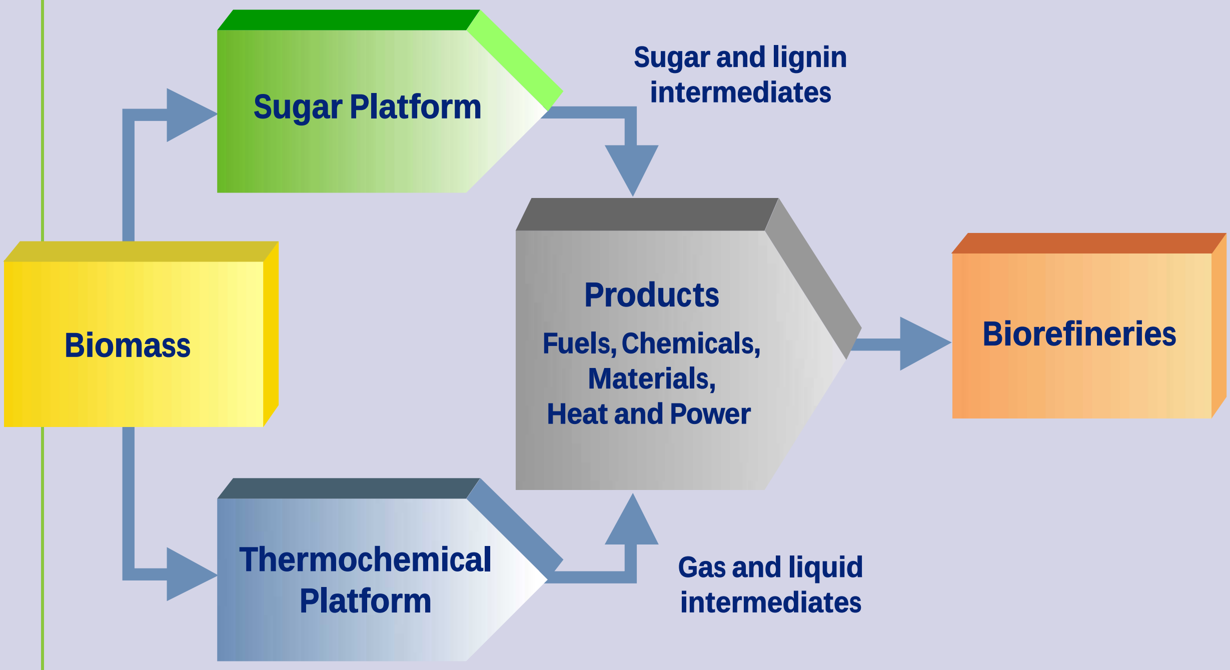
Biomass Program–
Sustainable Fuels,
Chemicals, Materials,
and Power

Biomass
Sustainable Fuels, Chemicals, Materials, and Power

Biomass Program

Multi-Year Technical Plan



U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

DRAFT FOR REVIEW

Table of Contents

Tables

Figures

1 Introduction

The Biomass Program is a comprehensive federally funded research, development, and deployment effort. It focuses on science and technology that will establish biomass as a significant source of sustainable fuels, heat, power, chemicals, and materials. Biomass is unique among all the options for renewable resources because it is the only single resource that by itself can serve as a sustainable supply of all of the following: food, fiber, heat, power, and carbon-based fuels and chemicals.

The Biomass Program is managed by the Office of the Biomass Program (OBP), within the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE). OBP is one of eleven offices responsible for the development of a portfolio of sustainable energy technologies. The overarching goals of the Biomass Program are to dramatically reduce or even end our dependence on foreign oil and to create a bioenergy industry in the United States.

This multi-year technical plan (MYTP) documents the Biomass Program's detailed strategies, plans, and activities over the next 5 years and beyond to achieve OBP's goals. This MYTP is the first such multi-year planning document covering the entire Biomass Program. The Program has changed and is likely to continue to change as DOE works to maximize the value of its investments in the research. The MYTP will be revised annually to document the adaptation of plans to DOE's changing needs and the progress of the research and development activities.

The true value of the MYTP is in the process used to develop the plan. Much of the information in the MYTP originated from a 3-day planning session in May 2003 and attended by representatives of OBP, five DOE National Laboratories, the U.S. Department of Agriculture (USDA), and DOE's Golden Field Office.

The disciplined thinking that went into the MYTP helped OBP identify the strengths and weaknesses of the strategies being used. This document is merely a snapshot of the most current plans; strategic plans will be improved further in the coming year. Annual revisions will allow measurement of progress towards the Program's goals. Because the planning process involves continually reassessing the Program's direction, the plan will also document changes in direction necessitated by new information or changes in the external environment.

In simple terms, the MYTP planning process enables understanding of where the Program should go in the context of where it has been, and it provides measurable milestones to assess progress. Finally, the MYTP reflects the limitations of what can be done based on the best understanding of federal resources that will be deployed in the Biomass Program.

1.1 The Evolution of the Biomass Program

The Biomass Program represents a consolidation of several previously distinct and separately managed programs. What is now known as the Biomass Program includes what had been:

- The Biofuels Program (BFP)
- The Biopower Program (BPP)
- Biomass-related elements from research previously sponsored by the Office of Industrial Technologies (OIT)

The BFP focused on research to produce liquid transportation fuels from biomass and was dominated by research on bioethanol (ethanol made from lignocellulosic biomass) with a modest amount of work on biodiesel (fatty acid esters, a renewable fuel substitute for petroleum diesel made from natural oils.) The BPP was focused on development of biomass gasification and combustion processes, including co-firing with coal, to produce heat and power. Research sponsored by OIT focused on development of value-added chemicals and materials from biomass. Biomass feedstock development activities, including research on production, harvesting, and assessment of biomass resources for energy use, were co-funded by BFP and BBD.

Figure 1 illustrates the relationship of these previously separate programs after being consolidated into one Biomass Program. The individual program activities are now managed by one office, resulting in a more integrated and concerted effort directed toward generating technology that can flow directly into industry-led partnerships for commercial development. The Biomass Program has five areas that fall into two categories: 1) core research and development (R&D) that emphasizes enabling technology for biorefineries and 2) integrated biorefinery development activities that pull together all the pieces of core technology for a specific commercial biorefinery scenario. As research moves from core R&D to integrated validation and demonstration of biorefinery technology, the lead in the work shifts from the public sector to the private sector.

This organization of the work allows the Program to allocate its federal funding resources toward pre-commercial enabling technology development that can lay the groundwork for future commercialization without competing with or duplicating work in the private sector. The pre-commercial "core program R&D" falls into four main categories:

- Feedstock Interface core R&D
- Sugar Platform core R&D
- Thermochemical Platform core R&D
- Products core R&D

The fifth area of work is Integrated Biorefineries, which consists of industry-led projects to integrate elements of the core program R&D into commercially viable integrated biorefineries.

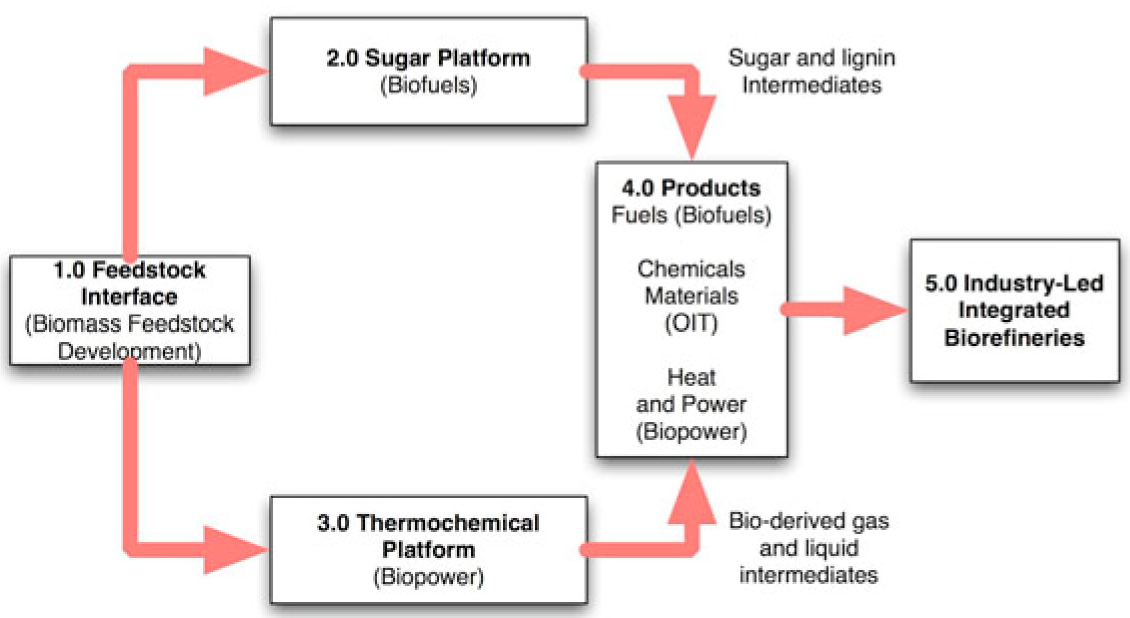


Figure 1: Workflow Schematic for the Biomass Program

1.2 Scope and Approach

Feedstock research historically covered a fairly broad range of research areas from crop development to optimal energy crop production and harvesting. The new Biomass Program focuses resources on the Feedstock Interface area, mainly on feedstock harvesting, storage, and transportation technology as it relates to the technology employed to convert biomass into energy and products. The broader issues of crop development, crop production, and management are now the domain of the USDA, which has an appropriate set of skills and resources to address biomass production in a comprehensive manner. OBP now emphasizes developing harvesting, storage, and transportation technologies that will reduce the cost of sustainable delivery of biomass to a biorefinery and on ensuring effective coordination between DOE and USDA biomass research efforts.

Research under the previous BFP spanned the entire gamut of technology needed to convert lignocellulosic biomass to ethanol and a lignin residue (a byproduct that could be used to produce other fuels, chemicals, or power.) Under the new Biomass Program, that research has been divided into two areas. The focus of the Sugar Platform is to develop cost-effective technology to release sugars from lignocellulosic biomass. This is called "enabling technology" because it enables development of an integrated industrial biorefinery using lignocellulosic biomass. The Sugar Platform represents the single largest area of core R&D in the Program. The downstream conversion of sugars (and lignin residue), chemically or biologically, into fuels, chemicals and materials, and/or heat and power is now the domain of the Products area.

Research under the previous BPP focused entirely on producing low-cost electrical power from biomass. The new Thermochemical Platform represents a major shift and refocusing of research in this area. The focus of the Thermochemical Platform is to develop cost-effective technology to thermochemically convert lignocellulosic biomass into gaseous and liquid intermediates that can serve as fuels or intermediates for fuel and chemical product opportunities.

At the time this MYTP was written, OBP's strategies in the Products area were still being formulated. Product initiatives must be market driven, with specific well-defined products and markets. Products research will be needed to find uses for all the intermediates and byproducts produced by the technology in the conversion platforms in a sustainable manner. The OBP strategy is to have industry lead most research in this area. DOE will cost share research and DOE laboratory resources will be available to support the industry partnerships. A smaller component of the research in the Products Area will be the development of crosscutting technologies that may help enable more than one specific product or biorefinery application.

Projects in the Integrated Biorefinery program area are primarily public–private partnerships led by industry, have significant private sector cost-share (20-50%), and are conducted by a team of performers frequently including academia and DOE National Laboratories. These projects have a relatively clear path to commercialization and include near term research and development, pilot scale integrated testing, and larger demonstrations.

1.3 Why a Biorefinery?

The integrated biorefinery is a conceptual framework that capitalizes on the synergies of integrating technologies from the previously separate biomass-related programs. In the older biofuels, biopower, and bioproducts paradigms, energy production from biomass had to compete head-to-head with very mature technology that uses non-renewable sources of feedstock such as coal, petroleum, or natural gas and bioproducts by themselves offered only small impact to reducing fossil energy dependence. Combining higher value products with higher volume energy production and employing any combination of conversion technologies has the greatest potential for making fuels, chemicals and materials, and power from biomass competitive. Figure 2 shows a concept of the biorefinery that represents a generic integration of all aspects of biomass conversion technology. In this figure, the biorefinery concept is not confined to only a biochemical conversion–based biorefinery or a thermochemical conversion–based biorefinery. In fact, the combined use of both conversion platforms offers the greatest opportunity for optimizing the conversion of biomass into a variety of different fuels, chemicals, and energy products. Not all biorefineries will be this complex, but some may have added complexity.

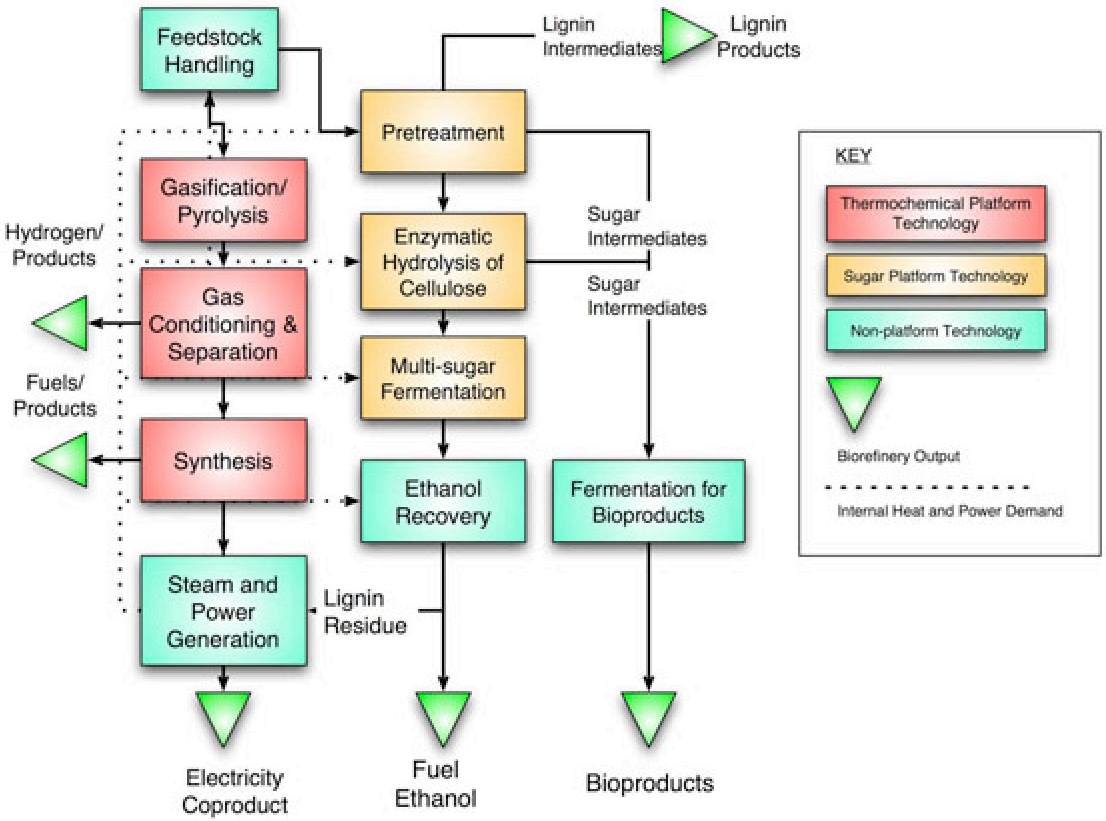


Figure 2: Schematic of an Integrated Biorefinery

The biorefinery should benefit from lessons learned during the evolution of modern-day petroleum refineries. The concept is analogous to a combined use of fluid catalytic cracking, thermal cracking, and hydrocracking technology to convert the higher-boiling-range fractions of crude oil into more useful lower-boiling-range products. Just as few petroleum refineries use all available conversion technologies, biorefineries too will use only those technology platforms that are most cost effective for converting a certain type of biomass into a certain collection of desired end products.

1.4 The Timing of Biorefinery Technology

This MYTP differentiates technology according to when it is predicted to become commercial. The portfolio of technology development falls into three categories:

- Existing biorefineries
- Emerging biorefineries
- Advanced biorefineries

Existing biorefineries are already commercial operations. In the case of the sugar platform, today's 2-billion-gallon-per-year corn grain ethanol industry is in that category. Examples of existing thermochemical biorefineries include today's pulp and paper mill industry, the growing biomass power industry based primarily on co-firing of biomass and other fossil fuels for the production of heat and power, and the more recent specialty chemical facilities based on fast pyrolysis technology for biomass.

Emerging biorefineries are based on technology that has not yet been proven commercially but which has a timeline for commercialization of 5-10 years. These use non-traditional sources of lignocellulosic biomass, such as agricultural residues and energy crops, as opposed to existing biorefineries that use traditional and currently available sources of biomass including grain or waste materials. The technology to cost effectively convert these materials is still in development.

