future initiative. OBP also incorporates activities that were previously conducted under the National Biobased Products and Bioenergy Coordination Office (see Section 1.3, Legislative Authority). The new structure establishes an integrated program for biomass technology R&D, and will enable more effective use of EERE resources in this area.

1.2.2. Mission of OBP

The mission of OBP is to partner with U.S. industry to foster research and development on advanced technologies that will transform our abundant biomass resources into clean, affordable, and domestically-produced biofuels, biopower, and high-value bioproducts. The result will be improved economic development, expanded energy supply options, and increased energy security.

OBP activities directly support the overall mission and priorities of DOE/EERE. OBP technology development and implementation activities will directly contribute to the creation of a new bioindustry, and will reduce U.S. dependence on foreign oil by supplementing the use of petroleum for fuels and chemicals.

1.2.3 Program Structure

OBP pursues its mission through competitively awarded, cost-shared RD&D partnerships with industry, academia, national laboratories, and private research institutes. OBP makes investments based on detailed market and technology analysis, and collaboration with leaders and technology experts in the industry. OBP structures its activities within five major R&D areas (see Figure 1-1). This structure reflects the technology development pathway pursued by OBP. The strategies and technical elements behind these program areas are outlined in the Technical Plan in Chapter 3.

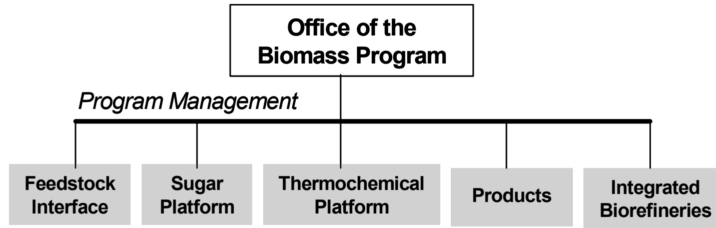

Figure 1-1 Program Structure for OBP

1.3 Legislative Authority

1.3.1. Primary Legislative Directives

The legislative authority behind the Office of the Biomass Program is well-established and rooted in legislation going back to the late 1970s. Over the last decade, however, growing interest in biomass as an energy resource has catalyzed the passage of several important laws aimed at encouraging the growth of the bioindustry (see Figure 1-2).

These legislative actions provide support for the technology development programs needed to move the industry forward. They are a major driver behind OBP and its research programs, and provide direction for development of the R&D portfolio. Appropriations made under Title XII of the **Energy Policy Act of 1992**, for example, supported some of the early ground-breaking research in biobased fuels and power systems that forms the foundation for current OBP R&D programs.

Role of the Federal Government

"Congress finds that....because of the relatively short-term time horizon characteristics of private sector investments, and because many benefits of biomass processing are in the national interest, it is appropriate for the Federal government to provide precommercial investment in fundamental research and research-driven innovation in the biomass processing area ...."

Biomass R&D Act of 2000

In 1999, Executive Order 13134 set policies to stimulate development of biobased technologies, and established the National Biobased Products and Bioenergy Coordination Office, under which some early OBP activities were conducted. Today the functions of the National Coordination Office are carried out in part under the purview of the OBP, which serves as co-chair of the Office with USDA.

The **Biomass R&D Act of 2000** superseded Executive Order 13134 and created a new legislative mandate for OBP. In addition to funds appropriated for biomass R&D under the general authority of the Secretary of Energy, the Act provides funds for OBP research under Section 307, *Biomass Research and Development Initiative*. OBP responds directly to the Act by conducting R&D to address some of the key technical issues outlined in the legislation.

Biomass *is produced from water and carbon dioxide by the process of photosynthesis. Primary biomass is produced by agriculture and forestry and includes energy crops such as short rotation trees, grasses and aquatic plants. The harvesting of these resources generates secondary forms of biomass such as straw, stover and forest residues in addition to lumber, pulpwood, and grains. Additional secondary resources include processing residues and byproduct streams from food, feed, fiber and materials production. A growing quantity of biomass is tertiary in nature and includes post consumer residue streams from urban activities such as fats, greases, oils, construction and demolition wood, as well as animal residues from concentrated animal feed operations.*

1.3.2 Other Key Legislative and Administrative Drivers

The efforts of the current administration to develop an energy plan will have important implications for the bioindustry and the OBP. The National Energy Policy (NEP) report, commissioned by President Bush, reviews the Nation's energy situation and presents a strategy to achieve a reliable energy structure that will support our quality of life and still maintain protection of the environment.

The increased use of renewable energy, including biomass, is an integral part of the NEP strategy and provides further justification for OBP activities in this area. The Executive Branch is now working with Congress to enact a National Energy Policy which will provide future guidance for this program. Under the new energy policy, it is anticipated that the R&D activities conducted by OBP will continue to be highly relevant and support national goals for energy security.

Figure 1-2. Legislative Mandates Behind the Office of the Biomass Program

Biomass R&D Act of 2000 (Agricultural Risk Protection Act of 2000, Title III) – *directs the U.S. Departments of Energy and Agriculture to integrate technology R&D programs to foster a domestic bioindustry producing fuels, power and chemicals. For purposes of research coordination and oversight, the Act establishes the Biomass R&D Board and the Biomass R&D Technical Advisory Committee. Section 307, Biomass R&D Initiative, authorizes grants, contracts and financial assistance for biobased products R&D in specific technical areas. The Act replaces Executive Order 13134, Developing and Promoting Biobased Products and Bioenergy, issued in 1999.*

Farm Bill 2002, Title IX – *is the first farm bill ever to include an energy title. The Bill contains five programs providing mandatory funding for bioenergy activities, and reauthorizes the Biomass R&D Act of 2000 through 2007. The Bill mandates the purchase of 'environmentally preferable bioproducts' by Federal agencies, and provides grants for development of biorefineries (Section 9003). The Bill establishes incentives and grants for biodiesel, fuel grade ethanol, and use of renewable energy in rural enterprises.*

Energy Policy Act of 1992, Titles III, IV, V and XII (EPAct) - *reauthorized portions of the Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989, expanded renewables R&D programs, and established new incentives for the use of biomass (and other alternatives) for power and fuels. Title XII provides appropriations for demonstration and commercial application projects in biobased fuels and power systems, including conversion of cellulosic biomass to fuels, ethanol production, and direct combustion or gasification of biomass. Title XII also creates an 'Alcohol From Biomass' R&D program to promote advanced alcohol production technologies (ethanol and methanol). Titles III, IV and V encourage the use of alternative fuels in the transportation sector through fleet incentives.*

2.0 Strategic Goals, Benefits and Opportunities

2.1 National Benefits and Opportunities

Using our indigenous biomass resources to supplement the U.S. energy supply will yield a multitude of benefits for the Nation. Biomass can be used to fuel our cars, heat homes, and provide many of the diverse products that are essential to daily life. Using biomass as an energy resource will allow the U.S. to reduce its dependence on foreign oil, stimulate economic growth, and positively impact the environment.

2.1.1 Energy Potential of Biomass Resources

Biomass resources in the United States are abundant and renewable, and offer tremendous potential to supplement our current energy resources. Current total available domestic biomass, beyond its current use for food, feed, and forest products, is between 500-600 million dry tons per year for the period 2010-2020[1]. These biomass resources represent about 3-5 quads of delivered energy or as much as 5-6 percent of total U.S. energy consumption.

In terms of fuels and and power, that translates into 60 billion gallons of fuel ethanol or 160 gigawatts of electricity. This is enough energy to meet 30 percent of U.S. demand for gasoline or service 160,000 households with power[2]. If only 10 percent of the biomass resource were converted to chemicals, the result would be 25-30 million tons of products or about five times the current production of industrial bioproducts[3].

Based on these estimates, available domestic biomass represents a potentially significant energy resource. Available biomass potential could be greatly increased through advances in technology and changes in public policy, infrastructure, and lifestyle.

2.1.2 U.S. Energy Security

Overall, U.S. consumption of energy far outpaces domestic production for all sources of energy. Decreasing U.S. dependence on imported oil through the use of biomass-based fuels, power and products is an issue of national security. This dependence increases our vulnerability to supply disruptions and amplifies the impacts of price volatilities.

Oil imported into the U.S. has been rising over the last three decades, and now accounts for 53 percent of U.S. oil supply (see Figure 2-1). Approximately 70 percent is used annually to produce transportation fuels. However, nearly half a billion barrels of oil per year are used to manufacture plastics, pharmaceuticals, paints, detergents, and many other important consumer products.

Displacing fossil energy with biomass will allow the U.S. to meet demand for fuels, products and power while reducing dependence on imported oil and increasing energy security. The efforts of OBP will develop and help to commercialize technologies that are needed to drive the new bioindustry and supplant imported oil use.

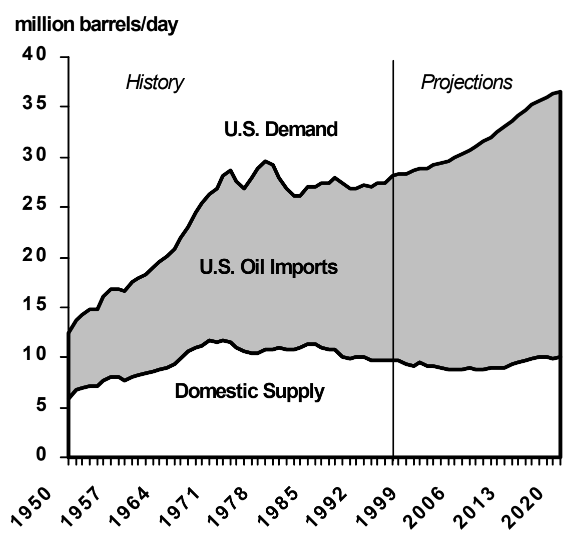

Figure 2-1 U.S. Oil Production and Consumption
[DOE/EIA Annual Energy Review 2000, Annual Energy Outlook 2001]

2.1.3 National and Rural Economic Growth

The creation of a new bioindustry, which is a strategic goal for EERE and a primary driver for OBP, will provide new opportunities for economic growth. History has shown that creating new industries yields the highest return in terms of jobs and domestic value. Developing our domestic sources of energy will also enhance our competitiveness in foreign markets.

A domestic bioindustry will require an increase in production and processing of biomass. This will directly impact rural economies by creating new cash crops for farmers and foresters, many of whom currently face economic hardship. New processing, distribution, and service industries will be established in rural communities, with positive impacts on rural economic growth. As the agricultural and forestry industries begin to provide feedstocks for more than just food, feed and fiber, they will become an integral part of the transportation and industrial supply chain.

2.1.4 Environmental Benefits

Biomass technologies will positively impact the environment by offsetting the use of fossil fuels and associated pollutant emissions. There is also the potential to reduce the generation of harmful wastes associated with the manufacture of chemicals from petroleum. Other environmental benefits include stemming the growth in emissions of carbon dioxide, better management of particulate emissions, reducing soil erosion, making use of thinnings in forest lands, and adding to ecological diversity.

2.2 Challenges in Creating the Bioindustry

Advances in science and technology will be key to the development of new bioprocessing systems and biorefineries. Integrated, multi-disciplinary research activities will be necessary to address major technical challenges, make progress toward demonstration and commercialization of new technology, and create a domestic bioindustry. OBP's well-coordinated research effort will create and nurture partnerships among stakeholders in industry, government and academia. Section 4 discusses the role OBP will have in building partnerships and coordinating R&D.

The overarching R&D challenge for OBP is to maximize the efficiency and minimize the costs of transforming plants to useful products, while keeping sustainability in mind. Key technical challenges exist in feedstock supply, biomass conversion, and sustainability, as well as the typical performance and financial challenges associated with the implementation of pioneering technology.

Availability, variability and biomass supply system logistics- Biomass resources vary in types and amount of biomass available in any given location and season. They vary widely in physical and chemical composition, size, shape, moisture content, and bulk densities. Biomass also has the handling, storage and transportation challenges of a low-density material.