In the case of the sugar platform, the Program envisions emerging biorefineries based on enzymatic hydrolysis of biomass to produce sugars and lignin, which can then be converted into a variety of fuels and products. In the case of the thermochemical platform, emerging biorefineries are based on the gasification or pyrolysis of biomass. In many cases, the thermochemical platform is an extension of technology that has been proven for coal but which still requires development before the technology can be cost effectively applied to biomass.

The advanced biorefinery is based on technology that is, at best, in the conceptual stages of development. The exact technologies that will be used in advanced biorefineries are unknown at present. Thus, the core R&D conducted today in support of advanced technology is less constrained by specific technical issues than the core R&D envisioned for the emerging thermochemical and sugar platform technologies. This research is more fundamental in nature, asking broader questions about the processing of biomass that could lead to new concepts for producing fuels and products.

The Program's integrated biorefinery projects are primarily divided into projects based on sugar platform technologies and those based on thermochemical processing. This division is somewhat arbitrary, however, in light of synergies of using technologies from both platforms, as discussed in Section 1.3, above. Nevertheless, the kind of ultimate integration of technologies (Figure 2) is predicted to occur further down the timeline. For both the sugar and thermochemical processing routes, there are projects that involve existing biorefineries and projects that involve emerging biorefinery concepts. Some projects combine existing and emerging biorefinery schemes. By definition, none of the integrated biorefinery projects involve advanced biorefinery concepts.

In the category of existing biorefinery projects, there are two types of projects. One type of project relates to improvements in emerging technology applied in existing biorefineries. These projects provide a way to accelerate the testing of key technology components for emerging biorefineries in the context of existing commercial operations. The second type of project involves introduction of existing technology into existing biorefineries. These are of more limited value to the program in terms of deploying technology that use new biomass sources.

1.5 The Biomass Program's Goals

DOE's and EERE's strategic plans provide the broad direction under which this MYTP was developed. The DOE strategic plan defines how DOE will meet the President's energy goals for the nation. The EERE strategic plan supports DOE's strategic plan and establishes nine portfolio priorities or strategic goals, of which two apply specifically to the Biomass Program. Figure 3 shows the hierarchy of the Program's goals, including goals for each section of the portfolio.

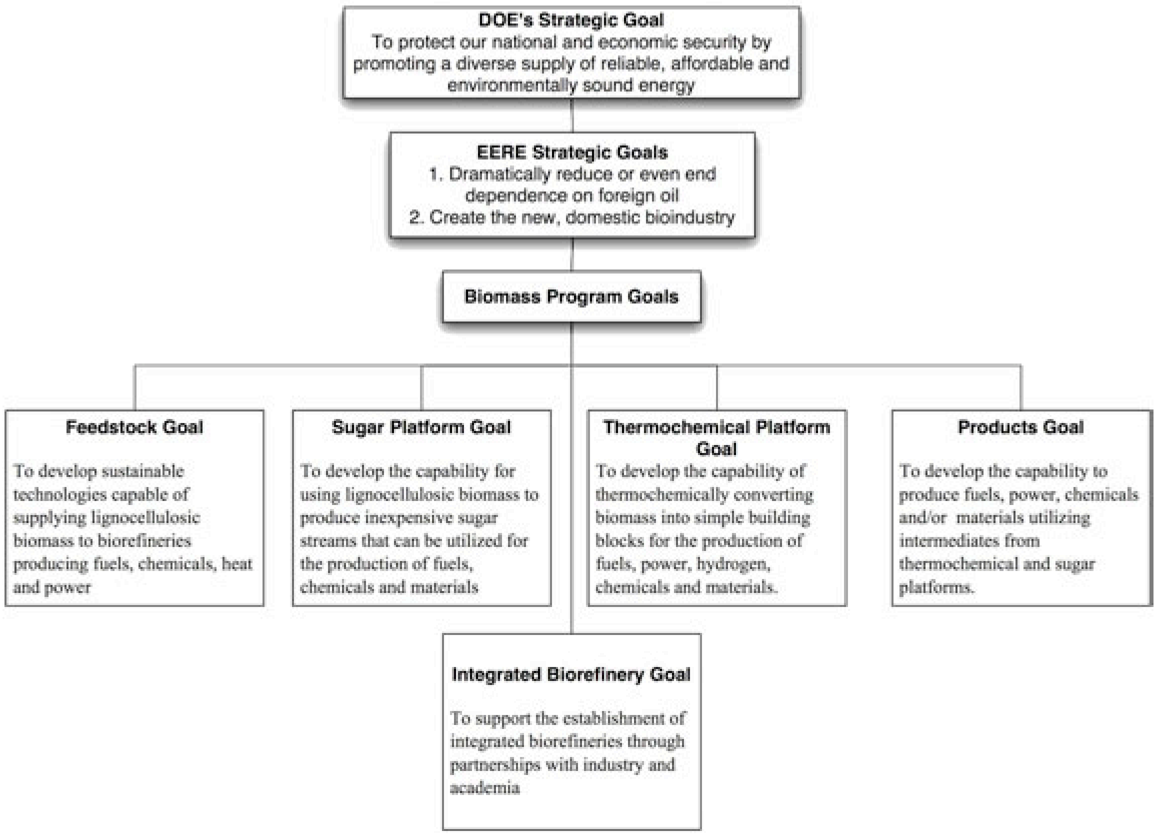


Figure 3: Biomass Program Goals

2 Technical Plan

This section of the plan provides a detailed outline of the projects within the five R&D elements, or technology areas, of the Biomass Program:

2.1 Biomass Feedstock Interface R&D

2.2 Sugar Platform

2.3 Thermochemical Platform

2.4 Products (including fuels, chemicals, materials, heat and electricity)

2.5 Integrated Biorefineries

Figure 2 below shows the overall work breakdown structure for the Program. Program Management, covered in Section 3, includes program-wide activities such as planning, budgeting, execution, evaluation, technical integration, and analysis, as well as crosscutting activities such as outreach, education, and partnerships.

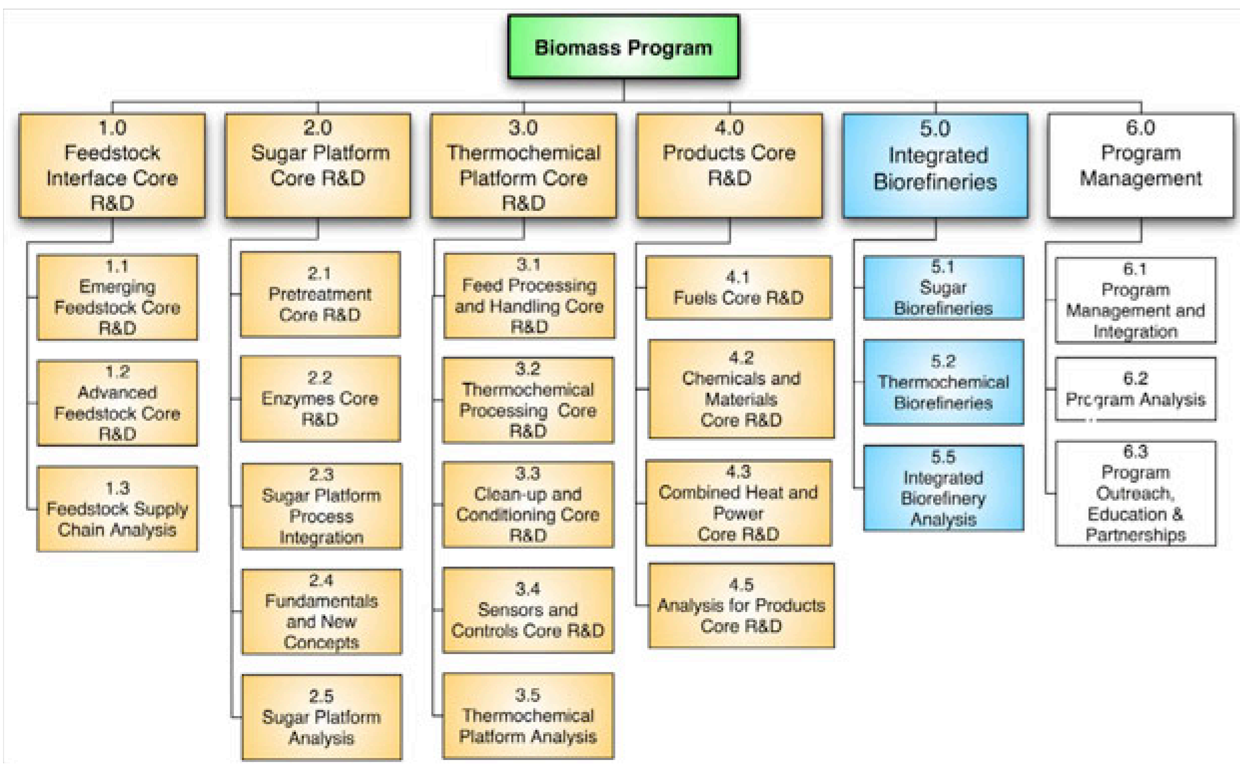


Figure 2: Overview of Biomass Program Work Breakdown Structure

The overall DOE resource allocation plan for the Biomass Program covering FY2004 through FY2008 is shown in Figure 3 and Table 1. The line at the top of the figure shows the level of the Program's FY2004 budget request to Congress, a total of $78.558 Million ($69.75 from Energy and Water Development and $8.808 Million from Interior and Related Agencies). This is important because the major resource constraint imposed on this MYTP was that the Program budget was assumed be flat for the period covered by the plan. What is shown in Figure 5 is simply a roll-up of the detailed resource plans developed for each program area and included in the appropriate sections of the report. The detailed plans were built up on a project-by-project basis, with projects defined as needed to overcome the technical barriers identified. The plans do not generally include future solicitations that would result in new projects being added to the portfolio.

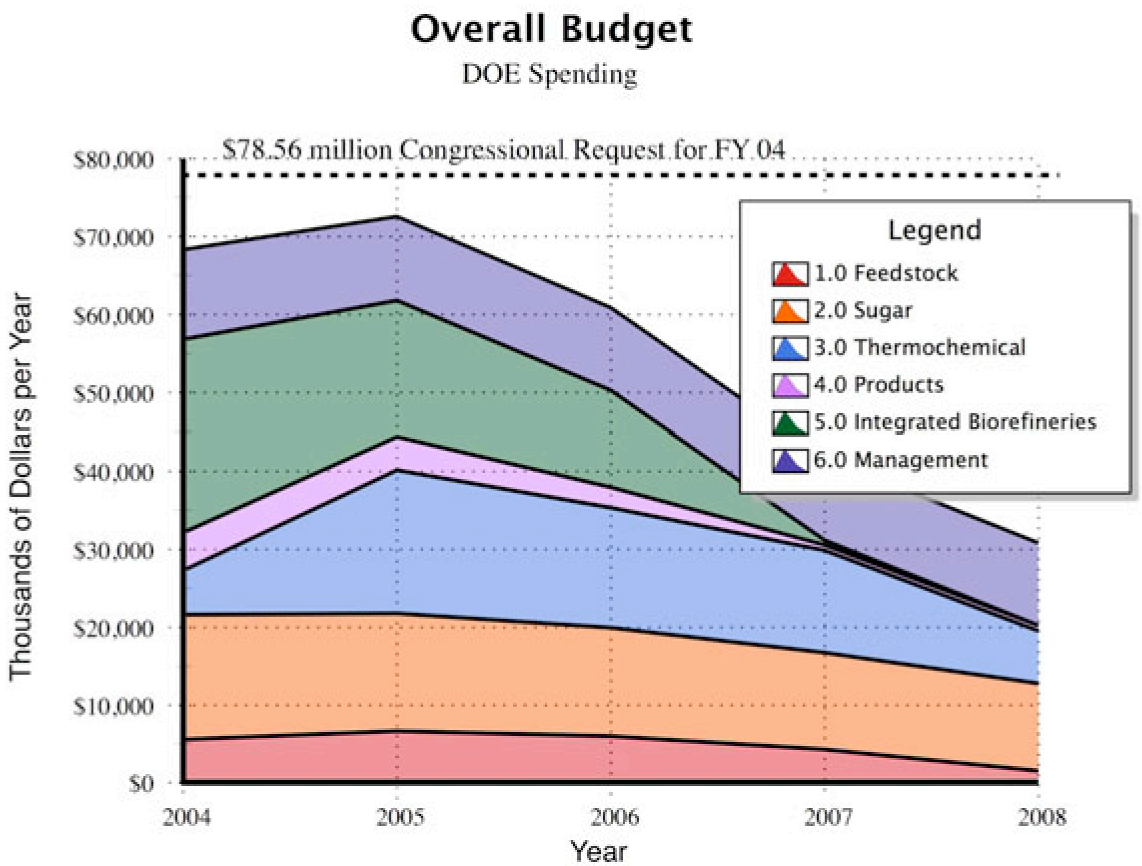


Figure 3: Biomass Program Resource Plan

The total resource plan level shown in Figure 3 is relatively flat for FY04 and FY05 and then begins a decline in FY06 that continues through FY08. This trend should not be interpreted as the need for Program funding is going down. Rather the decline is due to funding for current specific projects beginning to decline or even end in FY06. This is particularly evident looking at the Products and Integrated Biorefinery areas, which shows funding going to zero in 2007. This is the planned funding for the existing projects in those areas, most of which are public-private partnership projects awarded based on competitive solicitations. Since funding for future solicitations and therefore future projects are not discreetly identified or included in the detailed resource tables, the decline shown in the Figure 3 is exactly what should be expected. The difference between the total annual level budget of approximately $78.6 Million and the level of the resource plan shown for defined projects should be interpreted as the level of funding available either for new projects or for higher resource allocations to existing projects. Resource allocation decisions will be based on meeting Program objectives in the most cost effective manner through ongoing evaluation of performance, cost, schedule and risk.

Figure 4 shows the same resource information in Figure 3 and Table 1 but in a different format that makes it easier to see the relative resources planned for the five technical areas of the Program over the duration of the plan.

Table 1: Biomass Program Resource Plan

Year	1.0 Feedstock Interface	2.0 Sugar Platform	3.0 Thermo-chemical Platform	4.0 Products	5.0 Integrated Biorefineries	6.0 Management	Total
2003	$28,978	$1,015	$4,524	$4,845	$24,564		$65,929
2004	$5,536	$16,090	$5,860	$4,845	$24,564	$11,500	$68,395
2005	$6,605	$15,190	$18,372	$4,239	$17,401	$10,780	$72,587
2006	$5,950	$14,000	$15,400	$2,614	$12,328	$10,600	$60,892
2007	$4,250	$12,500	$13,125	$694	$600	$10,600	$41,769
2008	$1,500	$11,300	$6,740	$694	$0	$10,600	$30,834
Total	$52,819	$70,095	$64,021	$17,931	$79,457	$54,080	$340,406

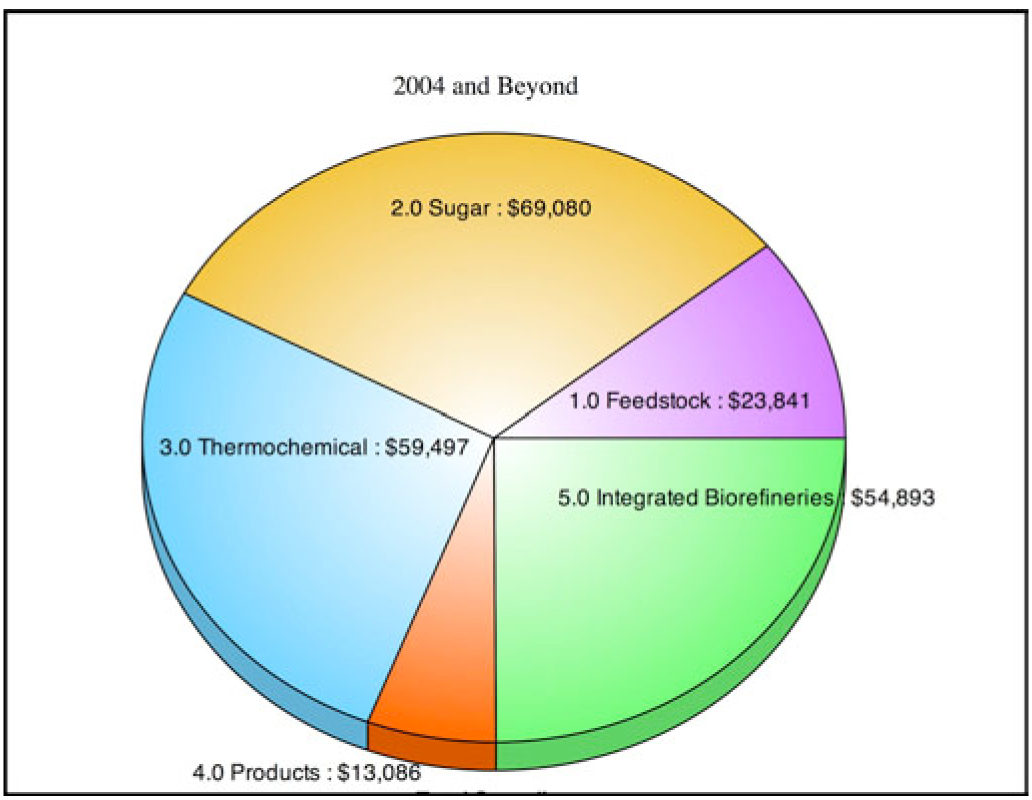


Figure 4: Biomass Program Resource Allocation Plan, Totals for FY04-FY08

2.1 Biomass Feedstock Interface R&D

The success of the biorefinery is critically dependent on having a large supply of low-cost, high-quality lignocellulosic biomass. The primary mission of the Feedstock Interface area is to work closely with the sugars and syngas conversion platforms to conduct the necessary R&D to meet their feedstock needs. Meeting the long-term needs of the biorefinery in a sustainable manner will require fundamental changes in the agricultural system and feedstock infrastructure system. Current technologies and agricultural practices are inadequate to meet this goal. The Feedstock Interface Area focuses on developing the new technology and methods necessary in the feedstocks infrastructure area to produce one billion tons of cellulosic feedstock per year in a sustainable manner at $35/ton or less. This will require working closely with USDA, growers, feedstock equipment manufacturers, and processors to bring about the necessary changes in the agricultural system and to form the integrated partnerships needed to support biorefinery development.