Conversion to fuels, chemicals and power - Plant cell walls are designed to withstand drought, pests and disease, and to keep plants standing upright. These same qualities make biomass resistant to conversion to chemicals by thermal, chemical or biological processes. To cost-effectively convert biomass to new products, advances will be needed in pretreatment as well as conversion technologies.

Thermochemical processing creates a synthetic gas that typically contains some unwanted mineral components and particulates. These contaminants will need to be removed for syngas to be a cost-effective and environmentally viable option for products and power.

Sustainability - Sustainability is a key criterion for acceptability of biomass technologies. Consideration of environmental soundness, stewardship of resources, social justice, and a consciousness for preserving a viable society for future generations are essential. OBP recognizes that careful analyses and consideration of sustainability issues must be undertaken simultaneously with R&D, and structures its programs accordingly.

Bioprocessing System integration - A successful bioindustry will require plants with well-integrated bioprocessing systems that are able to produce fuels, chemicals and power from a variety of feedstocks. Effective integration of feedstock pretreatment, the microbial system(s), separation of dilute products in aqueous systems, and purification of products will be major challenges.

Technical and financial risk - Considerable risk will be involved in building new biomass processing facilities, primarily due to the cost and performance uncertainties represented by new, unproven technology. These uncertainties are compounded by large capital investments and externalities such as regulatory requirements and government policies.

Factors associated with performance shortfalls and cost overages in new plants include plant complexity, percent of capital investments that involve new steps, actual heat and material balance data, difficulty of waste handling, and handling of solid feedstocks. To reduce risk, OBP research is directed toward creating knowledge in each of these areas for new bioprocessing plants.

Performance validation - Demonstration of integrated processing systems at prototype and market scale will confirm reliability, lower operating costs through optimization, and minimize the cost of environmental compliance. Understanding the risk associated with bioprocesses will allow investors to better judge capital investment needs, process performance, and feedstock and product prices. OBP will work with industry on validation projects that establish performance and operating characteristics.

What is a Biorefinery?

A biorefinery processes biomass into value added product streams. These can range from biomaterials to fuels such as ethanol and fuel gases, or key intermediates for the production of chemicals and other materials. Biorefineries are based on a number of processing platforms using mechanical, thermal, chemical and biochemical processes.

2.3 Goals and Objectives

2.3.1 Strategic Goals

In keeping with DOE/EERE priorities for energy security, OBP has set a long-term strategic goal for reducing U.S. dependence on foreign oil. This will be accomplished largely by supplanting the use of petroleum with biomass for the production of fuels, chemicals and power.

OBP has also embraced the long-range goals set by the Biomass R&D Technical Advisory Committee in their recent vision document[3], as shown in Figure 2-3. The technical strategy and program goals of OBP have been designed to help meet these targets.

Figure 2-3. Biomass R&D Technical Advisory Committee Goals for 2020

- *10 percent of transportation fuels will be biomass-derived by 2020.*
- *Biopower will meet 5 percent of total industrial and utility power demand in 2020.*
- *Biomass-derived chemicals and materials will account for 18 percent of production in 2020.*

2.3.2 Multiyear Program Plan Objectives

This five-year Multiyear Program Plan (MYPP) is designed to achieve the following goals and outcomes in support of EERE priorities. These goals coincide with the technical goals outlined in the Multiyear Technical Plan. Specifically, goals are to develop

- *sustainable technologies capable of supplying lignocellulosic biomass to biorefineries producing fuels, chemicals, heat and power;*
- *the capability for using lignocellulose biomass to produce inexpensive sugar streams as feedstocks for fuels and chemicals;*
- *the capability to thermochemically convert biomass into building blocks for production of fuels, power, hydrogen, and other chemicals and materials;*
- *the capability to produce fuels, power, chemicals and materials utilizing intermediates from sugar and thermochemical platforms; and*
- *support establishment of integrated biorefineries through partnerships with industry and academia.*

3.0 Technical Plan

3.1 Technical Approach

This Multiyear Plan is designed to address gaps, barriers, and opportunities limiting the development of a new bioindustry. The OBP approach is to focus on two important technology platforms- sugars and thermochemical (see Figure 3.1). These platforms produce the fuels and chemical intermediates with the most promise for achieving significant advances over the next 5-7 years. By concentrating resources on these platforms OBP can leverage work already completed by existing industries and focus efforts on new biomass opportunities.

OBP conducts activities in advanced R&D in both platforms to improve existing processes and develop new technologies. To maximize the utilization of biomass for new fuels and products, OBP conducts R&D to improve conversion of sugar and synthesis gas into fuels and products, and effectively integrate the associated plant unit operations. This includes reducing technical and financial risk through technology validation. To ensure that a viable feedstock infrastructure is in place to support new plants, OBP conducts activities to address feedstock supply issues. An overview of efforts planned for technology platforms, utilization and feedstocks is provided in the following sections.

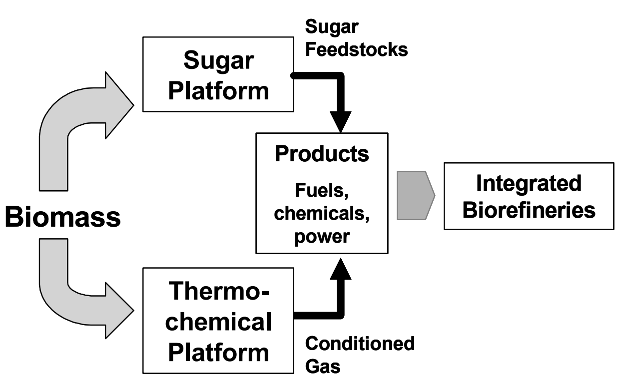

Figure 3-1 Technical Approach to Integrated Biorefineries

3.2 Biomass Feedstock Interface R&D

Biomass feedstocks are already supplying about 3 quadrillion Btus (Quads) to the Nation's energy supply based primarily on wood residues. The potential exists for increasing total biomass contribution up to 10 Quads nationwide. However, biorefinery developers require assured amounts of feedstock of desired quality on a year-round basis at specific locations.

Existing industries that already have a biomass supply infrastructure – such as corn wet and dry mills, and pulp and paper mills - can mitigate the issues of acquiring new feedstock supplies by more fully utilizing all components of the wood and grain residues. For new biorefineries, region-specific feedstock technologies and infrastructure will be needed to assure a steady supply of low-cost biomass with the desired quality.

The primary mission of the biomass feedstock interface area is to work closely with the sugar and thermochemical platforms to conduct the R&D needed to meet their feedstock needs. This will require fundamental changes in the current agricultural and feedstock systems, including new technologies and partnerships between growers, equipment manufacturers and processors.

3.2.1 Programmatic Objectives

The overall objective for sustainable feedstock technologies is to develop sustainable technologies capable of supplying lignocellulose biomass to biorefineries. Specific objectives include:

harvest and collection technologies to support 100 million dry metric tons per year by 2010, and 1 billion dry metric tons per year by 2050;

feedstock infrastructure technologies to meet the $30/ton price target; and

feedstock supply forecasts, models and analyses needed to optimize feedstock supply chains.

3.2.2 Status of Biomass Feedstock Interface Technology

Agricultural crops and residues are the largest potential new biorefinery feedstock resource. Current production is concentrated in the Midwest and Great Plains. Grain collection and supply infrastructure for the production of ethanol is a mature technology. The crop residues currently returned to the soil could be an additional revenue source for farmers. Limited research is ongoing to identify conditions where residues could be removed while maintaining soil nutrient status.

Wood residues generated by the forest products industry, including logging residues, bark and other mill residues and spent pulping liquors, are the source of about 2.5 quads of energy today. The forest products industry has in place an existing wood harvesting and preparation infrastructure for wood fiber that is already capitalized and operating. Wood residue collection could be expanded under the right ecological, financial and policy conditions with collection of more logging residues and with thinning of dense undergrowth creating fire hazard conditions. This industry adheres to a set of sustainable forestry principles that integrates the practices of reforestation, nurturing, and harvesting of trees with the conservation of soil, air and water resources, wildlife and fish habitat, and forest aesthetic values. Urban wood residues from tree trimmings and construction and demolition activities contributes about 0.4 quads of energy. This wood tends to be used only where tipping fees are high.

Plants such as grasses are already widely planted for land conservation purposes and forage. New varieties with a capability for sustained high biomass yields have been developed. The deep roots, perennial nature, and low nutrient demands of switchgrass and other grasses offer potential for a sustainable feedstock supply system.

Short-rotation trees have been established commercially for fiber and in a few locations as dedicated energy crops for demonstration projects as a result of previous DOE research and technology transfer. New varieties and culture techniques offer the capability for high yield, sustainable production systems similar to grasses.

The current focus of OBP research will be on agricultural crops and residues with the assumption that energy crops such as grasses and short-rotation trees will be developed by USDA or others. Work in basic plant sciences to improve existing and alternative energy crops will primarily be conducted by USDA, the DOE Office of Science, the National Science Foundation (NSF) or other groups.

3.2.3 Technical Barriers

Technical barriers that pose a challenge to developing biorefineries with a sustainable feedstock infrastructure based primarily on agricultural residues are shown in Table 3-1.

Biomass variability - The characteristics of biomass can vary widely in terms of physical and chemical composition, size, shape, moisture content, and bulk densities. These variations can make it difficult (or costly) to supply biorefineries with feedstocks of consistent quality year-round.

Engineering systems - These are relatively mature for the forest products industry and for crops used in food production or existing biorefineries (corn grain). Agricultural residues create engineering supply system challenges because of their low bulk density and low tons/acre yield. This requires new systems for cost-effective feedstock collection, transportation, and handling. The short harvest window for agricultural residues requires year-round storage with associated fire and health hazards and deterioration risks.

Resource availability - Constraints to biorefinery facilities are lack of information and uncertainty about amount, price, quality, and year-round reliability of residue feedstocks at any given location and the need for long-term fuel supply contracts. Better information on resource and market factors is needed to reduce uncertainty.

Sustainability Requirements - Successful biorefinery enterprises must be based on sustainable feedstock supplies and life cycle benefits compared to fossil fuel use. Collection of agricultural residues risk the loss of long-term crop productivity and reduction of soil carbon levels.

Table 3-1 Technical Barriers to Sustainable Feedstock Technologies	
Technical Area	**Barrier**
Biomass Variability	• local variation in types and amounts of biomass available • wide variations in physical and chemical composition, size, shape, moisture content, bulk densities of un-treated biomass
Engineering Systems	• handling and transportation challenges due to low bulk-density of biomass • inability to monitor fluctuations in feedstock properties • lack of robust feed preparation and handling systems • cost-effective collection and transport difficult due to low residue tons/acre • storage costs and risks due to short crop residue harvest window
Resource Availability	• lack of credible data on price, location, quantity, and quality of biomass • need for long-term fuel supply agreements
Sustainability Requirements	• potential loss in crop productivity, soil health and carbon levels with excessive residue removal-life cycle effects • insufficient information to predict environmental effects of residue removal

3.2.4 Technical Approach

A customer-driven roadmap for sustainable feedstock technology development was produced in FY 2003 through the joint efforts of feedstock research leaders at Idaho National Engineering & Environmental Laboratory (INEEL), Oak Ridge National Laboratory(ORNL), Department of Energy and USDA biomass staff, and key industry and producer stakeholders. This roadmap impacts the research agenda for the next 5 years particularly in the sustainability and engineering systems area. Major expected activities are planned to address emerging feedstock barriers, advanced feedstock barriers, and feedstock supply chain analysis.

Emerging feedstock barriers - National laboratories will collaborate with equipment manufacturers to design and test innovative collection, handling, and transport equipment. Research will focus on developing a one-step harvesting system with crop component separation capability. The near-term emphasis will be on agricultural residues, primarily corn stover and small grains. The overall objective is to reduce the current costs of agricultural residue collection, pre-processing, storage and transport systems and produce higher quality feedstocks. OBP partners will also develop a supply logistics system model useful for techno-economic analysis and supply systems optimization.