2.1.1 Technical Goals and Objectives

The overall goal of biomass feedstocks interface R&D is to develop sustainable technologies capable of supplying lignocellulosic biomass to biorefineries producing fuels, chemicals, heat, and power. The following are specific objectives:

- Develop sustainable biomass harvest and collection technologies capable of supporting an industry of up to 1 billion dry metric tons per year by 2050, with a near-term objective of supporting an industry of up 150 million dry metric tons per year by 2010
- Develop feedstock infrastructure technologies necessary to meet the $30/ton price target while assuring an economically sustainable venture for growers, equipment manufacturers, and biorefinery processors
- Develop feedstock supply forecasts, models, and analyses necessary to optimize feedstock supply chains to biorefineries and reduce supply risks

The long-term target of 1 billion tons of sustainable biomass supply is based on an estimate of the amount of biomass it would take to meet one-third of the current demand for gasoline in the US, assuming that the biomass were converted to ethanol as a direct gasoline substitute. The near-term goal of developing technology that could cost effectively deliver biomass at a level of up to 150 million dry metric tons per year is based on a recently developed roadmap for building a feedstock supply.[1] This does not mean that there will be a ready supply or a demand for 150 million tons per year of biomass. According to the plans presented here, the first full-scale commercial biorefineries will just be coming on line in this timeframe. The focus is on delivering technology that could address that level of demand.

2.1.2 Programmatic Status

Biomass feedstock availability is being fostered by the activities of two DOE national laboratories: Oak Ridge National Laboratory (ORNL) and Idaho National Engineering and Environmental Laboratory (INEEL). These laboratories work in close collaboration with researchers at many USDA research laboratories and with private industry. INEEL, in partnership with equipment manufacturers, has made considerable progress in the feedstock infrastructure area over the past few years. Specifically, projects of the ongoing, highly successful, OBP-sponsored Selective Harvest and Multi-Component Program have made, considerable progress on determining what components of agricultural residue biomass should be left in the field to address soil health and sustainability concerns and what parts should be harvested as biorefinery feedstocks. Also, these projects have developed numerical and computational models for

---

[1] *Roadmap for Agricultural Biomass Feedstock Supply in the United States*. Customer Review Draft, September 2003.

mechanical fractionation and air-stream biomass separation and integrated them into a format that can be analyzed in virtual reality. This allowed development of models for virtual engineering analysis of various biomass selective harvest techniques and of harvest methods that can be employed in a single-pass mode without negatively impacting the grain harvest. This innovative approach will significantly reduce the time and resources compared to conventional engineering prototype approaches.

Equipment manufacturers are unwilling to make the significant resource investment required to develop the necessary biomass harvest and collection technology and equipment until significant markets exist for this technology and equipment. On the other hand, processors are unwilling to commit the resources required to build biorefineries until reasonable guarantees of feedstock supply, price, and quality can be achieved. Initially, processors thought that feedstock needs could be largely met with existing harvest and collection technology and methods. However, more detailed analysis has shown this is not the case and that new technology and methods are needed to meet the feedstock needs of the biorefinery. This puts the biorefinery concept in a precarious chicken-or-egg scenario that could significantly delay or threaten the eventual success of the biorefinery. The virtual engineering prototyping approach towards development and implementation of single-pass sustainable biomass harvester technology is necessary for meeting the biorefinery feedstock availability and price targets in a sustainable manner an innovative method for overcoming this dilemma.

In partnership with growers and academia, INEEL has also evaluated bulk processing, handling, and transport technologies and methods as a more desirable, lower cost alternative to conventional baling for biorefinery feedstocks. Several concepts have been developed and conceptually evaluated that show promise for meeting the feedstock availability and price targets. Additionally, INEEL has evaluated several long-term storage technologies for wet and dry storage options that are low cost with minimal degradation and losses. These storage concepts need to be developed to support the long-term storage demands of the biorefinery.

Scientists at ORNL, in collaboration with their research partners in private and public institutions, have been engaged in developing and applying analysis tools in support of biomass feedstock development and supply systems for the past 15 years. Their research targets two highly integrated objectives: 1) providing robust forecasts and analyses of feedstock supply and 2) designing and implementing risk analysis tools for the development of supply logistics for biorefinery enterprises. The feedstock forecasts and analyses are designed to facilitate biorefinery development strategies, to support life cycle analyses of bioenergy and bioproducts, to support policy studies and policy development, and to respond to DOE’s need to provide reliable estimates of energy feedstocks.

To provide forecasts and credible analyses of feedstock supply issues, ORNL has developed a set of integrated modeling tools (ORIBAS, POLYSYS, and BIOCOST) and databases (ORRECL) for estimating current sustainable feedstock supplies and for forecasting supplies from new resources such as energy crops. These modeling tools account for economic, geographic, and environmental constraints in assessing the availability of biomass wastes, agricultural residues, and potential energy crops. Biomass resource estimates are sensitive to environmental and soil conservation issues, the scale of the processing facility, and the economics of farming. The models can be applied to provide estimates of the impacts of different development and policy scenarios on the cost and availability of biorefinery feedstocks. Recently, ORNL, in concert with NREL and Kansas State University, developed a soils and crop management based approach for estimating sustainable removal of crop residues and used that approach to estimate current and future potential agricultural residue supplies from all important corn and wheat soils in the United States.

ORNL research also focuses on the development and application of a logistics model for supplying feedstock from an agricultural setting to specific biorefineries. The model takes into account constraints on the supply chain from local climatic conditions, farm size and yields, transportation and storage networks, supply and demand schedules, and feedstock quality specifications. This supply-chain model projects costs and energy and utilization rates of current or future agricultural residue collection systems. The model will be linked to other ORNL tools such as the ORIBAS transportation model and eventually to NREL's biorefinery models to create an integrated model that can be used to assess the value and benefits of the proposed equipment and feedstock storage concepts being developed by DOE and USDA researchers. ORNL and INEEL scientists will work closely together to generate the experimental and operational data needed to validate and use this supply chain model. The model will be designed to directly interface with process models being developed by NREL and others.

2.1.3 Technical Barriers

The Biomass Program must address the barrier of a lack of a sustainable supply of biomass. This is not to say that a biomass supply does not exist. It means that the amount, cost, and impacts of using current or new supplies of biomass cannot be stated with certainty. Figure 5 shows the hierarchy of barriers, from general to specific, facing emerging and advanced biomass technology. Barriers to sustainability include the high cost of biomass and the lack of understanding of the environmental, economic, and social impacts of creating a large biomass supply.

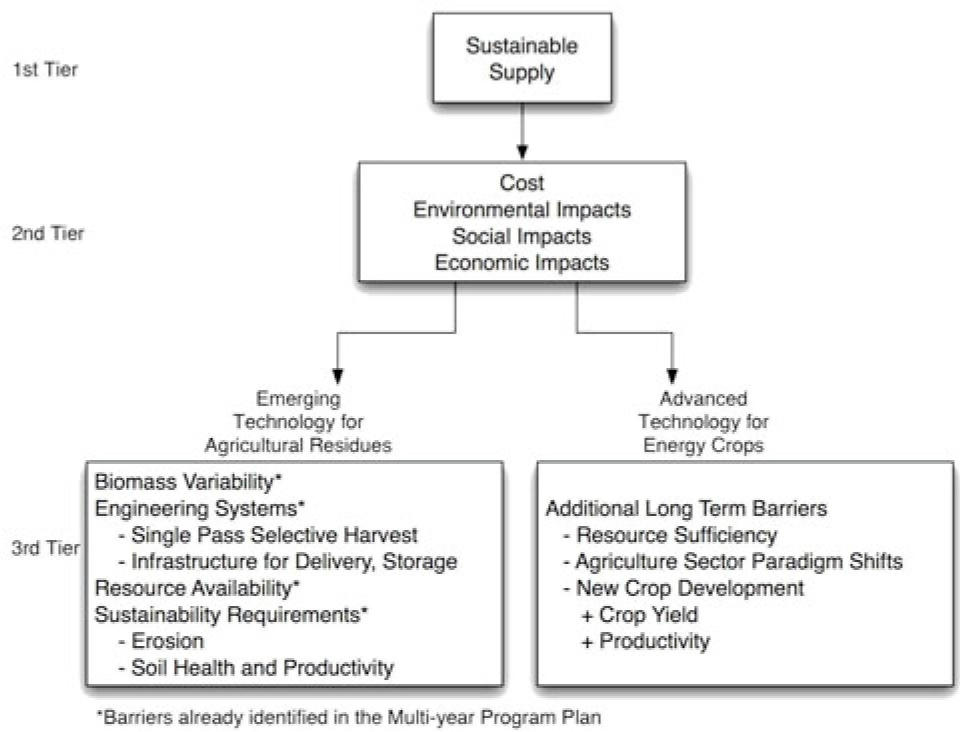


Figure 5: Hierarchy of Feedstock Interface Technical Barriers

In FY 2003, the Biomass Program conducted a series of meetings across the country with companies pursuing biorefineries, equipment manufacturers, environmental groups, transporters, farmers, and the USDA. The groups pulled together for these meetings represented the collective expertise necessary to address the needs of an emerging biomass industry based on agricultural residues. They identified the performance targets, technical barriers, and top priority research needed by OBP and USDA to achieve the near-term goals. They identified the following feedstock-related barriers for the emerging industry:

- *Biomass Variability*

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

- *Engineering Systems*

  Development of a reliable and cost-competitive feedstock infrastructure requires combining several engineering systems to create total feedstock supply chains. Current systems cannot meet the capacity, efficiency, or delivered price requirements of large biorefineries, nor can they effectively deal with the variability that is inherent in biomass feedstock supplies. Collection today requires removal of residue in a second pass through the field after harvest of the grain. Furthermore, current biomass harvest and collection methods do not have the ability to selectively and with minimal impact harvest the desired components of the biomass.

- *Resource Availability*

  The lack of credible data on price, location, quantity, and quality of biomass creates uncertainty for investors and for developers of emerging biorefinery technologies.

- *Sustainability Requirements*

  The lack of information and decision support tools to predict effects of residue removal as a function of soil type and the lack of a selective harvest technology that can evenly remove only desired portions of the residue make it difficult to assure that residue biomass will be collected in a sustainable manner. USDA researchers and regulators will need to play a major role in understanding sustainable limits to collection of biomass.

In the long term, large-scale replacement of petroleum calls for the introduction of a new generation of energy crops that can dramatically increase the potential supply of energy from biomass, without sacrificing the important role that agriculture plays in meeting our society's need for food and fiber. The barriers facing this long-term industry include the same ones facing the emerging industry, plus the following new issues:

- *Resource Sufficiency*

  There is no future vision for biomass in U.S. agriculture. The role biomass can play in the U.S. energy future cannot be understood until there is a comprehensive vision for how and at what level biomass can augment energy supply. Lacking that vision, biomass will not be a priority in the Nation's planning for a sustainable energy future.

- *Agricultural Sector-wide Paradigm Shift*

  Energy crops cannot simply be added to the list of crops and products that are handled by U.S. farmers. Energy production from biomass calls for a complete rethinking of farming, and it may involve dramatic changes in agriculture that take time to bring about.

- *New Crop Development*

  Large and cost-effective energy production on a scale that significantly impacts petroleum use calls for new crops with yield and productivity not currently available.

The strategy of the program is to develop the feedstock infrastructure necessary for the establishment of the biorefinery industry on near term feedstocks, i.e. ag residues, and then this will catalyze addressing the long-term issues through collaboration with USDA which is more suited to address the long-term issues of new crop development and ag-sector wide paradigm shift. This effort is more appropriately addressed directly by USDA.

Figure 6 shows cost reductions associated with the introduction of the various elements of an integrated feedstock supply systems designed to meet the needs of the biorefinery.

Figure 6: Translating Reductions in Technical Barriers to Feedstock and Ethanol Cost (Foust 2003)

2.1.4 Technical Approach

Figure 7 shows the work breakdown structure for the Feedstock Interface Area. The research is divided into three sub-areas:

- Emerging Feedstock Barrier R&D [Work Breakdown Structure (WBS) # 1.1]
- Advanced Feedstock Barrier R&D (WBS # 1.2)
- Feedstock Supply-Chain Analysis (WBS # 1.3)

Table 2 highlights the key activities and their milestones for the Feedstock Interface core R&D. Detailed project descriptions are provided in the Appendix.

The focus of R&D for the Emerging Feedstock Barrier Area is on solving the engineering systems barriers of collection, delivery, and storage of agricultural residues. It represents the bulk of the technical work in this area. Two feedstock infrastructure projects are being led by INEEL. One project is the development of a single-pass harvester capable of handling multiple components of the crop and selectively harvesting those portions of the plant optimally suited for various downstream processors, while leaving behind components that best meet the needs of good soil management. Eliminating a separate harvesting step will significantly reduce soil, making it more compatible with minimum or no till practices. while leaving behind components that best meet the needs of good soil management. The second project looks at the storage and delivery elements of the feedstock infrastructure. The three remaining projects under the Emerging Feedstock sub-area are independent projects looking at similar feedstock infrastructure technologies. It will be important to ensure regular communication and coordination among all of these projects to improve the likelihood of successfully developing the technologies needed to deliver agricultural residues within the cost constraints of the emerging biorefineries.

Partnerships with growers, equipment manufacturers, transporters, and processors will be critical to successful commercialization of the elements of this new feedstock infrastructure. At the same time, the Feedstock Interface Area will work closely with the Biorefinery Technologies Area to ensure infrastructure compatibility. The Feedstock Interface Area will also work proactively with USDA, growers and grower organizations, and environmental groups to form the vertical partnerships and collaborative efforts needed to support biorefinery development.

The Feedstock Supply-Chain Analysis Area will focus on the development of analytical tools for optimizing overall logistics of the infrastructure system as well as on tools for estimating the amount and price of agricultural residues and future energy crops.