Storage and transport issues will be addressed by evaluating and developing moisture control and densification technologies most appropriate for the types of biorefinery systems being developed and the regions where they will be implemented. In the near term, proposed operational modifications could reduce delivered costs by 10 to 20 percent, compared to baseline estimates.

Advanced feedstock barriers - Several projects are ongoing to explore and improve the commercial viability of various biomass energy feedstocks, including hybrid poplars, native flora, willow harvesting, and switchgrass. These projects address barriers unique to the harvesting, storage, collection, transport and use of the individual feedstock..

Feedstock supply chain analysis- To address uncertainties in biomass feedstock availability and biomass markets, activities will be conducted to develop high quality, credible, accessible information on the location, price, quantity, and quality of all types of biomass resources in the U.S. based on crop and forest data, sustainability constraints, and supply logistics. Included in this effort is the development of modeling tools that predict potential location, price, and quantity of new biomass crops that consider competitive demands for biomass resources.

Work will also be conducted to develop and document a vision for achieving an annual biomass supply of 1 billion dry tons under $35/ton, identifying the feedstock handling and agaricultural production changes that will be needed to support a biorefinery industry.

3.2.5 Key Milestones for Biomass Feedstock Interface R&D

Key milestones for sustainable feedstocks are shown in Table 3-2.

Table 3-2. Milestones for Biomass Feedstock Interface R&D

Barrier	FY 03-04	FY 04-05	FY 06-08
Emerging Feedstock Barrier R&D	• Create preliminary design for modified/new equipment to harvest, handle and store wheat straw stems	• Successfully demonstrate prototype dry storage system • Complete feedstock testing for combustion and straw-thermoplastic composites	• Successfully demonstrate multi-component selective harvesting system • Satisfactory prototype field testing of bulk collection and wet storage systems
Advanced Feedstock Barrier R&D	• Establish permanent harvesting operations for willow harvesting • Finalize permanent installation for switchgrass-to-energy generation	• Conduct research on technical and economic feasibility of developing a cellulosic ethanol industry moving from Minnesota into North and South Dakota • Complete market development issues to support commercial use of switch-to-energy facility	
Feedstock Supply Chain Analysis	• Complete national biomass vision with USDA and others • For supply system logistics, develop and validate models describing processes and operational data; implement model using specific soils, climate and weather information for planned biorefineries	• Complete supply-cost database for existing biomass feedstocks (national forest residues) • Develop vision for achieving biomass supply of 1 billion dry tons under $35/ton • Develop regional feedstock transportation cost estimates • Assist in development of a life cycle assessment of biohydrogen	• Complete supply-cost database for energy crops • Publish advanced technology forecast for agricultural residues

3.3 The Sugar Platform

The sugar platform involves the breakdown of biomass into component sugars by a range of chemical and biological processes. As shown in Figure 3-2, biomass is first subjected to pretreatment to hydrolyze the hemicellulose and expose the cellulose to attack by enzymes, a process that produces an intermediate (C5) sugar stream. The cellulose then undergoes enzymatic hydrolysis to produce glucose, which can be converted to fuels or chemicals. Residues are separated and used for power or other products.

Today's industrial sugar platforms exist in the corn processing industry (wet and corn dry mill operations). In these operations, the starch in corn grain is the feedstock that is hydrolyzed to release glucose for production of fuel ethanol and other chemicals.

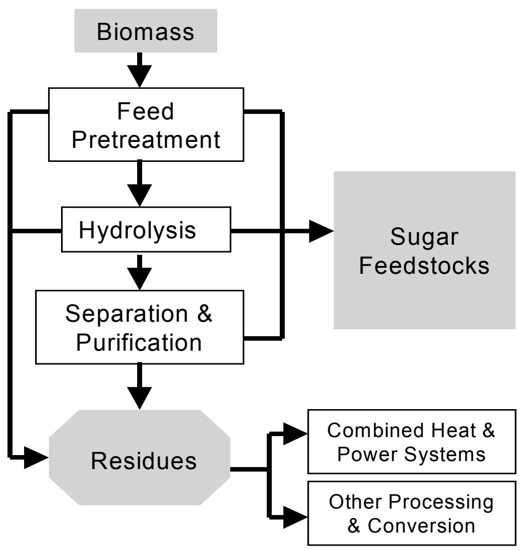

Figure 3-2 Platform for Conversion of Biomass into Sugars

The existing two-billion gallon per year fuel ethanol industry can serve as the basis for the next generation of technology for creating products from sugars. This expansion will require a shift toward new, inexpensive, non-traditional biomass feedstocks to open up new markets for sugar-derived products and facilitate the growth of the bioindustry.

Corn stover, for example, represents a large, accessible, lower cost source of sugars. The delivered cost of sugars from corn grain currently used to produce ethanol is around 5.5 cents per pound (corn price of $2/bushel). By contrast, the delivered cost of sugars available in corn stover (price of $35/ton) is only about 3 cents per pound[4].

New technologies will be needed to cost-effectively convert stover and other biomass feedstocks to sugars. As outlined in the remainder of this plan, OBP's role in technology development and deployment for this platform will be to conduct advanced R&D in feedstock pretreatment and enzymatic hydrolysis of sugars, with an initial emphasis on corn stover.

3.3.1 Programmatic Objectives

The overall objective for the sugar platform is to develop the capability for using lignocellulosic biomass to produce sugar feedstocks for fuels and other chemicals and materials in the biorefinery. A specific technical goal is to

reduce the cost of the sugar feedstock stream suitable for fermenation from the 2003 estimated cost of $0.14 per lb to $0.07 per lb by 2010.

3.3.2 Status of Sugar Platform Technology

Enzyme hydrolysis of starch from corn grain - The existing grain processing industry is based primarily on the conversion of starch in corn grain to sugar, ethanol and other products. In its early days, this industry hydrolyzed starch to produce glucose using acid hydrolysis. Today, acid technology has been replaced by enzymes (biocatalysts) that can hydrolyze glucose from starch much more efficiently and cost effectively. However, modern grain ethanol plants are approaching the limits of their potential yield of ethanol from corn starch. At the same time, these plants have achieved much greater energy efficiency.

Enzyme hydrolysis of lignocellulosic biomass - The DOE has supported R&D to convert lignocellulosic biomass into sugars for more than 20 years. As with corn grain to ethanol technology, biomass conversion has shifted from the use of acid technology to the use of enzymes (cellulases) to hydrolyze cellulose to glucose, coupled with some form of acid pretreatment to release hemicellulosic sugars. R&D has contributed to approximately ten-fold improvements in the cost and effectiveness of cellulase enzymes. However, cellulase enzymes remain a significant portion of the project production cost of sugars from lignocellulosic biomass. Reducing the cost of enzymatic hydrolysis depends on lower cost enzyme production technologies along with more efficient enzyme preparations and enzyme hydrolysis regimes.

Pretreatment - Thermochemical prehydrolysis of biomass, typically referred to as pretreatment, is key to successful conversion of biomass to sugars. Thermal and chemical pretreatment methods include autohydrolysis, steam explosion, acid prehydrolysis, organosolv pretreatment, and others. The goal of these processes is to solubilize the hemicellulose and in some cases, a portion of the lignin, in order to exposes the cellulose and makes it more susceptible to enzymatic hydrolysis. In the near term, lower cost pretreatment depends on the ability to process the biomass at high solids levels.

3.3.3 Technical Barriers

The technical barriers to the biomass to sugar platform range from insufficient knowledge of fundamental chemistries to equipment design and construction (see Table 3-3).

Pretreatment of biomass - Some form of pretreatment is required to open up the structure of biomass to allow efficient enzyme hydrolysis of the cellulose, which is protected by a sheath of lignin and hemicellulose. Advances in pretreatment technology are needed to improve the enzymatic digestibility of biomass and facilitate downstream processing into sugars. This will require better understanding of pretreatment chemistries, as well as new, more reliable reactor and equipment design.

Enzymatic hydrolysis - Current enzyme hydrolysis is limited by the low activity of the biocatalyst and resulting high costs of production. A new generation of enzymes for hydrolyzing cellulose to glucose will provide significant cost-reductions in the cost of production for ethanol, and enable expansion of the industry into new commodity-scale products based on sugars.

Process integration - Beyond the core steps of pretreatment and enzymatic hydrolysis, process integration remains a key barrier to the sugar platform. The lack of quality performance data on integrated processes at commercial scale presents risks for scale-up. Process integration work is needed to characterize the complex interactions between processing steps, and to identify separation requirements, bottlenecks and knowledge gaps.

Fundamental knowledge - Understanding the root causes of recalcitrance (resistance of biomass to chemical or biological degradation) remains a barrier to achieving aggressive performance improvements.

Table 3-3. Sugar Platform Technical Barriers

Processing Area	Key Technical Barriers
Pretreatment	Lack of fundamental understanding of • chemistry/biochemistry at work in pretreatment of biomass and the hydrolysis of hemicellulose • impact of biomass structure on pretreatment • physio-chemical causes of recalcitrance • cost of pretreatment options • reactor design fundamentals
Enzymatic Hydrolysis	• low specific activity of current commercial enzymes • high cost of cellulase enzymes • Costly enzyme production • lack of understanding of enzyme biochemistry • knowledge of mechanistic fundamentals
Process Integration	• lack of performance data on integrated processes to support scale-up • inadequate understanding of interactions between process steps
Fundamental Knowledge	• inadequate understanding of biomass structure and its impacts on recalcitrance

3.3.4 Technical Approach

Sugar platform core R&D in pretreatment, enzyme hydrolysis, process integration, and fundamental concepts is conducted in parallel with the development and demonstration of new technology in existing and emerging biorefineries. Sugar platform R&D addresses fundamental scientific and engineering barriers such as biomass recalcitrance, development of new tools for technology development, and development and evaluation of new process concepts.

Pretreatment - The emphasis of pretreatment work is on evaluation of and improvements to leading pretreatment concepts. The program leverages the work of the Biomass Refining Consortium on Applied Fundamentals and Innovation (CAFI), a group of pretreatment researchers funded by the USDA and recently selected for continued funding through a joint USDA/DOE solicitation.

Technoeconomic evaluations will be conducted to enable industry partners to review the most promising concepts for pretreatment for commercial demonstration in emerging sugar biorefineries. The program will also seek opportunities to explore evaluation of near-term pretreatment technologies in existing corn grain dry mills. Pretreatment options specific to lignocellulose biomass, and the effects of storage and preprocessing on pretreatment and enzymatic processing will also be explored.

Enzymatic hydrolysis - The focus of activities in this area will be on the development and deployment of new enzyme technology for conversion of corn fiber to ethanol in existing corn dry mills. Corn fiber is a captive cellulose source in existing ethanol plants, and these plants can serve as the test beds for new hydrolysis technology.

Research will focus on development of the next generation of enzymes tailored to provide high yields of sugars from corn stover feedstock. These enzymes will enable the development of the first lignocellulosic biorefineries. This research is expected to lower costs for producing enzymes and increase the potential limits of improvement possible in enzyme performance. Research will also improve fundamental understanding of the enyzmatic process through characterization of the cellulase function and cellulase-cellulose interaction.

Process integration - Activities will focus on integrating enzymatic hydrolysis process technology based on dilute acid pretreatment. The objective is to complete a limited pilot scale demonstration of integrating processing and us the performance data obtained to validate economic model assumptions. The program will also evaluate the factor underlying corn stover composition variability, with the objective of minimizing or exploiting this variability in the integrated biorefinery.

Fundamental and new concepts - The objective of R&D in this area is to develop a more fundamental understanding of the factors and causes underlying the recalcitrance of biomass to biological and chemical degradation. Embodied in this work is the development of enabling tools such as molecular modeling and more accurate chemical and structural analysis techniques for characterizing biomass at various stages during processing.

3.2.6 Key Milestones for the Sugar Platform

Key milestones for the sugar platform are shown in Table 3-4.

Table 3-4. Key Milestones for the Sugar Platform

Processing Area	FY 03-04	FY 04-05	FY 06-08
Pretreatment		• Comparative evaluation of AFEX and dilute acid/hot water pretreatment of corn fiber	• Technical review of pretreatment options
Enzymatic Hydrolysis	• Enzyme subcontracts achieve overall ten-fold cost improvement targets for cellulase in ethanol production	• Industry partnership research on 25-fold improved enzymes • Stage gate decisions on 25-fold improved enzyme R&D	• Industry partnership research on 50-fold improved enzymes
Integration		• Validate combustion of process residues for heat and power	• Demonstrate 24/7 integrated processing for one week (pretreatment, saccharification, and fermentation)
Fundamental and New Concepts	• Proof of concept for consolidated bioprocessing via heterologous cellulase expression	• Determine whether non-cellulase enzymes can reduce pretreatment severity	• Achieve better understanding of physical, chemical and ultrastructural features of corn plants that affect process performance • Understand effects of temperature on cellulases, cellulose and their interactions

3.4 The Thermochemical Platform

The thermochemical platform involves the use of elevated temperatures to convert biomass or biomass-derived biorefinery residues to intermediates that may be used directly as raw fuels or products, or that may be further refined to fuels and chemicals that are comparable to existing commercial commodity products. Intermediate products include synthesis gas (syngas), pyrolysis oil, hydrothermal oils, and gases rich in hydrogen or methane. These products can be used directly for heat and power generation, or may be upgraded to products such as gasoline, diesel, alchohols, olefins, oxochemicals, synthetic natural gas, or high-purity hydrogen. The generalized components of the thermochemical platform are shown in Figure 3-3.

Major thermochemical processes include gasification and pyrolysis, which both involve the conversion of solid or liquid organic matter to gases, organic vapors, water and residual solids at elevated temperatures. The primary product of pyrolysis is a liquid (pyrolysis oil), while gasification, which takes place at higher temperatures, produces mostly gases. A third alternative is hydrothermal processing with excess amounts of water and/or organic solvents at moderate temperatures. Hydrothermal processing in the presence of a catalyst produces mostly methane or hydrogen and is referred to as wet gasification.

An advantage of thermochemical conversion is that it can, in principle, convert nearly all the biomass feedstock into fuels and products, even those components that are difficult to process by chemical or biological means, such as residues. Thermochemical conversion provides a means to optimize biorefinery operations by utilizing residues or waste streams that might otherwise be landfilled or used for low-value products.

OBP will explore the potential use of gasification as a means of producing syngas, ensuring that technologies are compatible with the production of fuels and chemicals based on technologies currently available through the petroleum refining industry. Longer term efforts will ensure compatibility with advanced utilization technologies such as hydrogen fuel cells. Gasification-based combined heat and power systems will also be explored, including those using conventional biomass, biomass residues, and black liquor (a byproduct of wood pulping). Other thermochemical conversion processes such as pyrolysis and hydrothermal gasification will also be investigated for production of both fuels and products.

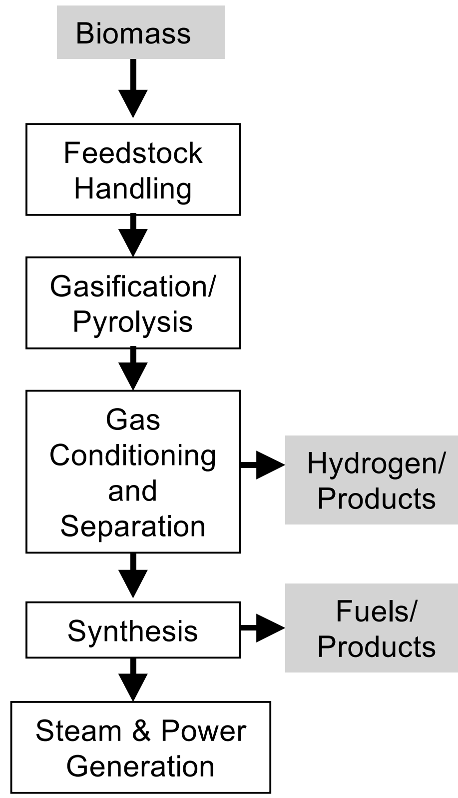

Figure 3-3 The Thermochemical Platform

3.4.1 Programmatic Objectives

The overall objective of the thermochemical platform is to reduce dependence on foreign oil and to stimulate the rural economy by using thermal processing to produce fuels,chemicals, hydrogen, and heat and power from a range of biomass feedstocks.

3.4.2 Status of Thermochemical Platform Technology

Biomass gasification technologies have been a subject of commercial interest for several decades. Interest in biomass gasification increased substantially in the 1970s because of uncertainties in petroleum supplies, with most of the development occurring in small scale systems. Low-energy gasifiers are now commercially available, and dozens of small-scale facilities are in operation.

In the 1980s, government and private industry sponsored R&D for large scale, medium-energy gasifier systems, primarily to gain a better understanding of reaction chemistry and scale-up issues. In the 1990s combined heat and power was identified as a potential near-term opportunity for biomass gasification because of incentives and favorable power market drivers. R&D concentrated on integrated gasification combined cycle (IGCC) and gasification co-firing demonstrations, which culminated in a number of commercial-scale systems. In the U.S. projects have been undertaken to process very recalcitrant feeds such as bagasse and alfalfa.

Black liquor gasification has many potential advantages in pulp mills, either as a replacement or supplement for the current Tomlinson recovery boiler. The pulp and paper industry's interest in gasification as an alternative to Tomlinson recovery boilers has peaked in recent years as the industry will need to replace a large number of aging recovery boilers over the next 10-15 years.

However, there are serious technical challenges still left to be resolved before gasification technology can be successfully integrated into operating commercial pulp mills. Currently, there are only a few technology developers that are actively pursuing commercialization of black liquor gasification technology. These developers have conducted a number of pilot-scale tests which have laid the groundwork for full-scale commercial demonstration efforts.

OBP is currently co-funding a series of commercial demonstrations and technology support projects designed to accelerate the commercial viability of gasification as a replacement to Tomlinson recovery boilers.

3.4.3 Technical Barriers

Technical barriers emerging from decades of development and more recent vision and roadmap activities include gas clean-up, containment, and process control (see Table 3-5).

Gas cleanup - The raw gases from biomass systems do not meet strict quality standards for downstream catalysts as well as some power technologies (fuel cells or fuel cell/turbine hybrids), and will require gas cleaning and conditioning to remove contaminants (tar, particulates, alkali, ammonia, chlorine, sulfur).

Containment (materials of construction) - Experience with black liquor gasifiers has shown that the reactions are difficult to contain, and long-term and economically acceptable approaches are yet to developed. Solutions involve metals for reactor shells and internals, refractories to line containment vessels, vessel design, and increased knowledge of bed behavior and agglomeration.

Process control and optimization - Effective process control will be needed to maintain gasifier performance and emissions at target levels with varying load, fuel properties, and atmospheric conditions. Validated computational fluid dynamic models and rugged sensor systems are two important challenges in this area.

Black liquor gasification - Commercialization of black liquor gasification technology has been hindered by issues of feed pretreatment, gas cleanup, containment, process control, and integration of operations within the mill (steam, power, pulping, recovery of pulping chemicals).

Table 3-5. Technical Barriers to Production of Syngas From Biomass

Processing Area	Key Technical Barriers
Feed Processing and Handling	• non-uniform feed, inadequate feed preparation, storage and handling
Thermo-chemical Processing	• lack of demonstrated gasifiers suitable for integration with fuel synthesis or hydrogen production • lack of methods for converting wet residues to energy-related products • lack of smaller syngas to synfuels catalytic conversion processes for distributed refineries
Gas Clean-Up	• syngas quality does not meet specifications for multiple uses due to chemical contaminants, tar formation, particulates • unproven gas cleanup and conditioning technologies for biomass syngas systems
Sensors and Controls	• inadequate control technology for gasifier systems and subsystems
Containment	• lack of economically feasible, reliable materials of construction and refractories for gasifier vessels

3.4.4 Technical Approach

To facilitate the development of advanced thermochemical conversion systems, OBP will conduct advanced R&D to address the technical barriers shown in Table 3-5.

Feed processing and handling - The objective of this work will be to improve the integration of biomass feedstock harvesting and supply issues with in-biorefinery issues such as feed preparation, storage and drying. OBP will conduct R&D in collaboration with industry to ensure appropriate biomass feeder systems are available.

Thermal processing - Working with industry, OBP will conduct R&D on advanced gasification technologies to develop more efficient, cleaner systems for a wide variety of biomass feedstocks.

R&D will include fundamental gasification studies, process modeling, and similar work to identify opportunities for technology improvements. Partners will include national laboratories, universities, and others, and will build on the base of information developed over two decades by the EERE Biomass Power and Black Liquor Gasification programs. R&D will also be conducted to explore materials of construction and refractories for black liquor gasifiers.

Other activities will include resolving technical questions related to operability and reliability of biomass and black-liquor gasification systems. The focus will be on addressing key barriers and fundamental information needs. Other thermal processes, such as pyrolysis, will also be evaluated to determine relative merit.

Gas cleaning and treatment - Significant efforts in gas cleaning and treatment will be required to integrate with advanced and next-generation syngas end-use technologies. OBP will work with the national laboratories, universities, and industrial partners to develop and evaluate advanced concepts in particulate removal and catalytic conversion of problematic syngas components. Activities will include

- analysis of hot gas particulate removal
- examining use of catalytic tar reforming crackers in biomass gasification streams
- analysis of gas conditioning with catalysts on a larger scale
- evaluating the chemistry and kinetics of biomass gasifier tar formation and maturation
- evaluation of advanced desulfurization adsorbents

OBP is evaluating advanced concepts for particulate and tar removal in existing gasification test-bed facilities, and is exploring new thermal and catalytic removal and treatment technologies and materials. Research is expected to improve gas treatment system performance. Efforts will include gasification of conventional biomass and biomass residues as well as black liquor.

Sensors and controls – Activities in this are will faciliate development of sensors and controls needed for syngas systems. Projects include better monitoring for biomass feed systems, and sensing of gas impurities. The ultimate objective is to improve the operability and reliability of biorefineries.

3.4.6 Key Milestones for the Thermochemical Platform

Key milestones for the thermochemical platform are shown in Table 3-6.

Table 3-6. Key Milestones for the Thermochemical Platform

Processing Area	FY 03-04	FY 04-05	FY 06-07
Feed Processing and Handling	• Define the characteristics of commercial feeders	• Issue solicitation for feeder development	• Complete testing of feeders and feed improvement systems
Thermochemical Processing	• Issue high efficiency gasifier solicitation • Issue solicitation for feasiblity studies of innovative gasifier opportunities in distributed biorefineries • Select and investigate suitable refractories for black liquor gasifiers	• Complete design and construction of gasification research center • Complete tests and submit materials for industrial trials	• Complete development of one gasifier suitable for hydrogen, fuels, or chemical production
Gas Cleanup	• Determine gas treatment needs based on target fuels, chemicals and CHP systems. • Resolve tar issues through integrated testing of candidate materials, catalysts, and technologies at appropriate scales.	• Demonstrate technology to achieve greater than 95% removal of <5 micron solids • Complete black liquor gasifier with hot gas cleanup process flow concept for commercial integration into paper mill	• Complete condensing and non-condensing gas cleanup studies • Complete testing to identify catalyst for use in full-stream reformer • Develop fluidizable tar reforming catalysts and supports
Sensors and Controls	• Solicitation for feed sensors		• Complete development of real-time feed sensor • Complete development of on-line alkali monitor

3.5 Products

The sugar and thermochemical platforms will provide the basic inputs for downstream conversion into products in the biorefinery – fuels, high-value chemical products, and heat and power.