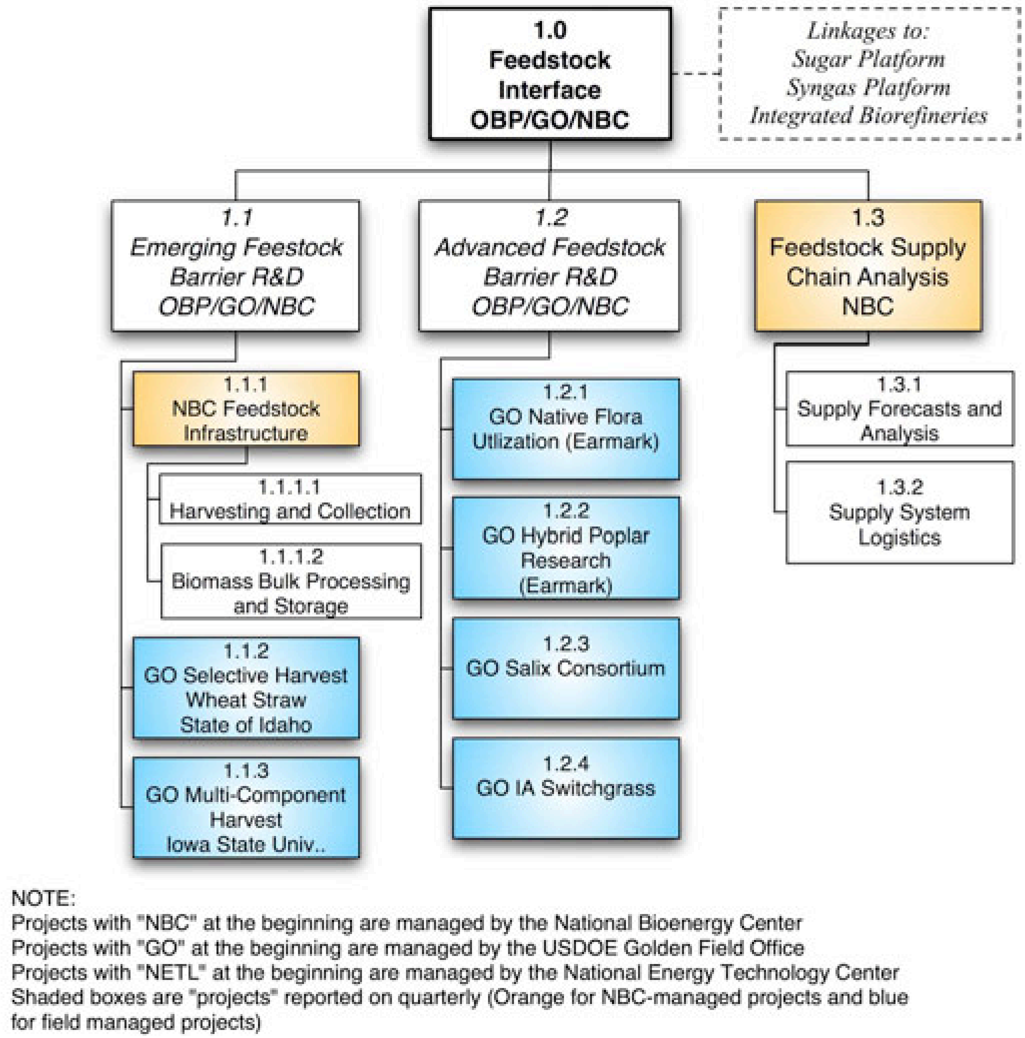


Figure 7: Work Breakdown Structure for Feedstock Interface Core Barrier R&D

The DOE Biomass Program has, over the past few years, reduced its efforts in the area of Advanced Feedstock Barrier R&D. The bulk of this work will become the responsibility of USDA. The six projects that remain in this area are a combination of Congressional earmarks and "legacy" projects first developed under previous programs that have now been combined in the Biomass Program.

ID	WBS	Task Name
1	**1**	**Feedstock Interface Core R&D**
2	**1.1**	**Emerging Feedstock Barrier R&D**
3	**1.1.1**	**NBC Feedstock Infrastructure**
4	**1.1.1.1**	**Harvesting and Collection**
5	**1.1.1.1.1**	**Mechanical Fractionation**
6	1.1.1.1.1.1	Biomechanical Property Determination
7	1.1.1.1.1.2	Cereal straw and corn stover classified
8	1.1.1.1.1.3	Fractionation modeling and testing for prototype development
9	1.1.1.1.1.4	prototype lab testing results satisfactory for mechanical fractionation
10	1.1.1.1.1.5	prototype field testing results satisfactory for mechanical fractionation
11	**1.1.1.1.2**	**Air Stream Separation**
12	1.1.1.1.2.1	Biomass Separation modeling and testing
13	1.1.1.1.2.2	grain and biomass separation model developed and validated
14	1.1.1.1.2.3	selective biomass separation model developed and validated
15	1.1.1.1.2.4	Separation modeling and testing for prototype development
16	1.1.1.1.2.5	prototype virtual engineering testing results satisfactory
17	1.1.1.1.2.6	prototype field testing results satisfactory
18	**1.1.1.1.3**	**Multi-Component Harvest**
19	1.1.1.1.3.1	virtual enginnering evaluation of design configurations
20	1.1.1.1.3.2	develop final design and build prototype
21	1.1.1.1.3.3	protoype testing
22	1.1.1.1.3.4	prototype field testing results satisfactory
23	**1.1.1.1.4**	**Single -Pass Harvest**
24	1.1.1.1.4.1	develop design concepts and perform virtual engineering evaluation

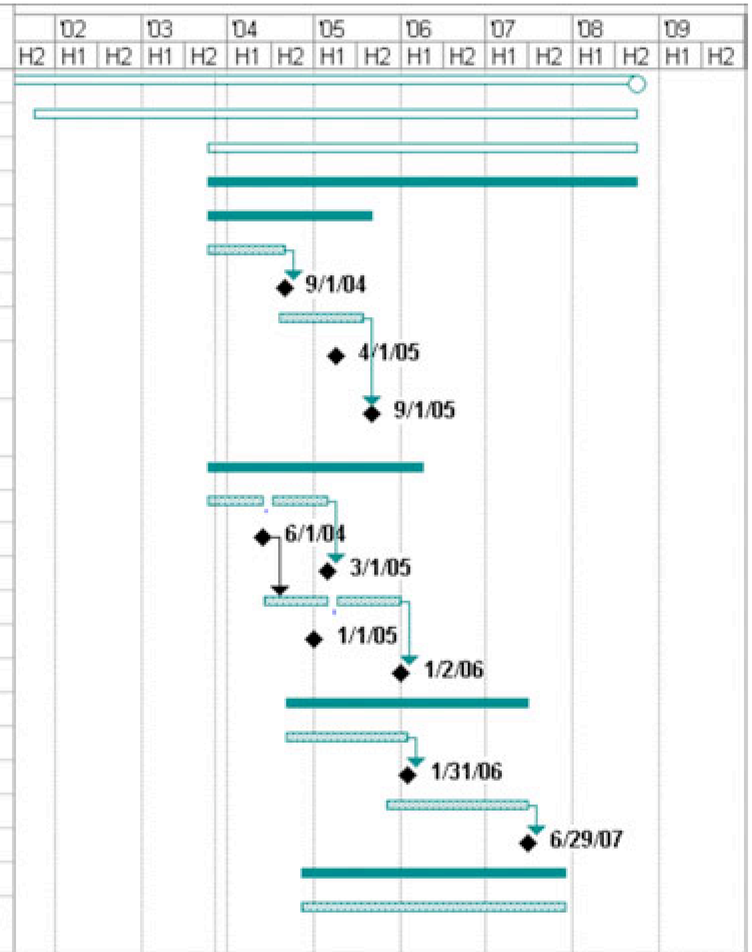


Figure 8: Feedstock Interface Core R&D Gantt Chart

ID		WBS	Task Name
25		1.1.1.1.4.2	develop final design and build prototype
26		1.1.1.1.4.3	Test/evaluate and optimize prototype single-pass harvester
27		1.1.1.1.4.4	Demonstrate prototype single-pass harvester
28		**1.1.1.1.5**	**Integrated Selective, Multi-Component, Single-Pass Harvester**
29		1.1.1.1.5.1	integrate three capabilities into an integrated harvester
30		1.1.1.1.5.2	develop final design and build prototype
31		1.1.1.1.5.3	evaluation, testing and optimization
32		1.1.1.1.5.4	protoype successfully demonstrated
33		1.1.1.1.6	Prototype harvester
34		**1.1.1.2**	**Biomass Bulk Processing and Storage**
35		**1.1.1.2.1**	**Dry Storage Systems**
36		1.1.1.2.1.1	evaluate feedstock and format
37		1.1.1.2.1.2	evaluate environmental effects and how to control
38		1.1.1.2.1.3	evaluate storage system configurations
39		1.1.1.2.1.4	develop conceptual designs of storage system configurations
40		1.1.1.2.1.5	storage system design and testing
41		1.1.1.2.1.6	prototype dry storage system testing satisfactory
42		1.1.1.2.2	Prototype dry storage system
43		**1.1.1.2.3**	**Wet Storage Systems**
44		1.1.1.2.3.1	evaluate feedstock diversity and format
45		1.1.1.2.3.2	develop ensiling requirements including pile design
46		1.1.1.2.3.3	investigate acidified anerobic storage
47		1.1.1.2.3.4	wet storage requirements defined
48		1.1.1.2.3.5	develop and evaluate wet storage system configurations
49		1.1.1.2.3.6	develop conceptual designs of storage system configurations
50		1.1.1.2.3.7	wet storage system final prototype design
51		1.1.1.2.3.8	storage system design, testing and optimization
52		1.1.1.2.3.9	prototype wet storage system testing satisfactory
53		1.1.1.2.4	Prototype wet storage system

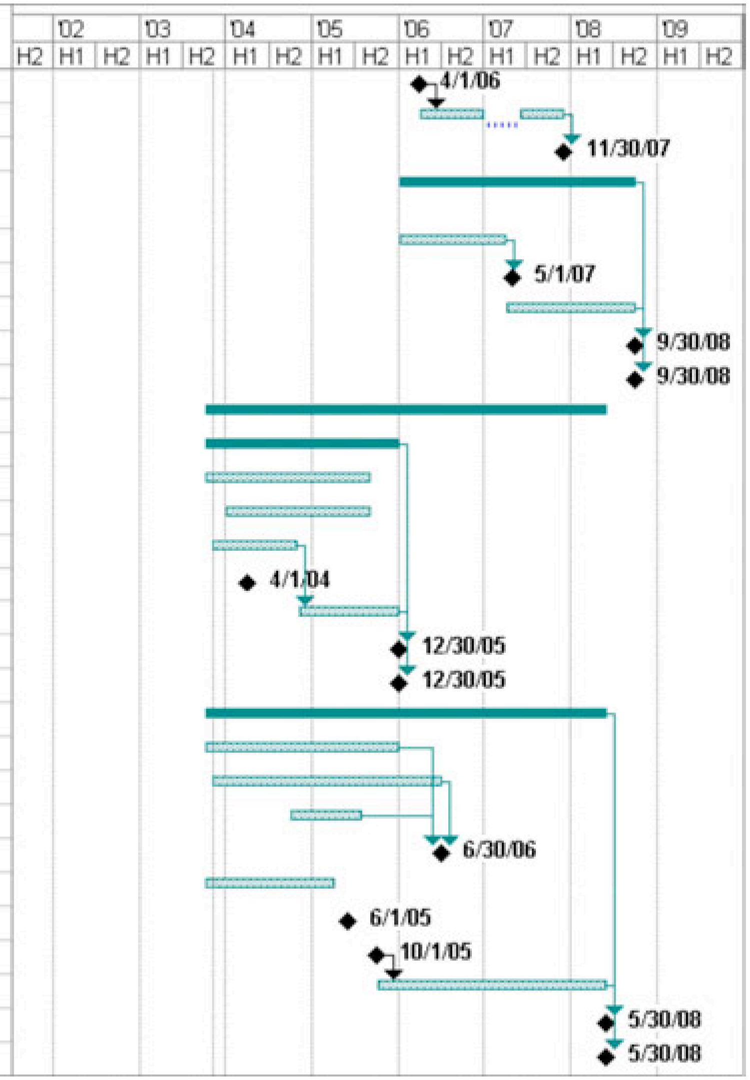


Figure 8: Feedstock Interface Core R&D Gantt Chart (continued)

ID		WBS	Task Name
54		**1.1.1.2.5**	**Preprocessing**
55		1.1.1.2.5.1	develop understanding of biomechanical and physical properties
56		1.1.1.2.5.2	develop preprocessing for size reduction, flowability and density
57		1.1.1.2.5.3	develp prototype bulk preprocessing and handling system configurations
58		1.1.1.2.5.4	test and optimize prototype system configurations
59		1.1.1.2.5.5	prototype field testing of bulk collection system results satisfactory
60		1.1.1.2.5.6	Prototype field testing of bulk collection system results satisfactory
61		**1.1.2**	**GO Selective Harvest Wheat Straw (State of Idaho)**
62		1.1.2.1	Selective Harvest Wheat Straw (State of Idaho)
63		1.1.2.2	Idenity and evaluate low-cost methods for removing undersirable components from wheat straw
64		**1.1.3**	**GO Multi-Component Harvest (IA State U.)**
65		1.1.3.1	Multi-Component Harvest (contract)
66		1.1.3.2	Develop commercially viable technologies needed to use crop residu
67		**1.2**	**Advanced Feedstock Barrier R&D**
68		**1.2.1**	**GO Native Flora Utilization (Earmark)**
69		1.2.1.1	GO Native Flora Utilization (contract)
70		1.2.1.2	Determine technical/economic feasibility and enviromental implications of Norther Plains cellulosic ethanol industry
71		1.2.2	GO Hybrid Poplar Research (Earmark)
72		**1.2.3**	**GO Salix Consortium**
73		1.2.3.1	GO Salix Consortium (contract)
74		1.2.3.2	Produce, harvest, preprocess, and deliver willow for power Northeast
75		**1.2.4**	**GO IA Switchgrass**
76		1.2.4.1	GO IA Switchgrass Subcontract
77		1.2.4.2	Determine technical/economic feasibility and enviromental implications of Norther Plains cellulosic ethanol industry

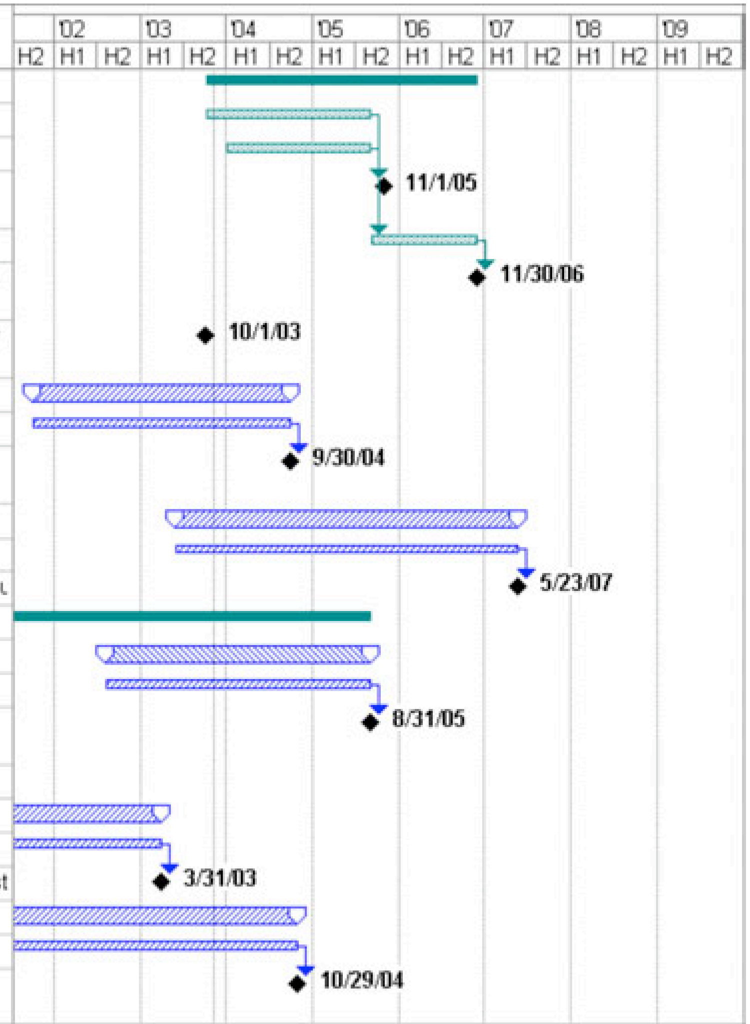


Figure 8: Feedstock Interface Core R&D Gantt Chart (Continued)