As shown in Figure 3-4, products take three forms: fuels, chemicals and materials, and heat and power. Within each category a diversity of products can be derived from platform outputs. Most of these products are manufactured today from fossil energy resources such as petroleum or natural gas. Using biomass to create these products provides an alternative to the use of fossil energy, and ultimately reduces our dependence on imported oil and gas. In addition, these products are critical to our everyday lives. They not only fuel our vehicles, but are used to create a myriad of consumer goods such as plastics, paints, pharmaceuticals, and detergents.

Outputs from the sugar and thermochemical platforms vary widely depending on the source of the biomass and the processes used to isolate different components (see Table 3-7). To optimize the profitability and economic viability of the biorefinery, utilization of all platform outputs is necessary. Products R&D will emphasize value-added products that utilize all components of the biomass feedstock, while minimizing environmental impacts and effectively integrating heat and power requirements within the biorefinery.

Producing fuels, chemicals, materials, and power in the biorefinery should reduce overall production costs and increase commercial viability. Similar to the petroleum refinery, much of the feedstock is expected to be consumed in the production of commodity-scale fuels, while biobased chemicals and materials will make up a smaller, but more higher-valued product stream. Onsite generated heat and power will improve processing efficiency and generate a source of electricity that could be exported to the local grid.

Products R&D will focus primarily on products derived from the sugar and thermochemical platforms. In addition, other components such as oils and plant extractives will be explored.

Table 3-7 Typical Platform Outputs

Sugar Platform	6 carbon sugars 5 carbon sugars lignin/ash extractives protein
Thermochemical Platform	Gases (CO, CO_2, H_2, H_2O, CH_4)

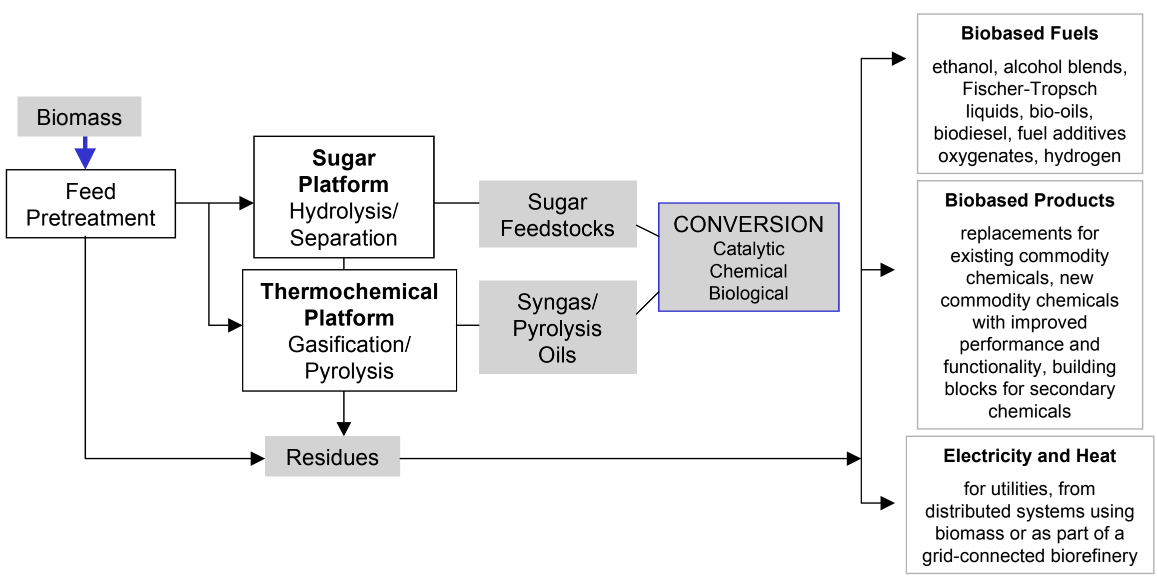

Figure 3-4 Products from the Sugar and Thermochemical Platforms

3.5.1 Programmatic Objectives

The overall objective of products R&D is to support the EERE goals of reducing dependence on foreign oil and creating a new, domestic bioindustry. Specific objectives include :

By 2010 develop technology that allows for production of ethanol at a cost of 1.32 $/gallon from 0.07 $/lb sugars.

By 2010 establish the industrial viability of four commodity-scale chemicals or materials co-produced in an integrated biorefinery.

3.5.2 Status of Technologies for Bio-derived Products

Biobased fuels - Production of ethanol from high quality glucose (C6 sugar, or six carbon sugar) streams is a a well-developed industry. Today's corn wet mills are home to a two billion gallon per year fuel ethanol industry, which is based on fermentation of C6 sugars. However, there are still many barriers to be overcome in the production of fuel-grade ethanol from less expensive lignocellulosic mixed sugar streams.

Production of Fischer-Tropsch liquids from clean natural gas-derived syngas is a well-developed technology. However, the production of Fischer-Tropsch liquids from complex, biomass-derived syngas is not yet commercially viable due to the problems presented by tars and impurities.

Biooils can be produced at low cost and used directly for some fuel applications or upgraded into more valuable products. R&D is needed to explore viable upgrading processes. Production of biodiesel from oilseeds and animal byproducts is a well-developed technology. However, to increase production volumes for biodiesel will require new value-added uses for the glycerol that is generated as a byproduct.

Biobased Chemicals and Materials - Today's corn wet mills use a multi-step process to produce starch, corn germ, corn oil and glucose, which is then converted into a industrial products in addition to fuel ethanol, food and feed. Manufacture of these industrial products, which include citric acid, sorbitol, and starch adhesives, paper additives, and coatings, is relatively mature with well-established markets. In addition to corn products, there are a wide variety of consumer products that are manufactured at least in part from biomass sources (soy beans, rapeseed, mint, soft woods), such as solvents, cleaners, adhesives, surfactants, inks, paints, and pharmaceuticals.

Technological advances are beginning to reduce the cost of producing products and fuels from biomass, making them more competitive with those produced from petroleum-based hydrocarbons. In the chemicals area, derivatives of glucose sugars hold the most initial promise, including lactic acid, succinic acid, butanol, 1-3- propanediol, others).

Pentose or C5 sugars such as xylose are so far an untapped resource. There is active research today to develop microorganisms that utilize pentose sugars alone or in combination with glucose, with the objective of enabling greater utilization of the available biomass and improving the economics of biobased products.

The petroleum and petrochemical industries have developed first generation commercial catalytic processes for conversion of fossil-based syngas to fuels and chemicals. Examples include methanol-to-gas, methanol synthesis, ethanol via modified Fischer-Tropsch synthesis, mixed alcohol synthesis, hydrocarbon fuels, and hydrogen. The source of syngas for these processes is primarily steam reforming of natural gas, but naphtha reforming and coal gasification are also used.

Heat and power generation - Biopower is a commercially proven electricity generating option in the United States. The next generation of stand-alone biopower production will substantially mitigate high costs and efficiency disadvantages through coal-biomass cofiring, high-efficiency gasification combined cycle systems, and efficiency improvements in direct combustion systems. Technologies presently at the R&D stage, such as integrated gasification fuel cell systems, and modular systems are expected to be competitive in the future.

3.5.3 Technical Barriers

Technical barriers associated with biological and chemical processes for conversion to fuels and products are shown in Table 3-8.

Fermentation - Organisms exist today that have been genetically engineered to ferment the five and six carbon sugars found in biomass, but significant research challenges remain. The availability of biocatalytic organisms for producing fuels and chemicals remains deficient when compared with petrochemical catalysts.

Chemical Catalysis - The development of catalysts for converting sugars into higher value products is in its infancy when compared to today's petrochemical counterparts. Fundamental research will be needed to support development of new catalysts for hydrogenation of sugars and oils, as well as oxidation, dehydration, and selective bond cleavage. Catalyst selectivity and contamination are barriers to future use of syngas for products.

Biocatalysis - Barriers to the use of biocatalysts for productions of fuels and chemicals include a need for low-cost biocatalysts, a lack of understanding of hybrid chemical/biological process, long development times, and limited use of biocatalysts in chemical processing. Fundamental barriers include poor interface with organic solvent systems, and stability in extreme environments.

Separations - Integration of fermentation and catalytic processes faces the challenges above as well as the issue of separations. In both chemical and biological processing, byproducts are an issue. Most fermentation products contain impurities such as protein, amino acids, which can lead to rapid catalyst deactivation. Improved catalyst lifetimes via improved catalyst or purification methods will need to be developed to ensure cost-effective separation of product streams.

Table 3-8 Technical Barriers to Utilization of Sugars and Syngas for Fuels, Products and Power

Processing Area	Barrier
Fermentation	• lack of organisms with the facility to handle all five biomass sugars at relevant process conditions • robustness of microbes for demanding industrial conditions of low pH and high temperature • inadequate tolerance of organisms to high product concentrations, especially for solvents such as acetone, butanol and ethanol • lack of fundamental understanding of behavior in extreme environments, of two-phase systems, and non-aqueous phase milieu
Chemical Catalysis	• lack of homogeneous and heterogeneous chemical catalysts for conversion of biomass feedstocks into chemicals and fuels (hydrogenation of sugars and oils, mild oxidation, acid catalysts for dehydration, hydrogenolysis for conversion of alcohol sugars) • insufficient knowledge of mass transfer, adsorption and desorption properties • limited catalyst lifetimes, selectivity, weight hourly space velocity, and catalyst recovery • insufficient understanding of the formation and destruction of tars • impurities that can cause rapid catalyst deactivation • lack of methods for improving catalyst lifetimes in aqueous systems
Biocatalysis	• limited low-cost biocatalysts • lack of understanding of hybrid chemical/biological processes • long development times for new biocatalysts
Separations	• inadequate separation processes for byproducts or nutrient components • insufficient analytical tools and sensors for process development and control • lack of fundamental characterization of biomass feedstocks and interactions between biomass substrates and enzymes and catalysts at the molecular level

3.5.4 Technical Approach

The products R&D approach has two elements. The first involves highly leveraged interactions with industry that are cost-shared and include a team of partners. The focus is on integrated processing for the biorefinery, with the objective of validating processes for fuels and value-added products. Projects conducted under this first strategy will be developing and demonstrating biobased products for integrated biorefineries and for specific commercial markets.

The second incorporates cross-cutting R&D to address technical barriers and increase the fundamental understanding needed to successfully develop new products. The emphasis of the second element is on prioritizing requirements for the different platforms and ensuring all platform outputs are efficiently utilized. Projects conducted under this strategy will develop the fundamental knowledge needed to overcome technical barriers that are common to many processes used to produce bioproducts.

Activities are conducted in biobased fuels for transportation, biobased products for chemicals and materials, and heat and power. Supporting activities in analysis are also conducted, with an emphasis on specific technology development.

Biobased fuels - OBP will conduct advanced R&D to enable the cost-effective conversion of mixed sugar streams (as many as five sugars) to fuels and other products. This research could increase ethanol yields by 10-20 percent through the full use of carbohydrates found in residues such as corn fiber.

R&D will also be conducted to evaluate catalysts for the destruction of tars and other impurities contained in biomass-derived syngas, and to evaluate commercially available catalysts to determine their viability for use of biomass-derived syngas of variable quality. Other research will focus on upgrading of biooils, and new value-added uses for glycerin or fatty acid residues, which are byproducts of biodiesel production.

Biobased Chemicals and Materials - Strategy one projects will focus on feedstocks and technologies that are nearer to commercialization, such as those that use relatively clean sugars, and more valuable thermochemical outputs and oil crops. Under strategy two, major barriers - improved fermentation and catalysts for sugar conversion - identified through a “top ten” analysis will be the initial focus of R&D. Projects will focus on the more complex, less attractive biomass components, such as lignin, protein and char.

Research will be conducted to explore new catalytic systems for producing value-added products from sugars. The objective is a suite of catalysts suitable for a range of processing conditions, and new, flexible chemical platforms that are suitable for a diversity of applications. Fermentation research is expected to yield more robust organisms suitable for fermentation of biomass sugars in streams with a range of purity (very clean to contaminated) and process conditions (high temperature, salts, inhibitors).