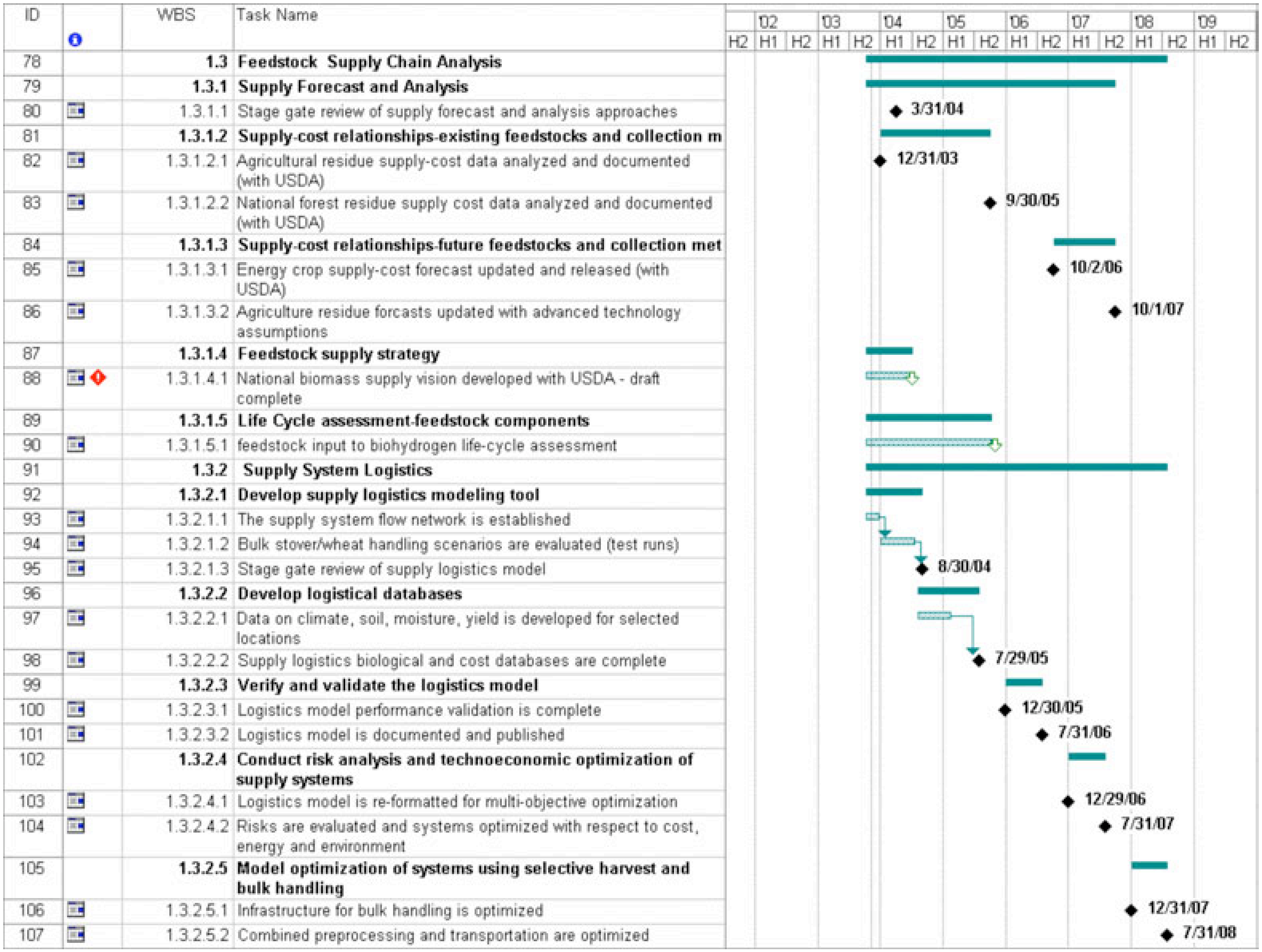


Figure 8: Feedstock Interface Core R&D Gantt Chart (Continued)

2.1.5 Feedstock Interface Projects and Milestones

Table 2: Feedstock Interface Projects and Milestones

Biomass Program Goal: To develop sustainable technologies capable of supplying lignocellulosic biomass to biorefineries producing fuels, chemicals, heat and power.

Objective:

- Develop selective biomass harvest and collection technologies necessary to meet the 1 billion tons per year by 2030 goal and a near-term (2010) goal of 300 million dry tons per year in a sustainable manner.
- Develop feedstock infrastructure technologies necessary to meet the $35/ton price target while assuring an economically sustainable venture for growers, equipment manufacturers and biorefinery processors.
- Develop feedstock supply forecasts, models and analyses necessary to optimize feedstock supply chains to biorefineries and reduce supply risks.

Technical Barrier Area	**Project**	**Specific Technical Barriers Addressed**	**Milestones**
Engineering Feedstock Barrier R&D OBP/GO/NBC	1.1.1.1 Harvesting and Collection	• Biomass cannot be selectively harvested to meet sustainability and availability targets. • Grain harvest occurs in a short time window and modern day combines are operating at their maximum capacity. • Current biomass harvest technologies require multiple passes across the field increasing costs and soil compaction.	Selective Harvest 4/1/04 Technical properties determined for cereal straw 9/1/04 Mechanical properties determined for corn stover 4/1/05 Mechanical fractionation prototype lab testing results satisfactory 9/1/05 Mechanical fractionation prototype filed testing results satisfactory 6/1/04 Grain and biomass separation model developed and validated 3/2005 Selective biomass separation model developed and validated

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
			1/2005 Separation prototype virtual testing results satisfactory 1/2006 Separation prototype field testing results satisfactory Multi-component harvester 1/2006 Prototype designed and built 6/2007 Prototype testing results satisfactory Single-Pass 4/2006 Prototype designed and built 10/2006 Prototype testing results satisfactory on cereal straw 11/2007 Prototype testing results satisfactory of corn stover Integrated Selective, Multi-Component Single-Pass Harvester 5/2007 Prototype designed and built 9/2008 Prototype successfully demonstrated
	1.1.1.2 Biomass Bulk Processing and Storage	• Handling and storage of high moisture biomass. • High moisture biomass in susceptible to spoilage, rotting, spontaneous combustion, and odor problems that will result in significant to complete loss of the biomass if not stored and handled properly.	Dry Storage Systems 4/2004 Develop conceptual designs of storage system configurations 12/2005 Prototype dry storage system testing satisfactory Wet Storage Systems 6/2005 Develop conceptual designs of storage system configurations

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
		stored and handled properly. • Distributed preprocessing. Lignocellulosic biomass is inherently lightweight and difficult to collect and handle. • Preprocessing 3,000 tons/day of biomass feedstocks at the biorefinery is costly and creates a number of environmental and safety hazards. • Bulk handling. Current bale-based methodologies for harvesting, collecting, storage, and transport of the biomass are too costly and inefficient for handling million ton quantities of biomass.	system configurations 10/2005 Wet storage system final prototype design 6/2006 Wet storage requirements defined Preprocessing 11/2005 Develop prototype bulk preprocessing and handling systems 11/2006 Prototype field testing of bulk collection systems satisfactory
	1.1.2: GO Selective Harvest Wheat Straw (State of Idaho)	• Biomass cannot be selectively harvested to meet sustainability and availability targets • Feedstocks – engineering systems • Sugar biorefinery – pretreatment • Products – Syngas Conversion	9/2004 Create a preliminary full-scale design for modified/new equipment to harvest, handle, and store straw stems. 9/2004 Complete feedstock testing for combustion and straw-thermoplastic composites. 9/2004 Develop biological pretreatment methodology

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
		Conversion	pretreatment methodology
	1.1.3: GO Multi-Component Harvest (Iowa State University)	• Wheat straw is not economically utilized as an inexpensive source of commodity fermentable sugars due to obstacles including capital costs, energy consumption, waste streams, production logistics, and the quality of the biomass feedstock. These obstacles hinder industrial-scale production of sugars from crop residues..	12/2002 Wheat lignin regulation genes identified and cloned 7/2003 Complete alteration of lignin biosynthetic pathway to reduce wheat straw lignin content 12/2002 Complete biomass separation experiments and visualize results in the virtual combine chamber 3/2004 Validate threshing/separation numerical models 10/2004 Virtual simulation/engineering tools functioning for CNH design team review 5/2004 Install pre-commercial intelligent control system sensors and software on CNH combines 10/2004 Complete sugar yield assessment and hydrolysis processing optimization of the harvested altered wheat straw
Advanced Feedstock Barrier R&D OBP/GO/NBC	1.2.1 GO Native Flora Utilization (Earmark)	• Broad ranging from feedstock production to use.	09/2005 Perform research on the technical and economical feasibility and environmental implications of developing a cellulosic ethanol industry moving west from Minnesota into North and South Dakota

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
			implications of developing a cellulosic ethanol industry moving west from Minnesota into North and South Dakota
	1.2:2 GO Hybrid Poplar Research (Earmark)	• Broad ranging issue for implementing fast growing tree plantations.	TBD Crop Development Research TBD Integrated Research Program TBD Full Cost/Benefit Analysis
	1.2.3 GO Salix Consortium	• Inefficient willow harvesting • Lack of delivery systems for willow biomass • Need for long-term fuel supply agreements	10/2003 Process improvements B Double harvester and chipper performance 10/2003 Secure commercial hauling contractors and delivery agreements 10/2003 Establish permanent harvesting operations 10/2003 Finalize logistics and accounting for WilloWatts at Dunkirk
	1.2.4 GO IA Switchgrass	• Feedstocks engineering systems	1/2004 Complete Interim Test Burn at Ottumwa Generating Station 5/2004 Finalize Permanent Installation Equipment Design 5/2005 Complete Long-Term Test Burn at Ottumwa Generating Station 9/2005 Complete all market development issues, including contractual arrangements, required to support the commercial use of biomass to generate energy.

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
			arrangements, required to support the commercial use of biomass to generate energy.
	1.3.1 Supply Forecasts and Analysis	• Lack of credible data on price, location, quantity, and quality of biomass.	12/2003 Document FY2003 analysis of current sustainable corn stover and wheat straw supplies. 6/2004 Develop and document a vision for achieving an annual biomass supply of 1 billion dry tons under $35/ton, identifying the feedstock handling and agricultural production changes that will be needed to support a biorefinery industry. 9/2005 Re-evaluate forest residue supply forecasts information (with USDA) and put on website 9/2006 Update energy crops supply forecasts with new assumptions and put on website 9/2007 Update agricultural residues supply forecasts with advanced technology assumptions and put on website.
	1.3.2 Supply System Logistics	• Feedstock supply is a significant cost component of bio-based fuels, products or power.	7/2004 Develop supply logistics modeling tool, evaluate scenarios

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
		component of bio-based fuels, products or power. • The uncertainty and fear of feedstock supply chain risks is a major barrier to procuring capital funding for start-up biorefineries.	scenarios 7/2005 Develop logistical databases 7/2006 Verify, validate and publish logistics model 7/2007 Evaluate supply system risks (with industry partners) 7/2008 Model optimization of supply chain systems using selective harvest and bulk handling

2.1.6 Resource Allocation Plan

Current and planned projects in the Feedstock Interface Core R&D area through FY 2008 represents over $80 million of investment, with around $53 million in DOE funds leveraged with cost share from Program partners to a total of $80 million (see Figure 9). The year-to-year spending the projects in this area are shown in Table 3 and in Figure 10. The high level of spending in 2003 reflects the last year of spending on the Iowa Switchgrass project in Chariton Valley. Most of the research spending for the Feedstock Interface Area is related to meeting the needs of agricultural residue collection and delivery infrastructure in time for the first corn stover based biorefineries, anticipated to be in place by 2010. In addition, the Biomass Program is supporting resource analysis related to understanding the cost, amount, and sustainability of biomass supplies. Planned spending drops off by 2008, assuming that new feedstock harvest and collection technology development will shift to the private sector as demand for biomass supplies become substantial.

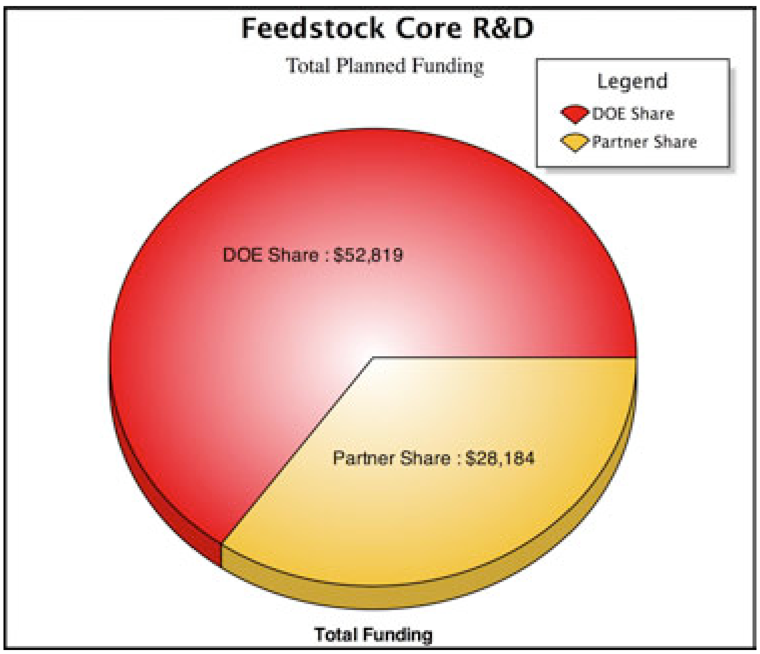


Figure 9: Total Planned and Currently Commited Funding for Feedstock Interface Core R&D[2]

[2] Includes pre-FY 2004 dollars from DOE and partners for ongoing projects started prior to the start of this plan. See funding details in Table 7

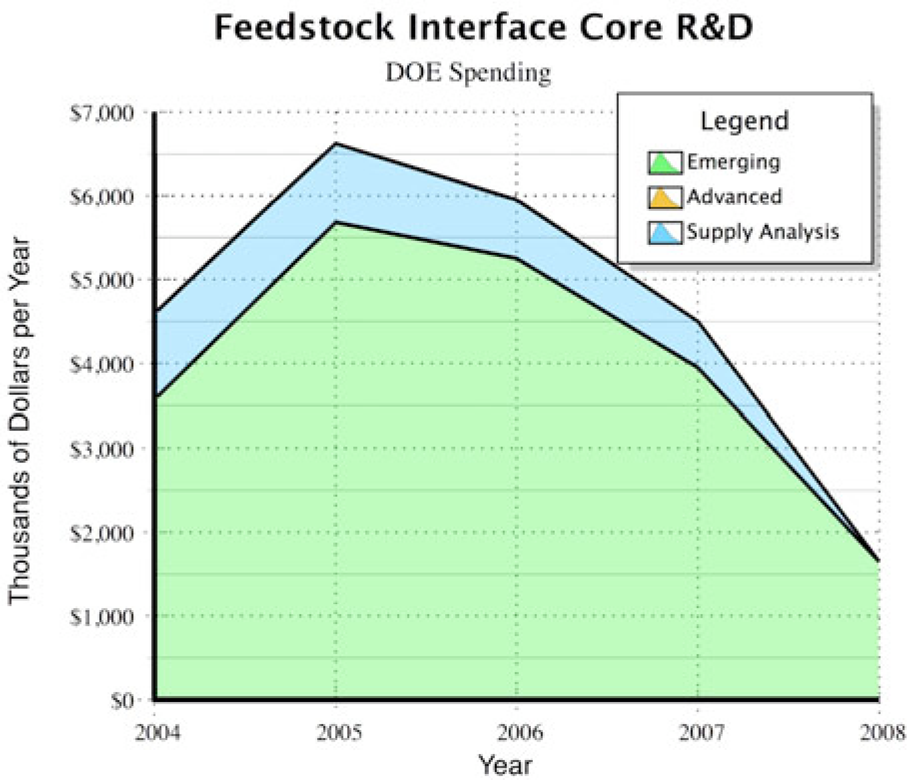


Figure 10: Feedstock Interface Core R&D Resource Plan

Table 3: Feedstock Interface Resources *Fully Funded Prior to FY04

WBS	Title	2003	2004	2005	2006	2007	2008
1	**Feedstock Interface Core R&D**	**$56,615**	**$6,036**	**$6,652**	**$5,950**	**$4,250**	**$1,500**
	DOE Share	***$28,978***	***$5,536***	***$6,605***	***$5,950***	***$4,250***	***$1,500***
	Partner Share	***$27,637***	***$500***	***$47***	***$0***	***$0***	***$0***
1.1	Emerging Feedstock Barrier R&D Subtotal	$1,380	$5,016	$5,707	$5,250	$3,700	$1,500
	DOE Share	*$998*	*$4,516*	*$5,660*	*$5,250*	*$3,700*	*$1,500*
	Partner Share	*$382*	*$500*	*$47*	*$0*	*$0*	*$0*
1.1.1	NBC Feedstock Infrastructure Subtotal	$0	$3,514	$5,660	$5,250	$3,700	$1,500
	DOE Share	*$0*	*$3,514*	*$5,660*	*$5,250*	*$3,700*	*$1,500*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
1.1.1.1	Harvesting and Collection	$0	$2,373	$3,780	$3,500	$2,550	$1,050
	DOE Share	*$0*	*$2,373*	*$3,780*	*$3,500*	*$2,550*	*$1,050*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
1.1.1.2	Biomass Bulk Processing and Storage	$0	$1,141	$1,880	$1,750	$1,150	$450
	DOE Share	*$0*	*$1,141*	*$1,880*	*$1,750*	*$1,150*	*$450*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
1.1.2*	GO Selective Harvest Wheat Straw (State of Idaho)	$1,380	$0	$0	$0	$0	$0
	DOE Share	*$998*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$382*	*$0*	*$0*	*$0*	*$0*	*$0*
1.1.3	GO Multi-Component Harvest (IA State Univ)	$0	$1,502	$47	$0	$0	$0
	DOE Share	*$0*	*$1,002*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$500*	*$47*	*$0*	*$0*	*$0*
1.2	Advanced Feedstock Barrier R&D Subtotal	$55,235	$0	$0	$0	$0	$0
	DOE Share	*$27,980*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$27,255*	*$0*	*$0*	*$0*	*$0*	*$0*
1.2.1*	GO Native Grass Utilization Project	$1,176	$0	$0	$0	$0	$0
	DOE Share	*$940*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$236*	*$0*	*$0*	*$0*	*$0*	*$0*
1.2.2	GO Hybrid Poplar Research (Earmark)	$481	$0	$0	$0	$0	$0
	DOE Share	*$481*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
1.2.3*	GO Salix Consortium	$19,168	$0	$0	$0	$0	$0
	DOE Share	*$9,354*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$9,814*	*$0*	*$0*	*$0*	*$0*	*$0*
1.2.4*	GO IA Switchgrass	$34,410	$0	$0	$0	$0	$0
	DOE Share	*$17,205*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$17,205*	*$0*	*$0*	*$0*	*$0*	*$0*
1.3	Feedstock Supply Chain Analysis	$0	$1,020	$945	$700	$550	$0
	DOE Share	*$0*	*$1,020*	*$945*	*$700*	*$550*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*

2.2 The Sugar Platform

Lignocellulosic biomass is essentially a heterogeneous composite of interlinked hemicellulose, cellulose, and lignin polymers. Cellulose—a crystalline polymer of glucose—and hemicellulose—a non-crystalline polymer of the hexoses D-glucose, D-galactose, and D-mannose and the pentoses D-xylose and L-arabinose (and minor levels of acetic and uronic acids)—together make up the carbohydrate portion of biomass, constituting approximately two thirds of biomass on a dry weight basis. Lignin, a high-energy polymer of alkyl-linked phenolic units, constitutes the majority of the remainder. Other minor components include protein, oils, and waxes.

Lignocellulosic biomass can be converted into mixed sugar solutions plus lignin-rich solid residues by the sequential use of thermochemical pretreatment and enzymatic saccharification. Technical barriers impacting cost and performance currently hinder commercialization of this technology; projected operating and capital equipment costs for facilities implementing the best developed technology exceed those of current grain-based alternatives. OBP and its predecessors have historically supported fundamental and applied research and technology development targeted at producing low-cost sugars from lignocellulosic biomass with fuel ethanol as an end product. Figure 11 shows how the Program's view of this technology has evolved into the concept of the emerging sugar biorefinery—a concept that is central to most of the work planned in this core R&D area.

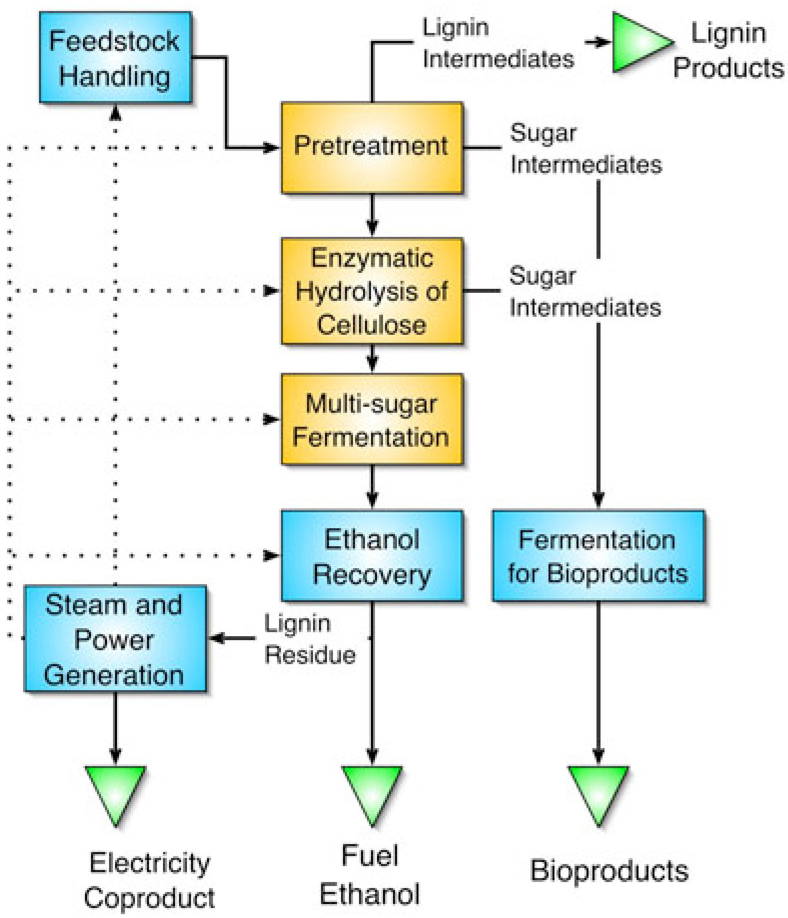


Figure 11: Schematic of an Emerging Sugar Biorefinery

2.2.1 Technical Goals and Objectives

The technical goal of the Sugar Platform is to develop the capability for using lignocellulosic biomass to produce inexpensive sugar streams that can be used for the production of fuels, other chemicals, and materials. The 2010 goal is to reduce the cost of a mixed, dilute sugar stream suitable for fermentation to ethanol, in a mature biochemical plant, from the 2003 estimated cost of $0.14/lb to $0.07/lb.

2.2.2 Programmatic Status

The Sugar Platform is derived from work supported by the previous Office of Fuel Development targeting production of fuel ethanol from lignocellulosic biomass. With the reorganization of EERE, the efforts to produce inexpensive, mixed sugar streams have been separated from the production of fuel ethanol, which now lies in the Products area. The model process for lignocellulosic saccharification, selected to provide necessary focus for a resource-limited effort, includes thermochemical pretreatment followed by enzymatic saccharification. Modest efforts with alternative model processes have been and continue to be included in the research. Status of the work on the Sugar Platform core R&D is summarized below:

Analysis in Support of the Sugar Platform

- A technoeconomic model of dilute acid pretreatment/cellulase saccharification/ethanol process has been developed and refined

Pretreatment

- Preliminary technoeconomic analysis has been extended to alternative pretreatment chemistries represented in the Biomass Refining Consortium on Applied Fundamentals and Innovation (CAFI)
- Improved cellulose digestibility has been demonstrated with pretreated and hot washed material using a Pneumapress
- Improved total saccharification with dilute acid has been demonstrated with a novel “shrinking bed” reactor design

Enzyme Hydrolysis

- Subcontracts with major enzyme-producing companies have provided 10X cost reductions for cellulases
- Different performance in alternate cellulase assays has suggested a need to identify factors to clarify results and an opportunity for cellulase improvement
- Thermotolerant and high-specific-activity glycosyl hydrolases have been identified

Sugar Platform Integration

- Pretreatment demonstrated at solids levels approaching 35%
- Rapid analysis methods developed for corn stover and pretreated corn stover using multivariate analysis to correlate near-infrared spectroscopy with wet chemical analyses

Advanced Fractionation and Concepts

- Molecular Mechanics Modeling has indicated the presence of high-density water above the hydrophobic face of cellulose
- The crystal structure of a highly active thermophilic family 12 endoglucanase has been solved
- A profile of thermal-up mutations in a family 1 beta-glucosidase has been developed

2.2.3 Technical Barriers

There is a hierarchy of barriers for the Sugar Platform, with each level more specifically targeted to a more specifically defined technology (Figure 12). At the most general tier, the barrier to commercial success is conversion cost for biomass to sugar(s). At a second level, cost elements are described at a generic level: product yield, product concentration, conversion rate, product quality, and capital investment. Selection of a specific technology allows greater specificity of barriers in terms of process unit operations that must perform to standards and process integration that must be achieved to reach cost targets.

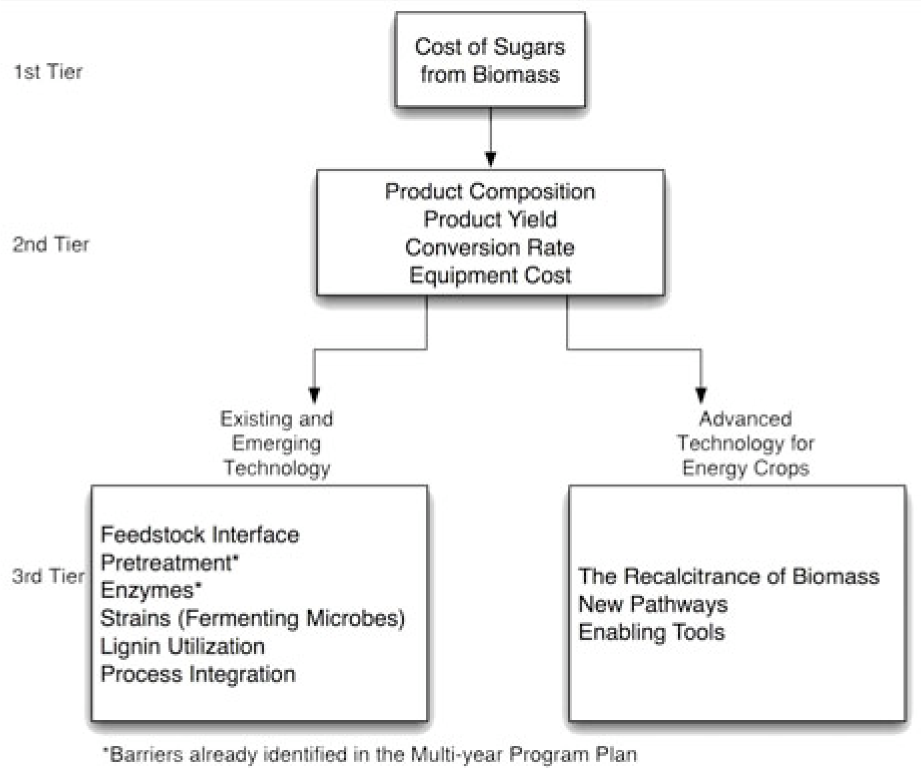


Figure 12: Hierarchy of Barriers to Deployment of the Sugar Platform

In DOE's current multi-year program plan (MYPP), the barriers identified for the Sugar Platform are based on implicit assumptions about the nature of the technology being used. The MYPP identifies only two technical barriers: enzymatic hydrolysis and pretreatment. As shown in Figure 2, these two barriers are specific to the enzymatic hydrolysis process that now serves as the basis for improvements to existing sugar-based biorefineries (e.g, dry and wet mill corn processors) and emerging biorefinery concepts including lignocellulosic biomass, which are being developed by a number DOE industry partners. The Biomass Program identified other barriers within the context of the existing and emerging biorefinery work. The list of barriers to deployment of existing and emerging sugar-based biorefineries now includes:

- Feedstock variability and its effect on process performance

Much of the focus of OBP-supported work over the past several years has been on corn stover as an available low-cost feedstock. The Program's experience with corn stover has proved that it is sufficiently variable in carbohydrate content to warrant the development of analytical methods that provide real-time information on potential sugar yield.

- The need for a cost-effective pretreatment step to release hemicellulose sugars and improve the ability to hydrolyze cellulose

Thermochemical prehydrolysis of biomass, typically referred to as pretreatment, is required to open up the structure of biomass and increase its susceptibility to subsequent enzymatic hydrolysis by cellulase enzymes. In the nearer term, developing lower cost pretreatments depends on the ability to process the biomass at high solids levels in reactors fabricated out of cost-effective materials. Pretreatment catalyst use and the requirement for any catalyst recovery and recycle also must be considered in the overall costs of the pretreatment step. In the longer term, continued significant cost reductions in pretreatment technologies require developing a better understanding of pretreatment process chemistries and elucidating the roles that biomass structure and composition play in biomass recalcitrance.

- The lack of cost-effective enzymes to catalyze the hydrolysis of cellulose to glucose

Cellulase enzymes remain a significant portion of the projected production cost of sugars from lignocellulosic biomass, despite approximately tenfold cost reductions achieved in recent OBP-sponsored cost reduction subcontracts to industry. In the nearer term, reducing the cost of enzymatic hydrolysis depends on developing lower cost enzyme production technologies ($/kg enzyme) in conjunction with identifying more efficient enzyme preparations and enzyme hydrolysis regimes that permit lower dosages (kg enzyme/kg substrate) to be used. Substrates that allow for enhanced enzymatic hydrolysis as a result of improved pretreatment processes can also impact the enzyme use requirements and thus the overall costs of enzymes for production of sugars. In the longer term, enzymes that exhibit high thermostability and substantial resistance to sugar end-product inhibition will be essential to fully realize enzyme-based sugar platform technology. The ability to develop such enzymes and consequently very low enzymatic hydrolysis technology requires increasing our understanding of the fundamental mechanisms underlying the biochemistry of enzymatic cellulose hydrolysis, including the impact of biomass structure on enzymatic cellulose decrystallization.

- The need for robust biological and chemical catalysts capable of utilizing all sugars in biomass and able to handle pretreated biomass

Sugar solutions resulting from thermochemical pretreatment are impure, containing a mixture of sugars and a variety of non-sugar components. Potential impurities include acetic acid liberated upon hydrolysis of hemicellulose, lignin-derived phenolics solubilized during pretreatment, inorganic acids or alkalis or other compounds introduced during pretreatment, various salts, and hexose and pentose sugar degradation or transglycosylation products. Mixed sugars alone provide significant conversion challenges for many target products, and the presence of other compounds that can be inhibitory to microbial fermentation or biocatalysis or which can poison chemical catalysts further adds to these technical challenges. Despite significant progress in developing microorganisms capable of producing ethanol from all biomass sugars at high selectivity and yield, strains that perform robustly on pentoses remain elusive; much greater hardiness is typically observed in hexose-using strains. Even less progress has been made in developing chemical catalysts for high-selectivity mixed sugar conversion. Currently, neither appropriate microorganisms nor appropriate chemical catalysts are available that enable economic utilization of complex, impure, biomass-derived sugar streams. Thus, in the nearer term, more economical methods of separating sugars prior to conversion, or of separating products from sugar mixtures after conversion, are needed to exploit existing microbial, enzymatic, and chemical catalysts. In the longer term, efforts must continue to develop hardier and more effective microbial and chemical catalysts.

- The uncertainty surrounding the use of lignin for producing heat, power, and other products

Process residues remaining after the conversion of the carbohydrates in biomass to sugars contain mostly lignin, a relatively high-heat-content material that was assumed to be used in the sugar biorefinery as its sole source of heat and power. There is, however, no experience working with this relatively high-moisture-content material in commercial boiler/turbogenerator systems. The potential for generating higher value products from lignin is an unpopulated target of the Products area.

- The lack of experience with and understanding of the complex interactions among each of the steps in an integrated process

Beyond the core saccharification steps of pretreatment and enzymatic hydrolysis, process integration remains a key technical barrier hindering development and deployment of biomass sugar platform technology. Sugar platform technology currently presents large scale-up risks because there is a dearth of high-quality performance data on integrated processes carried out at the high solids conditions required for industrial operations. Nearer term process integration work is essential to characterize the complex interactions that exist between many of the processing steps, identify unrecognized separation requirements, process bottlenecks and knowledge gaps, and generate the integrated performance data necessary to develop predictive mathematical models that can be used to guide process optimization and scale-up. Demonstrating integrated process technology is also a prerequisite to producing process intermediates (e.g., pretreated solids that are required to evaluate the progress of enzyme cost reduction efforts) and residues (e.g., residual lignaceous process solids that are needed to validate their assumed value as an energy source for producing steam, heat, and electricity, or as a substrate for gasification to produce a biomass-derived synthesis gas or pyrolysis to produce a biomass-derived high-energy liquid).

By expanding the view of the technology barriers beyond the existing and emerging technology to consider future technology options yet to be determined, other more fundamental barriers have been identified:

- The lack of understanding of the root causes of the recalcitrance of biomass

For more than a century, scientists and engineers have worked to overcome the natural resistance of biomass to chemical and/or biological degradation. The body of research in this area, which is often highly empirical in nature, has led to improvements in yield and cost of accessing the sugars. This empirical approach, however, is not good enough to meet the kind of aggressive performance requirements needed to compete with petroleum. The leap to this level of competitive technology will require delving into the fundamentals of biomass structure and its effects on chemical and biological hydrolysis and the interaction between biomass and chemical and biological catalysts.