Combined Heat and Power (CHP) - Products R&D will be designed to effectively integrate heat and power requirements in the biorefinery while optimizing use of the biomass feedstock. Combined heat and power systems offer the potential to improve processing energy efficiency and overall biorefinery economics, while providing a potential source of revenue if excess electricity is exported to the grid.

Analysis - Analysis efforts are cross-cutting and support the entire products R&D area. A key activity will be to identify the products that will best meet EERE goals for reducing dependence on foreign oil and creating a new domestic bioindustry. Targeted product markets are those with the potential for larger volumes (greater than one billion pounds). The first planned study is limited to products from sugar and syngas.

3.5.5 Key Milestones for Products

Key milestones for products R&D are shown in Table 3-9. Additional milestones will be added as analysis of product opportunities progresses.

Table 3.9 Key Milestones for Products			
Processing Area	**FY 03-04**	**FY 04-05**	**FY 06-07**
Biobased Fuels	• Demonstrate arabinose anaerobic fermentation in a yeast • Place a competitive subcontract for a metabolic model of *s. cerevisiae* • Comprehensive report describing R&D opportunities for products from fatty acids and glycerin to help guide future platform R&D	• Develop commercial product yield, production in yeast fermentation of arabinose.	• Integrate arabinose fermentation with best available xylose fermentation in yeast • Evaluate predictions for genetic engineering of *s. cerevisiae* to improve a key parameter of ethanol fermentation • Demonstrate synthesis of methanol and mixed alcohols using biomass-derived syngas • Demonstrate microchannel reactor for FT gasoline
Biobased Chemicals and Materials	• Improve xylose to lactose fermentation • Complete technical feasibility of bio-oil coproducts • Perform wood-based natural resin and bark adhesive comparisons • Establish feasibility of making polyols from soy oil • Identify and sequence genes of sorghum, and links between genes and grain composition • Identify potential portfolio of products from sorghum • Complete top ten analysis (products and barriers)	• Construct xylose to lactose fermenting microorganisms • Completion of catalyst evaluation unit suitable for integration with syngas production systems • Establish feasibility of making polycarboxylic acid from soy oil • Develop PHA co-polymers	• Create tools for genetic engineering of most promising strains of xylose to lactose fermenting microorganisms • Establish technical and commercial feasibility for polymer building blocks from vegetable oils • Develop optimized recovery processes for PHA • Investigate applications for PHA
Combined Heat and Power	• Complete baseline testing of SOFE on natural gas and bottled syngas • Complete microturbine testing on reformed syngas	• Complete integrated TCPDU-SOFC testing	• Complete SOFC scale-up and integration into thermochemical platform

3.6 Integrated Biorefineries

In theory, any industrial facility that uses biomass to make more than one product is a biorefinery (see Figure 3-5). This simple definition captures a range of existing, emerging and advanced biorefinery concepts.

Much like a petroleum refinery, the biorefinery of the future will produce fuels as its largest volume product. However, the key to profitability will lie in production of a small percentage of high-value chemical products. The biorefinery will also need to optimize its product slate of fuels, power and chemicals to yield the greatest return.

The integrated biorefineries activities conducted by OBP support the notion that the biorefinery's slate of fuels and chemicals should maximize the value of the biomass and ultimately financial returns. The integrated biorefinery is the central strategy for the Biomass Program, and the R&D conducted in feedstocks, sugar and thermochemical conversion, and products all feed into this concept.

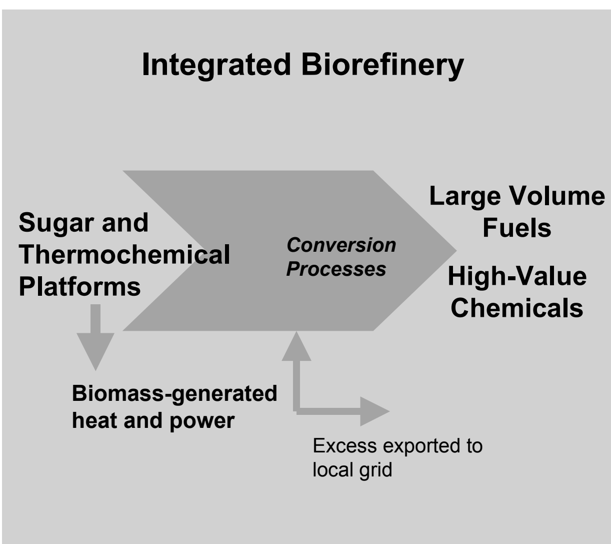

Figure 3-5 Integrated Biorefinery

3.6.1 Programmatic Objectives

The overall goal of the integrated biorefinery program is to support the establishment of integrated biorefineries through partnerships with industry and academia. Specific objectives, which reflect four of the overarching goals for this MYPP, include

complete analysis of biorefinery options by 2004 to identify the most promising products;

complete technology development necessary to enable start-up of a biorefinery producing fuels, chemicals, and power by 2007;

demonstration of a fully-integrated black liquor gasification system for heat and power at a commercial pulp and paper mill by 2009; and

helping U.S. industry to establish the first large-scale sugar biorefinery based on agricultural residues by 2010.

3.6.2 Status of Integrated Biorefinery Technology

The biorefinery concept has already proven successful in the U.S. agricultural and food processing industries, where such facilities now produce food, feed, fiber, fuels, or chemicals. Large corn wet-milling plants, for example, are biorefineries that produce enzymes, lactic and citric acids, amino acids, and fuel ethanol from sugars derived from corn grain. The primary market for these products today is the food and feed industries. In some facilities, residues are used to provide heat and power for processing.

Pulp and paper mills are another example of existing biorefineries. In these facilities wood is converted into pulp for papermaking, and various byproducts are used to produce chemicals, fibers and plastics. Black liquor, a byproduct of the pulping process, is used in on-site cogeneration systems to meet a large share of electricity and steam requirements for the plant.

3.6.3 Technical Barriers

The barriers to core biorefinery technologies are largely being addressed by R&D conducted under the sugar and thermochemical platforms and products research. Technical barriers that are particular to the goal of demonstrating and deploying commercially successful biorefineries include

- the challenge of end-to-end, feed-to-product, process integration
- the inherent risks of pioneer technology

3.6.4 Technical Approach

The technical approach for integrated biorefineries is to address the issue of risk of deploying new technology by reducing the cost of the later stages of commercial development, particularly process development and commercial-scale demonstration. A number of projects in this area are cost-shared efforts to develop specific applications for using biomass.

In the interest of protecting the intellectual property rights of individual partners, core R&D is undertaken to provide information that is widely available to anyone interested in entering the bioindustry. The Program must carefully differentiate between defining research related to barriers that are general enough to support the industry needs, yet contribute significantly to overall risk reduction.

Activities encompass both improvements in existing biorefinery technology and the introduction of emerging technology in existing biorefineries. Analysis is conducted to support specific technology development opportunities.

Integrated Biorefinery Solicitation - In 2002 the OBP awarded funds to six major biorefinery development projects that are focused on new technologies for integrating the production of biomass-derived fuels and other products in a single facility. The emphasis is on using new or improved processes to derive products such as ethanol, 1,3 propandiol, polylactic acid, isosorbide, and various other chemicals. A synopsis of these projects is given in Table 3-10. Milestones for these projects will be developed over the next year.

Table 3-10 Integrated Biorefinery Project Awards for 2002
2nd Generation Dry Mill Biorefinery - Broin and Associates, Inc. of South Dakota will enhance the economics of existing ethanol dry mills by increasing ethanol yields and creating additional co-products. Broin estimates that its process will increase ethanol output at existing plants by approximately 10-20% by 2006.
New Biorefinery Platform Intermediate - Cargill, Inc. of Minnesota will develop a bio-based technology to produce a wide variety of products based on 3-HP acid, which is produced by the fermentation of carbohydrates.
Integrated Corn-based Bio Refinery (ICBR) - Delaware's E.I. du Pont de Nemours & Co., Inc. (DuPont) will build a bio-based production facility to convert corn and stover into fermentable sugars for production of value-added chemicals.
Making Industrial Bio-refining Happen - Based in Minnesota, Cargill Dow LLC National will develop and validate process technology and sustainable agricultural systems to economically produce sugars and chemicals such as lactic acid and ethanol.
Advanced Biorefining of Distiller's Grain and Corn Stover Blends - High Plains Corporation, with plants in Kansas, Nebraska and New Mexico, will develop a novel biomas technology to utilize biorefined distiller's frain and corn stover blends to achieve significantly higher ethanol yields while maintaining the protein feed value.
Separation of Corn Fiber and Conversion to Fuels and Chemicals - The National Corn Growers Association, based in Missouri, will develop an integrated process for recovery of the hemicellulose, protein, and oil components from corn fiber for conversion into value-added products.

Mill-scale validation activities are planned for a large black-liquor steam reforming gasification system in Big Island, Vermont, and another large biomass gasification system in Louisiana. Georgia-Pacific, Boise-Cascade, Gas Technology Institute (GTI), MTCI, several national laboratories (NETL, ANL, and ORNL), universities, A&E firms, and equipment suppliers are participating. The outcome will be two or more operating commercial-scale black liquor and biomass gasifiers with validated performance to support future implementation.

A number of projects are already underway to develop technologies for entirely new industrial bioproducts from corn-derived sugars, sorghum, and vegetable oils. The activities conducted range from fundamental research on new feedstock-specific catalysts to integration of new technology into the biorefinery. Products are diverse, ranging from corn- and oil-based polymers to chemicals such as malonic acid and isosorbide. Partners include national laboratories (NREL, ORNL, PNNL, SNL), individual chemicals, food and enzyme manufacturers, universities, and trade associations such as the Iowa Corn Promotion Board, United Soybean Board, and the National Corn Growers Association.

3.6.5 Key Milestones for Integrated Biorefineries

Key milestones for the Integrated Biorefinery area are shown in Table 3-11.

Table 3.11 Key Milestones for Integrated Biorefineries

Processing Area	FY 03-04	FY 04-05	FY 06-07
Emerging and Existing Sugar Biorefineries	• Achieve conversion of bran to value-added products in 2nd Generation Corn mill, and conduct economic evaluation • Identify enzyme technologies to increase ethanol yield (Abengoa) • Scout hydrolysis/cellulase screening and discovery (DuPont) • Complete pilot-plant engineering for xylose conversion (Cargill Dow)	• Complete bench scale improvements for increasing ethanol yield (Abengoa) • Develop pretreatment process, complete cellulase discovery and evolution (DuPont) • Develop 2nd generation strain for xylose conversion (Cargill Dow)	• Optimize catalyst for conversion of fermentation-derived 3-HP to acrylic acid (Cargill) • Pre-commercialization demonstration of biorefining of distillers grain and stover (Abengoa) • Optimize and scale-up pretreatment processes (DuPont) • Develop 3rd generation strain for sugar conversion (Cargill Dow)
Emerging and Existing Thermo-chemical Biorefineries	• Complete gasifier pilot unit testing and gas clean-up design (Mississippi Ethanol) • Complete site preparation and engineering for mixed waste biorefinery in Alabama (GTI) • Complete site preparation and engineering for mixed waste biorefinery in Colorado (Changing World Technologies)	• Optimize selection and performance of fermenting organisms (Mississippi Ethanol) • Complete site preparation and engineering for commerical TDP demonstration in Nevada (GTI) • Begin shakedown and plant operation for TDP in Alabama (GTI) • Begin shakedown and plant operation for mixed waste biorefineries	• Begin shakedown and plant operation for TDP in Nevada (GTI)
Alternative Biorefineries	• Complete engineering and design study and economic impact study, obtain contracts and permits for Black Belt Bioenergy Demo	• Complete project management plan for Black Belt Bioenergy	

4.0 Program Management

The OBP has the overall authority and responsibility for managing DOE research, development and demonstration activities relating to the use of renewable biomass for fuels, chemicals and power. In some cases, DOE field and operation offices as well as the national laboratories have responsibility for execution of contracts and other administrative actions.

The OBP will provide the overall strategy, policy, management, direction, and programmatic expertise necessary for a balanced program of research, development, testing, and evaluation that will catalyze the establishment of biomass technologies. Further, the OBP will build its investment portfolio on detailed market and technology analysis, in collaboration with leaders and technology experts from industry, academia, and the national laboratories and in union with the other programs within EERE.

The key characteristics of the management approach are:

- Structure that promotes clear lines of accountability and responsibility
- Cooperative partnerships to leverage the OBP investment
- Program integration functions that focus on overcoming barriers to success and identify strategies to achieve success most efficiently
- Analysis used to support decision-making throughout the Program
- Communication strategies and information sources that enable robust participation by all program stakeholders

4.1 Program Management Structure

The organizational structure providing R&D management for OBP is shown in Figure 4-1. The OBP is one of eleven programs residing within the Office of Energy Efficiency and Renewable Energy (EERE), and under the purview of the Assistant Secretary for EERE. Overall management responsibility for the program resides with the OBP Program Manager, who reports directly to the EERE Deputy

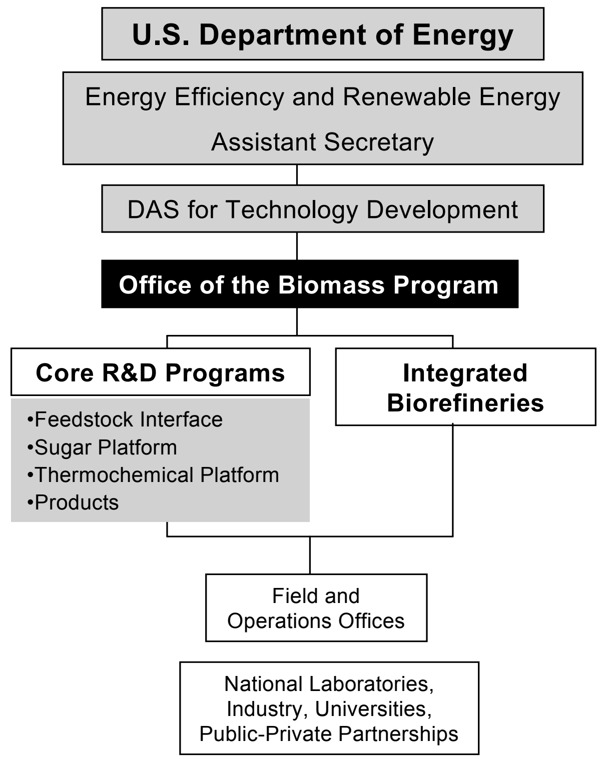

Figure 4-1 U.S. Department of Energy, Office of the Biomass Program Organization and Management Structure

Assistant Secretary (DAS) for Technology Development.

The OBP has created a strategic organization that fosters effective partnerships with its stakeholders in the public and private sectors. In keeping with the President's Management Agenda, and the EERE Strategic Review, the OBP has established a structure that focuses on program management and minimizes layers of authority, with the R&D goals as a centralizing theme. The respective capabilities of headquarters, field and operations offices, and national laboratories are utilized in a way that will optimize the strengths of these organizations and best ensure the success of the program.

Direct program management activities are conducted at DOE Headquarters, through DOE Field Offices and in the national laboratories.

4.1.1 Headquarters Management

The OBP is responsible for the routine operations of the office, as well as formulating strategic plans, justifying and allocating resources, establishing R&D and programmatic priorities and goals, and evaluating the performance of its programs. Overall program management is in keeping with the President's National Energy Policy, EERE's strategic plan and priorities, and the EERE strategic program review.

OBP implements agency policies and procedures, and reports on progress and activities to senior DOE organizational management. The office is also responsible for implementation of certain public laws (see Section 1-2). The Multiyear Program Plan, Multiyear Technical Plan, Annual Operating Plans and a Communications Plan provide the program management framework. Strategic planning occurs internally and is subject to review by appropriate panels.

Corporate communications are managed by the EERE Communications Office. Contract management and budget execution support is provided through the EERE Deputy Assistant Secretary for Business Administration, and through DOE operations and field offices.

4.1.2. Field Management

OBP contracts directly with the national laboratories, universities, and industry to conduct RD&D programs, and in some cases, delegates contracting and project management authority to DOE field offices and the national laboratories. The DOE Golden Field Office (GFO) supports OBP through field project management of R&D partnerships, laboratory contract administration, and a variety of professional, technical and administrative support functions. GFO is accountable for the funds expended under the NREL contract and those expended under grant programs administered through EERE regional offices.

The National Energy Technology Laboratory (NETL) manages research projects on behalf of OBP in the areas of black liquor gasification and biomass gasification in the forest products industry.

4.1.3 National Bioenergy Center

The National Bioenergy Center (NBC) was established in 2000 to unify all of the resources of the DOE national laboratories for producing fuels, chemicals, materials, and power from biomass. The NBC provides technical assistance and is responsible for managing core research activities. The NBC, under the leadership of NREL, includes R&D carried out at NREL, Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), Idaho National Environmental and Energy Laboratory (INEEL), and Argonne National Laboratory (ANL).

4.1.4 Intra-agency Coordination

Intra-agency interactions include other EERE Offices (Office of Industrial Technology, Hydrogen, Transportation, Power, States Energy Office, Federal Energy Management Program-FEMP). Biomaass is a near-term energy source for hydrogen, and the core R&D conducted in OBP directly supports the goals of the Hydrogen program. Research on renewable diesel and E-diesel is coordinated with the Freedom Car and Vehicle Technologies program.

OBP actively participates in the FEMP Biomass Deployment program - Buy Bio, and various weatherization and intergovernmental programs such as Clean Cities. OBP contributes to the EERE State Energy Program (SEP), which provides support to communities and states to extend energy-efficiency technologies and practices. OBP also contributes to the State Technologies Advancement Collaborative (STAC) program, which facilitates collaboration between States and the Federal government on energy R&D.

The OBP also interacts with the DOE Office of Science, and Office of Fossil Energy (FE). FE involvement in coal gasification and liquid fuels from syngas provide a basis for interactions with OBP. OBP also takes advantage of co-funding opportunities through other DOE initiatives such as Small Business Innovation Research (SBIR) and the science initiative.

4.2 Public-Private Partnerships

The OBP leverages the capabilities and experience of its diverse stakeholders through cooperative partnerships with other federal agencies, state and local governments, universities, and industry.

4.2.1 The Biomass R&D Board

The Biomass Act created the Biomass R&D Board (the Board) which is responsible for coordinating biomass activities across Federal agencies. This cabinet level board coordinates biomass R&D performed by the major Federal sponsors (DOE and USDA) and other relevant agencies (EPA, NSF, DOC/NIST, DOI/BLM, among others).

The Board coordinates programs within the Federal Government for the purpose of promoting the use of biomass. With its strategic planning, the Board seeks to guide the activities of various participating agencies in terms of Federal grants, loans, and assistance.

4.2.2 The Biomass Technical Advisory Committee

The Biomass Act of 2000 created the Biomass R&D Technical Advisory Committee, an advisory group to the Secretaries of Energy and Agriculture. The Committee includes 30 industrial experts, advises DOE/OBP on its technical focus and reviews and evaluates proposals. The Committee also facilitates partnerships among Federal and State agencies, producers, consumers, the research community, and other interested groups.

4.2.3 Collaboration with USDA

OBP works closely with USDA in a number of ways. The technology base for products and energy within the USDA is provided by the USDA/Agriculture Research Service (ARS) through programs conducted at the five USDA Regional Agricultural Utilization Laboratories and their partners. Similarly, the USDA/Forest Service has the Forest Products laboratories to address use and resource conservation, including forest management. Science for soil and water conservation is provided by USDA Soil Conservation laboratories. Figure 4-2 illustrates key USDA-DOE interactions and programs.

Figure 4-2 USDA-DOE Interactions

- ***Solicitations*** *- The Biomass R&D Initiative within the Farm Bill authorized USDA to spend $5M on bioenergy projects in FY02 and $14M annually for FY 2003 - 2007. USDA selected projects from the biorefinery selections made by DOE for the initial funding. Future joint solicitations are possible.*
- ***Joint research -*** *DOE laboratories, USDA Agricultural Research Centers and the Forest Products Laboratory are undertaking joint work under Interagency Agreements employing capabilities at each institution to accomplish biobased products, biofuels, or biopower research.*
-
- ***Forest management*** *- Stemming from a workshop on strategic federal laboratory partnerships, USDA is employing DOE/Industry-developed technology to assess the use of small modular biomass power systems to manage forest residues. The Forest Products Laboratory and DOE's National Bioenergy Center are jointly monitoring this work..*
- ***Energy Audit and Renewable Energy Development Program*** *-for entities to administer energy audits and renewable energy development assessments for farmers, ranchers and rural small businesses (led by USDA Rural Development).*
- ***Renewable Energy Systems and Energy Efficiency Improvements*** *for loans, loan guarantees and grants to assist eligible farmers, ranchers and rural small businesses. (Led by USDA Rural Development/Rural Business- Cooperative Service).*

4.2.4 State and Regional Interaction

The OBP works with state and local governments and communities to integrate technologies and assess regional bioenergy opportunities. OBP also sponsors and participates in regional activities directed at expanding the bioindustry.

DOE/EERE Regional Offices are a resource that enables OBP to take advantage of opportunities at the state and local levels. The Regional Offices manage more than $200 million in grants for energy efficiency and renewable energy programs, and provide states with technical assistance on the use of Systems

Benefit Charges (these can create funding for renewable energy). A strategy is currently being developed by OBP to expand interaction at the regional level and take advantage of the resources represented by the Regional Offices.

The OBP also plans to work with the Governors' Ethanol Coalition (GEC) to increase the use of ethanol fuels through various activities. This group, which was formed in 1991, now has 27 member states as well as international representatives from Brazil, Canada, Mexico and Sweden.

4.2.5 Universities

Universities provide a vital link to fundamental science and technology expertise. They also provide the critical foundation and setting for the development of a new set of engineers and scientists skilled in the disciplines necessary to build a bioindustry. A number of universities are partners in OBP activities, and participate via the same competitive mechanisms as industrial partners and national laboratories.

4.2.6 Industry

Partnerships with industry exist through OBP Integrated Biorefinery projects, which are industry-led. Industry statekholders also participate in guiding and reviewing the portfolio through the Biomass R&D Technical Advisory Committee (see Section 4.2.2).

Industry groups are formally organized to provide input on key areas and gaps. For forest products, the American Forest and Paper Associations prepared the Agenda 2020 vision and technology roadmaps. The Biomass Interest Group, a consortia of electric utility companies and technology developers led by the Electric Power Research Institute, provides a mechanism for feedback and interactions among developers and users. The chemical industry is engaged via their Vision 2020 group and industrial roadmaps. Farm communities, their trade associations, and other interested industries are also engaged regularly.

4.2.7 International

OBP cooperates with the International Program within the EERE Office of Weatherization and Intergovernmental programs on biomass-related activities, and co-sponsors a World Biomass Conference with Canada and the European Union.

OBP participates in the biomass-related activities of the International Energy Agency (IEA), and the OBP Program Manager represents the U.S. on the Executive Committee for IEA Bioenergy. The primary value of participation for OBP is the sharing of emerging information on bioenergy. Efforts supported by the U.S. currently include such topics as Short Rotation Crops for Bioenergy Systems; Conventional Forestry Systems for Sustainable Production of Bioenergy; Gasification of Biomass; and Liquid Biofuels.

4.3 Program Management Approach

Program management includes program-wide activities such as planning, budgeting, execution, evaluation, and technical integration and analysis, as well as cross-cutting activities such as outreach and education.