- Limited understanding of the potential for alternative conversion technology pathways

Making the leap from technology that can compete in niche or marginal markets for fuels and products also requires expanding the array of possible concepts and strategies for processing biomass. Concepts such as consolidated bioprocessing, in which the hydrolysis and conversion of carbohydrates to products is done using a single organism, offer new possibilities for leapfrog improvements in yield and cost. New concepts are likely to arise from the advances in fundamental understanding of biomass and its hydrolysis.

- Lack of fundamental enabling technology tools

Much more work is needed to develop a comprehensive list of these fundamental barriers. OBP uses technoeconomic analysis to judge the relative cost impacts of addressing these technical barriers for a given technology. Figure 3 is an example of such an analysis for a number of the critical barriers identified in the emerging sugar platform based on enzymatic hydrolysis technology. In this case, analysis examined the impact of progress on the following barriers:

- FY 03 Cost: Represents the plant performance in line with what has been experimentally verified. The overall cost is dependent upon the assumed cost of feedstock delivered to the plant. $53 per ton has been used here.[3]

---

[3] The cost of $2.73 per gallon is based on a modification to a documented case for current ethanol cost based on best available experimental data and a feedstock cost of $40 per dry ton. At $40 per dry ton, the cost of ethanol was

- Feedstock Interface: Reduce cost of feedstock from $53 to $30 per dry ton; this or another goal would be better stated in terms of ethanol potential per ton of biomass
- Pretreatment: Increase yields of hemicellulosic sugars from demonstrated level of 60%-70% to 80%
- Pretreatment: Decrease pretreatment systems capital cost by 24% based on by increasing solids concentration in the reactor from 19% to 30%. This lowers capital cost for pretreatment equipment from 35.8 million in FY 03 to $27.4 million.
- Enzymatic Hydrolysis: Reduce the cost of enzyme from $0.64[4] to $0.10 per gallon of ethanol
- Strains: Achieve high yields of ethanol from all sugars

As indicated in Figure 13, the cumulative effect of achieving these targets in all of the barriers provides approximately 50% savings in the cost of ethanol relative to the experimentally verified performance of the technology in FY 2003.

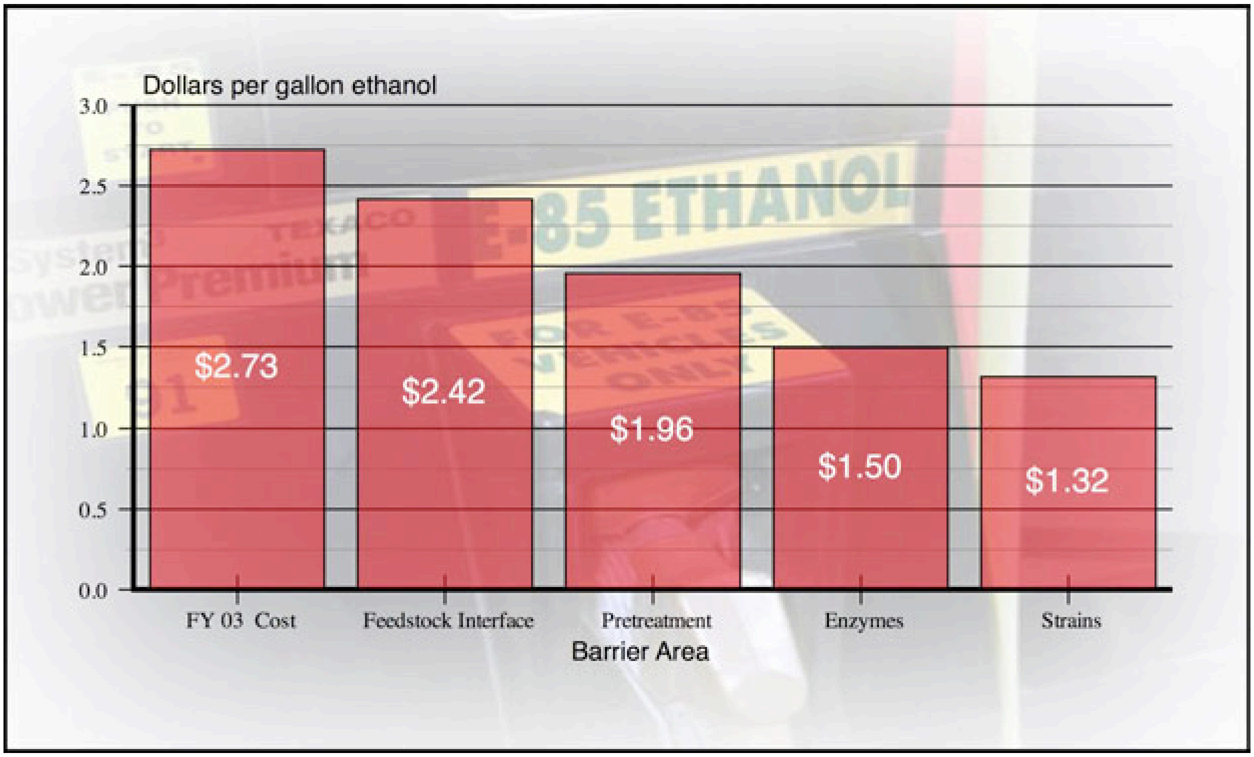


Figure 13: Translating Reductions in Technical Barriers to Cost Savings for the Sugar Platform (1 gallon of ethanol contains 80 MJ of energy (lower heating value))

$2.56 per gallon. (Ruth, M., "Development of Two Process Assessment Cases: 2003 State of Technology and 2002 Experimental Parameters," NREL Technical Memo, October 8, 2003)

[4] Cost of enzyme after improvements in enzyme production process and enzyme performance available at the end of the current industry-led enzyme improvement research subcontracts. The cost of enzymes prior to the initiation of the DOE's contracts with Genencor International and Novozymes Biotech was roughly an order of magnitutde higher

2.2.4 Technical Approach

The core research for the Sugar Platform is organized in terms of the barriers described in the previous section. These barriers can be grouped in terms of those related to existing and emerging biorefinery development and advanced (long-term) biorefinery development. The timing of the core research and development activities related to existing and emerging biorefinery technology is constrained by the timing of industry-led projects aimed at deploying these technologies. In the language of stage gate management, the integrated biorefinery projects being developed by industry are "commercial line" activities, whereas the technical barrier work directly addressed by the program are "research line" activities. This relationship is shown in the Pert chart in Figure 14.

Commercial line activities are already underway in the program, each with the goal of addressing specific opportunities for translating emerging technology into commercial integrated biorefineries or using new technology components in existing biorefineries. As these projects move through process development (stage 3) and into a commercial demonstration (stage 4), they can take advantage of the ongoing core R&D that continues in parallel with them. Obviously, the window of opportunity timeframe for R&D focused on emerging technology becomes more and more constrained as the commercial line projects approach final deployment. Beyond that point, some research can continue on incremental improvements to the new commercial technologies, but this is more likely to be done by industry.

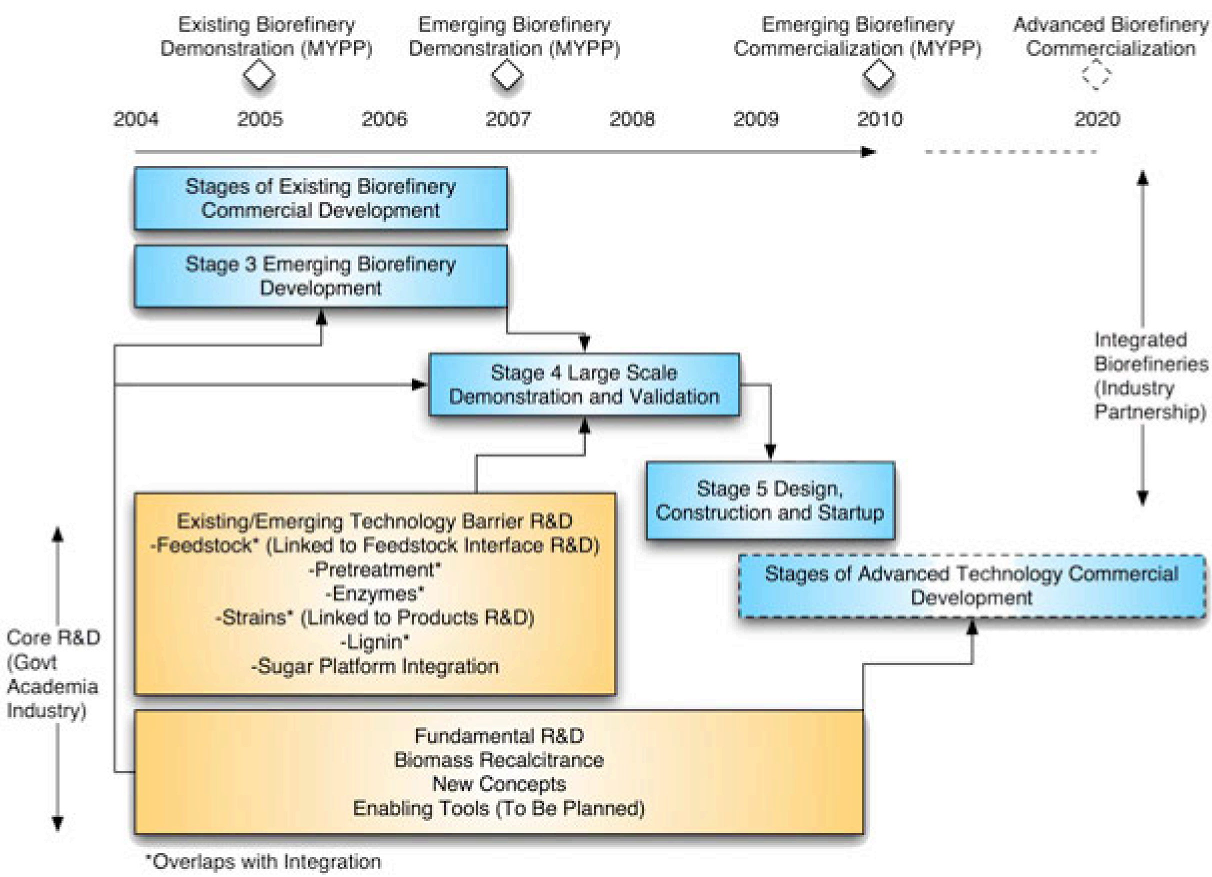


Figure 14: Relation of Sugar Platform Core R&D to Integrated Biorefinery Activities

The commercial line projects drive the timing of many of the major outcomes for the program. Although a better enzyme preparation or a more efficient fermentation strain may be expected to integrate well into a previously designed or constructed facility, substantial changes in pretreatment chemistry or process integration insights might be expected to require expensive retrofits. The existing biorefinery projects support the goal of demonstrating the key technology components of pretreatment and enzymatic hydrolysis in existing corn grain processing facilities in 2005. One or more of the industrially led partnerships established as part of the program's biorefinery solicitation conducted in FY 2002 will lead to the program's two other important outcomes for the sugar platform—demonstration (in 2007) and commercialization (in 2010) of technology capable of producing low-cost sugars.

Research on advanced technology—longer term and higher risk approaches—must begin today. Thus, this MYTP for the Sugar Platform includes research activities that address the more fundamental scientific and engineering issues that face the Sugar Platform if it is to play a role in our long-term energy supply. By focusing on the fundamental causes of biomass recalcitrance, the development of new tools for technology development, and the development and evaluation of new process concepts, these advanced R&D projects will lead to the next generation of technologies that will feed into the commercial development pathway. The timing of this work is inherently less clear than that of the emerging technology projects.

The work breakdown structure shown in Figure 15 translates the core R&D strategy outlined here into a working organization of focused projects. The core R&D effort for the Sugar Platform is broken into five distinct projects. The first three projects directly address three of the existing/emerging technology barriers (pretreatment, enzymes, and process integration). The process integration project includes some limited work on the barriers related to feedstock variability and lignin utilization. The Fractionation Fundamentals and Advanced Concepts project addresses all of the advanced barriers related to understanding the recalcitrance of biomass and developing new concepts for processing of biomass sugars.

Not all of the technical barriers related to the Sugar Platform fall neatly within the bounds of this program area. In the work breakdown structure shown in Figure 15, there are linkages between the Sugar Platform core R&D area and the areas of feedstocks, products from sugars, and commercial line integrated biorefinery projects. The work on feedstocks described in the Feedstock Interface R&D has very close ties with the research done directly in support of the Sugar Platform elements and their integration. Perhaps the most significant crossover occurs between the Products R&D area and the Sugar Platform core R&D. Finally, the line between core R&D and the commercial development of an integrated sugar biorefinery is also hard to draw. Some amount of integration work is critical as part of the development of individual process steps, because it is the integrated performance of these individual steps that is important. Thus, some amount of product-related work will occur as part of the core R&D. In the Sugar Platform, partly because of the Program's history and partly because fuel production is central to the Program, ethanol production is used as a reference product for conducting integrated process research. However, each biorefinery project will face its own specific set of integration issues that are dictated by the specific feedstock, process configuration, and product slate associated with it.

2.2.4.1 Existing and Emerging Sugar Biorefineries

The following briefly summarizes the strategies that underlie each of the three projects that address the technical barrier areas of pretreatment, enzymes, and process integration (see Figure 17 for detailed Gantt chart of activities).

2.2.4.1.1 Pretreatment

More than 20 years of research have gone into developing pretreatment technologies for enzyme-based hydrolysis processes. The emphasis of the Program's work on pretreatment is, therefore, on evaluation of and improvements to the leading pretreatment concepts that have surfaced during this period. Figure 6 is a Gantt chart describing the pretreatment R&D planned to support the existing and emerging biorefinery efforts over the next 5 years. 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 in the FY03 USDA/DOE solicitation. Technoeconomic evaluations of competing pretreatment concepts will be done in two stages, based on the best available data on the performance of each technology. By the end of 2007, consistent comparative data of the top three to five most promising concepts will be available for review by industry partners facing critical technology choices prior to entering the commercial demonstration for their specific emerging sugar biorefinery projects. At the same time, the program will seek opportunities to explore evaluation of near-term pretreatment technologies in existing corn grain dry mills. Adoption of lignocellulose-specific pretreatment technologies provides a way of releasing additional sugars from fiber in the grain and thus offers a means of accelerating commercial experience with these technologies. Finally, the program will support some linking research on the effect of different biomass storage and preprocessing strategies on the performance of pretreatment and subsequent enzymatic saccharification.