4.3.1 Planning

Five planning documents guide and integrate the work of the OBP. This document, the Multiyear Program Plan (MYPP), describes high-level goals and strategies consistent with the DOE and EERE strategic plans. The Multiyear Technical Plan (MYTP) links detailed project plans with the goals in the MYPP. The Multiyear Analysis Plan (MYAP) describes the analysis required to support OBP R&D areas and overall goals. The Annual Operating Plan (AOP) outlines one-year operation at the project level, and includes parameters for evaluating performance such as milestones, schedules and cost projections. The OBP Communications Plan describes stakeholder audiences and specific communications Activities.

4.3.2 Budgeting

Budget preparation and revision is a continuous process that occurs throughout the year. OBP budgets fall under two Congressional appropriations subcommittees: Energy and Water Development for Biomass and Biorefinery Systems R&D, and Interior and Related Agencies for Biomass and Biorefinery Systems R&D.

4.3.3 Execution

R&D is identified to target and overcome specific technical barriers. Projects are carried out by industry contractors, national laboratories, universities, or combinations thereof. Cost-shared R&D is initiated via competitive solicitations, which facilitates industry involvement from a technical, planning and financial standpoint. Funding vehicles include cooperative agreements (generally used with industry and universities); GOCO contracts or CRADAs (industry and national laboratories); and Interagency agreements and grants (used with Federal and State agencies). Industry cost share for R&D varies from 20 -50 percent, in line with the Energy Policy Act of 1992.

Activities are prioritized by assessing status against out-year targets. All related targets must be met for a technology effort to be successful, and based on composite results for a given area, R&D may be redirected or refocused.

OBP has implemented a weekly highlights email and two intranets (DOE only, DOE-NBC). These mechanisms facilitate communication among program and project management participants and promote timely internal exchange of information.

4.3.4 Program and Project Evaluation

Evaluation of the portfolio and overall program direction is facilitated by programmatic peer reviews conducted every two years. Guidance and evaluation is also sought from program reviews conducted through the National Academy of Science, National Research Center.

Periodic project-level Stage Gate reviews are conducted with field investigators, industry experts and program management. These in-depth reviews provide a means for making disciplined, informed decisions about RD&D.

Stage Gate Management Principles

Stage Gate management is a process for making disciplined, informed decisions about R,D&D investments that helps ensure program dollars are used effectively and efficiently. Stage Gate management as practiced by the Biomass Program includes two paths, or tracks, that a project can take depending on the planned outcomes from the project. The commercial track is for projects where the outcome is a commercial process or product. The research track is for more basic and applied research. Figure xx shows the stages for both the commercial and research paths. As a project passes from one stage to the next, it moves to a higher level of spending. Decisions are made at the end of each stage as to whether a project will pass through the "gate" to the next stage. The result is that projects with technical or market issues are weeded out earlier rather than later, and more funds are spent on projects with the greatest potential for success. Project decisions are based on evaluation of gate criteria including strategic fit, market risks and benefits, technical feasibility, competitive advantage, environmental risks and benefits, showstopper identification, and sound planning. Stage Gate management is the main process employed by the Biomass Program to ensure that the OMB Applied R&D Investment Criteria, as described in the EERE Strategic Plan, are applied to all projects in the Program portfolio.

Organizations conducting research must submit quarterly and annual progress reports outlining technical status, impediments, achievements, and costs. Results presented in quarterly and annual reports provide technology managers and program integration staff the information needed to track research and measure progress toward program goals.

OBP project managers monitor task schedules, milestones, labor and capital requirements, and projected costs over time. Invoiced costs are provided to OBP management on a monthly and quarterly basis to support project management activities.

4.3.5 Technical and Business Integration

The goal of integration is to manage the complex interactions between technical and program elements to best meet program objectives. The interface between all five R&D elements and even between individual projects need to be understood and effectively aligned.

Program integration is conducted in cooperation with the staff of OBP, NREL, GFO, and NBC at all participating laboratories.

Business integration involves field budget development, tracking, metrics, cost performance and procurement planning. Technical integration includes technical planning (MYPP, MYTP, AOP), tracking of technical information (milestones, progress reports), creating and maintaining an integrated program baseline (performance requirements and goals), and capabilities integration.

4.3.6 Analysis

OBP uses engineering and analysis activities to support decision-making, elucidate progress toward goals, and direct research activities. It is needed to guide research toward critical areas, and can reduce the risk associated with technology development. Platform-level analysis provides direction, focus and support to development and introduction of feedstock production, processing and use technologies. Analysis activities are described in Section 3 within the specific R&D areas.

Integrated analysis provides cross-cutting, quantified data to support portfolio management, and includes seven components.

- *Analysis infrastructure* includes methods and tools for conducting analysis.
- *Biomass resource and infrastructure assessment* focuses on the quantity anlocation of biomass resources at the state, county and land-type levels.
- *Technical and economic feasibility analysis* is conducted to determine the potential economic viability of a process or technology for commercial success.
- *Environmental analysis* is used to quantify the environmental impacts of biomass technologies.
- *Integrated biorefinery analysis* combines technology assessments to determine the optimal mix of technologies to produce a slate of projects in the biorefinery.
- *Bioindustry analysis* examines market penetration for biorefinery products from multiple biorefineries.
- *Benefits analysis* helps quantify and communicate the benefits of biomass RD&D, such as imported oil displacement, miles driven on domestic fuels, and greenhouse gas mitigation, using models such as NEMS and MARKAL. The results of this analysis are used to respond to the Government Performance Reporting Act (GPRA), to predict the potential impacts of Federally-funded research, and to make realistic projections of market adoption.

Figure 4-3 illustrates the timing of management activities, which are scheduled to coincide with Congressional budget schedules, fiscal year start-end, and internal planning factors.

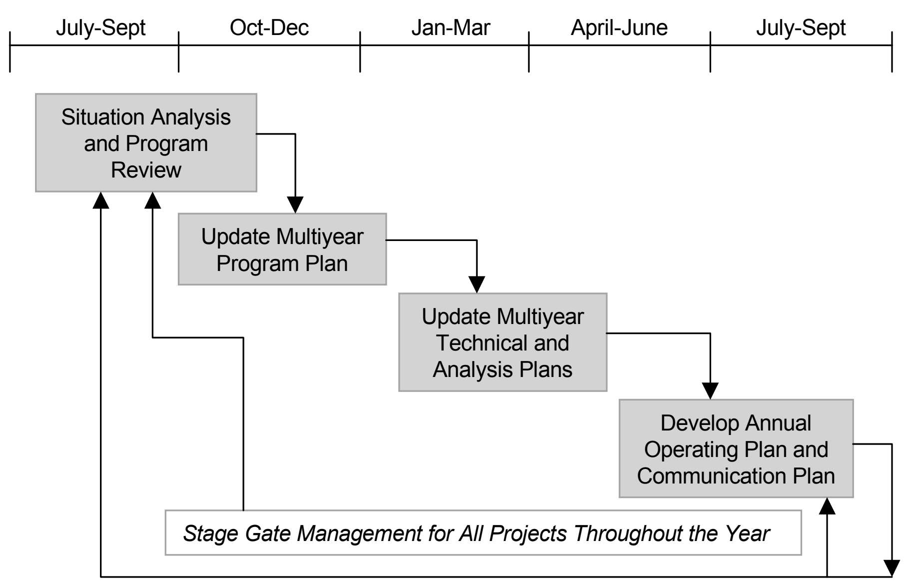

Figure 4-3 Management Planning and Evaluation Schedule

4.4 Outreach, Education and Partnerships

OBP conducts crosscutting activities in outreach, education and partnership development. Partnership activities are broad in nature with the goal of increasing collaboration with regional, state and local governments or organizations, and encouraging participation of small businesses.

Through its core R&D programs OBP builds partnerships by conducting joint research and facilitating the commercialization of technologies and processes. In addition, OBP educates consumers and governmental agencies on the use of biobased fuels, chemicals, and products, and provides information and technology transfer assistance to potential users of biomass systems.

4.4.1 Communications

OBP develops a communication plan every year to guide outreach efforts. OBP has identified key audiences and targets communications products to get the word out on the benefits of using biobased technology.

Communications products include publications, a web site, workshops, conferences and educational materials. Technical papers in peer reviewed journals, patents, conference proceedings, and presentations at professional meetings serve as venues for advertizing the technology developed by DOE.

OBP sponsors technical conferences and workshops on a variety of subjects to accelerate technology development and implementation. Examples are the Bioenergy series of regional conferences and the Biotechnology for Fuels and Chemicals Symposia (rotated yearly between Colorado and Tennessee and organized by NREL and ORNL). A number of regional and state activities are also sponsored. The Regional Offices have considerable activities devoted to information dissemination for EERE programs, including the OBP.

The OBP communicates technology development and other information to industry or customers through the Internet (http://www.bioproducts-bioenergy.gov). OBP's website provides information on new technologies, products, solicitations, publications, and legislative activities. It links with key USDA sites and other government and private sector activities, provides information on biomass activities sponsored by DOE, and characterizes the contribution of biomass to the economy.

OBP also transfers technology and knowledge to U.S. industry and others through cost-shared RD&D, interagency agreements (Federal and States), Cooperative Research and Development Agreements (CRADAs), international agreements, and FIFA inquiries.

4.4.2 Education

OBP has undertaken several activities to develop science-based education and outreach programs in biomass for k-12 as well as at the college and university levels.

OBP has worked with eight universities on university curriculum development geared toward providing knowledge and experience in biomass processing and conversion technology. This work involves engineers and scientists at both the undergraduate and graduate level.

In FY 2003 OBP launched an innovative program to take biomass feedstocks, conversion technologies and processes to schools through a mobile learning lab. OBP is also supporting the BRISA Program (Biomass Research Initiative for Student Advancement), which was established to increase Hispanic student involvement and an eventual career path in the sciences and engineering.

OBP is cost-sharing the development of the Biomass Rapid Analysis Network (BRAN) which will provide new tools and analytical methods for monitoring the composition of biomass feedstock and biomass-derived materials. BRAN supports the need for a trained workforce for conducting R&D and working in the emerging bioindustry.

4.2.3 Partnerships

OBP is currently involved in several activities to promote partnerships at the regional, state and local levels, and to encourage participation by small businesses.

Regional partnership efforts involve five Regional Host Organizations (RHOs) - Council of Northeast Governors, Council of Great Lakes Governors, Southern States Energy Board, Western Governors Association, and DOE Seattle Regional Office. Each RHO provides leadership in addressing policies and technical issues in their regions relating to the use of biomass.

The State Energy Program (SEP) provides funding to states for the maintenance of State Energy Offices and the undertaking of state-specific energy conversation projects.

OBP participates in serveral programs designed to provide funds to small businesses. These include the Small Business Innovative Research (SBIR) Program; the Small Business Technology Transfer (STTR) Program; and the State Technologies Advancement Collaborative (STAC) Program. All these programs seek to increase participation of small businesses in Federal R&D and to increase commercialization of technology developed through Federal R&D. The STAC Program specifically targets cooperative projects between states and the Federal government on energy RD&D.

For More Information on the Office of the Biomass Program

Office of the Biomass Program Official Website

http://www.bioproducts-bioenergy.gov/.

Information about the Biomass Technical Advisory Committee

http://www.bioproducts-bioenergy.gov/pdfs/AdvisoryCommitteeRDRecommendations.pdf .

ENDNOTES

1. Data from ORNL Analyses

2. Assumes 5.9x10^6 btu/barrel of oil, 13,161 btu/lb ethanol (high heating value), and oil consumption associated with gasoline is about 7.9 million barrel/day or about 2.9 billion barrels/year. Assumes delivered prices of biomass residues at $50/ton.

3. *Vision for Bioenergy & Biobased Products in the United States*, Biomass R&D Technical Advisory Committee, October 2002.

4. National Corn Growers Association, World of Corn, based on data from USDA National Agricultural Statistics Service, 2000 Crop Production Annual Summary.