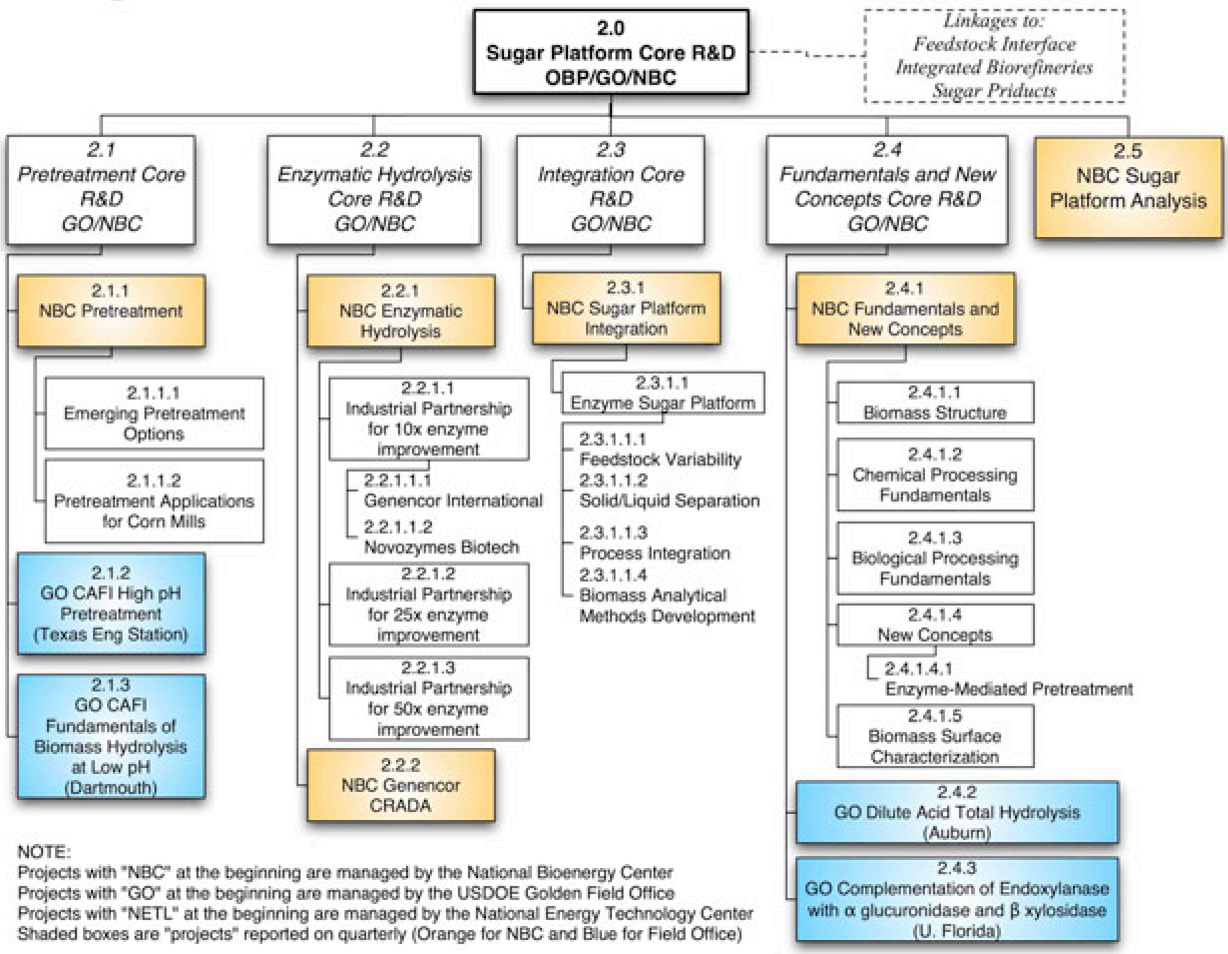


Figure 15: Work Breakdown Structure for the Sugar Platform Core Barrier R&D

2.2.4.1.2 Enzymes for Cellulose Hydrolysis

The Program's strategy for near-term work on reducing the cost of cellulose-hydrolyzing enzymes is to cost share and technically support continued enzyme cost reduction efforts by DOE's industrial enzyme partners, including Genencor and Novozymes. The current projects led by these two companies have led to the potential to reduce enzyme costs to around \$0.30-\$0.50 per gallon of ethanol for an integrated process in which sugars produced by pretreatment and enzymatic hydrolysis of corn stover are converted to ethanol by genetically modified fermenting bacteria. Provided cost share funding continues, both companies are expected by 2005 to have developed a clear route to a final cost of $0.10/gallon ethanol or less by the 2010 commercialization timeframe. Data from further development and evaluation of these second-generation enzymes should be sufficiently complete to support decisions by industrial partners preparing to make critical technology choices for commercial demonstration of their specific emerging sugar biorefinery projects.

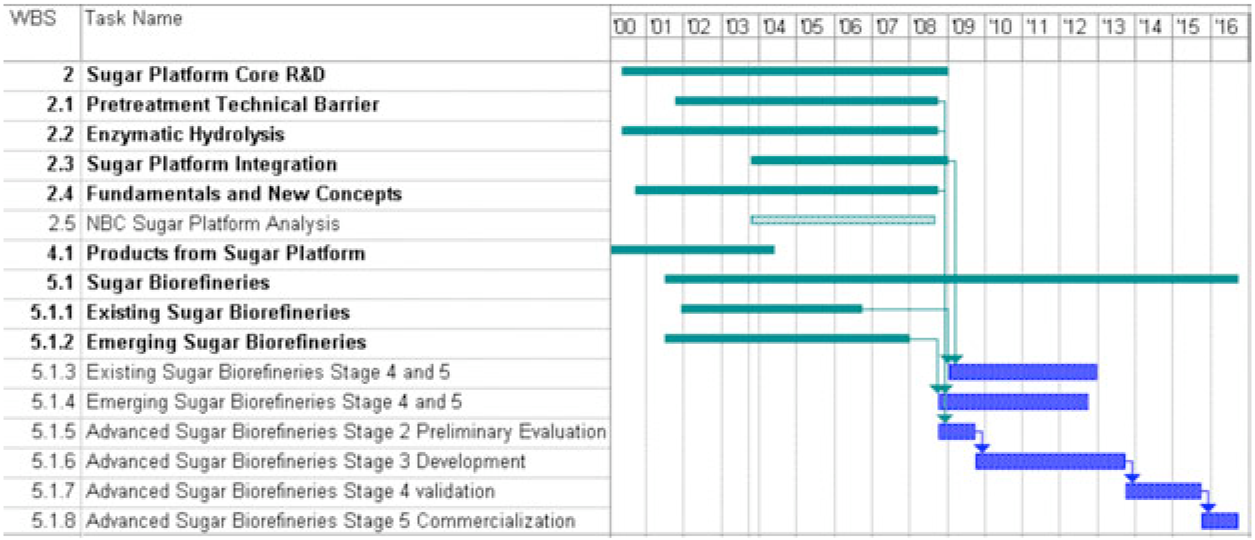


Figure 16: High-Level Gantt Chart of All Sugar Platform Related Activities in the MYTP

2.2.4.1.3 Process Integration in Support of Emerging Biorefineries

The Program's effort to address the barrier of integration focuses on integrating enzymatic hydrolysis process technology based on dilute acid pretreatment that incorporates the advanced, lower-cost cellulase enzymes being developed by Genencor and Novozymes with DOE cost share (see Figure 17 for detailed Gantt chart of activities related to the Sugar Platform). The major milestone is to complete a limited pilot scale demonstration of integrated processing and to use the process performance data to validate (or update) process economic modeling assumptions by 2006. Interim milestones are: 1) demonstrate reliable compositional analysis methods and accurate pretreatment yield measurement (defined as achieving a C-balance closure of 95% across pretreatment) by 2004; 2) achieve high-yield high solids pretreatment (defined as 85% sugar yield from hemicellulose and 90% enzymatic cellulose digestibility at 30% solids) by 2005; 3) demonstrate integrated processing in 2006, with the minimum goals being to run the process continuously for 1 week at the 1-ton/day process scale. Finally, as part of linkage between the Sugar Platform core R&D and the Feedstock Interface R&D, the Program will evaluate factors underlying corn stover compositional variability, with an eye toward strategies that minimize or otherwise exploit this variability. A small effort will be undertaken to validate the combustion value of lignin residues resulting from integrated process testing. Part of this work is the continued development of rapid analysis techniques that support the ability to generate timely mass balance data.

2.2.4.2 Fractionation Fundamentals and Advanced Concepts

The goal of the research for advanced sugar biorefineries is to develop a more fundamental and deeper understanding of the factors and causes underlying the recalcitrance of biomass to biological and chemical degradation. Research on biomass recalcitrance is broken into research on biomass ultrastructure and micro-scale chemistry, fundamentals of biologically based biomass fractionation, and fundamentals of chemically based biomass fractionation. Embodied in much of this work is the development of enabling tools, such as molecular modeling simulations and more accurate and sensitive chemical and structural analysis techniques for characterizing biomass materials at various stages during processing. The Sugar Platform Analysis project captures process engineering and life cycle analysis needed to direct the research by translating all of the proposed and actual outputs from research into quantifiable costs and benefits for the technology.

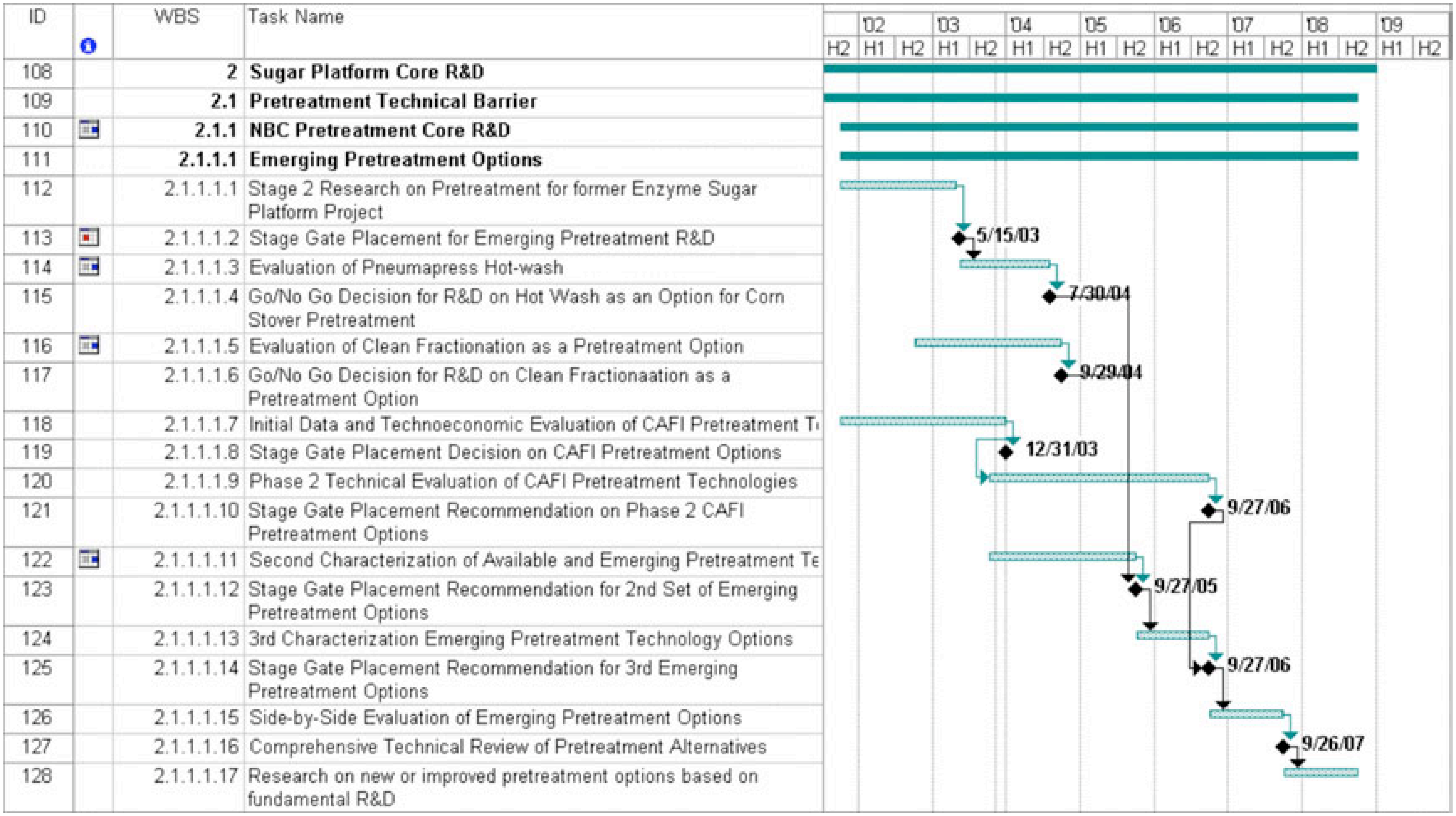


Figure 17: Biomass Program Activities Addressing the Barriers for Deployment of the Sugar Platform

ID		WBS	Task Name
129		2.1.1.1.18	Stage Gate Placement Recommendation for New or Improved Pretreatemnt Options
130		**2.1.1.2**	**Pretreatment Applications for Corn Mills**
131		2.1.1.2.1	Evauate AFEX, Hot Water, and Dilute Acid Pretreatment Options for
132		2.1.1.2.2	Stage Gate Decision Pretreatment Development for Corn Mills
133		2.1.1.2.3	Develop and/or Validate Pretreatment of Corn Fiber in a Corn Mill
134		**2.1.2**	**GO Fundamentals of Biomass Hydrolysis at Low pH (Dartmouth)**
135		2.1.2.1	CAFI Dartmouth project
136		2.1.2.2	Develop models to elucidate fundamental mechanisms underlying hemicellulose release in pretreatment and subsequent enzymatic
137		2.1.3	GO CAFI Integration of Leading Biomass Pretreatment Technologies (Dartmouth)
138		**2.2**	**Enzymatic Hydrolysis**
139		**2.2.1**	**NBC Enzymatic Hydrolysis**
140		**2.2.1.1**	**Industrial Partnerships for 10x Enzyme Improvement**
141		**2.2.1.1.1**	**Genencor International 10x Enzyme Improvement**
142		2.2.1.1.1.1	Genencor International 10x Enzyme Improvement Subcontract
143		2.2.1.1.1.2	Document 10x reduction in enzyme cost for new Genencor International cellulase enzymes
144		**2.2.1.1.2**	**Novozymes Biotech 10x Enzyme Improvement**
145		2.2.1.1.2.1	Novosymes Biotech 10x Enzyme Improvement Subcontract
146		2.2.1.1.2.2	NBC Support of Industrial R&D for 10x Improved Enzyme
147		2.2.1.1.3	Document 10x reduction in enzyme cost for new Novozymes Biotech cellulase enzymes
148		2.2.1.1.4	Go/No Go Decision on Research to Develop 25x Improved Enzyme
149		**2.2.1.2**	**Industry Partnership Research on 25x Improved Enzymes**
150		2.2.1.2.1	NBC Support for Industrial R&D for 25x Improved Enzyme
151		2.2.1.2.2	Provide analysis to support Stage Gate Decision to Continue Industry-led Research for Further Enzyme Cost Reduction
152		2.2.1.2.3	Stage Gate Decision on Enzyme Research
153		**2.2.1.3**	**Industry Partnersho[Research on 50x Improved Enzyme**
154		2.2.1.3.1	Develop new enzymes that contribute no more than $0.10 per gallon to ethanol production

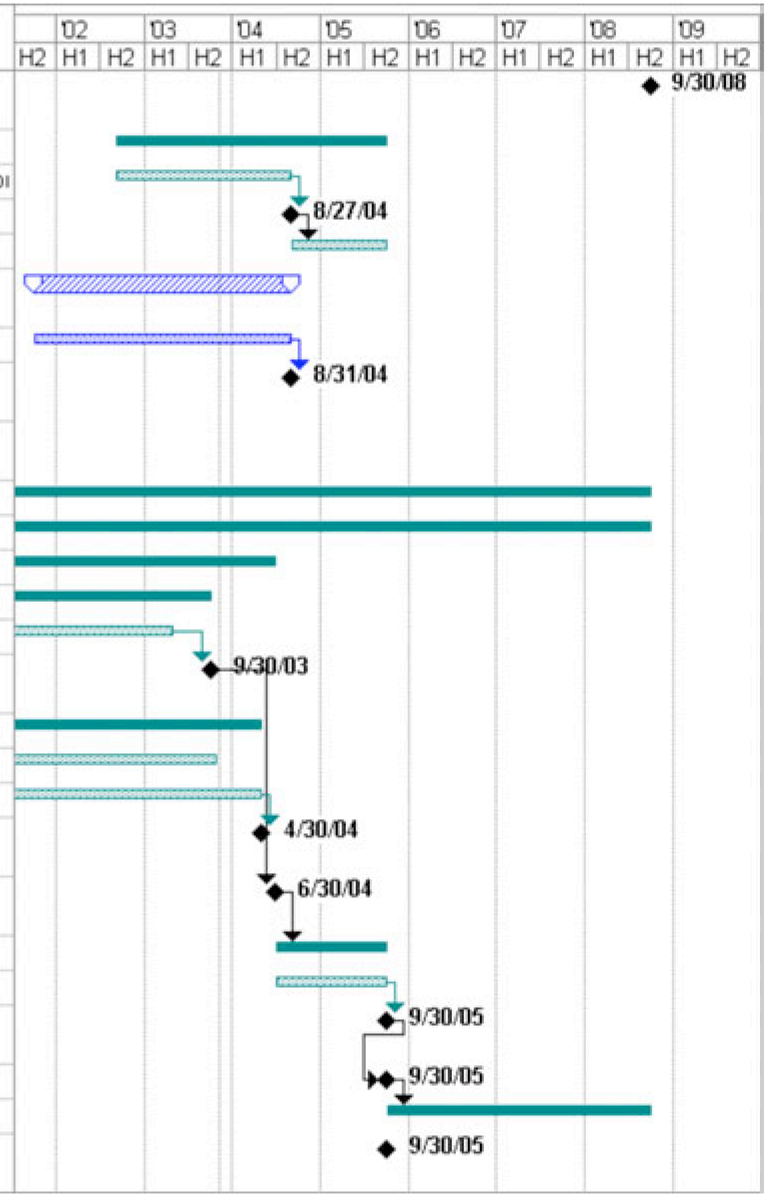


Figure 17: Biomass Program Activities Addressing the Barriers for Deployment of the Sugar Platform

ID		WBS	Task Name
155		2.2.1.3.2	Evaluate Opportunites for Improved Process Configurations
156		2.2.1.3.3	Recommend Improved Processing Methodlogies for Enzymes
157		2.2.1.3.4	Validate Enzyme Cost Reductions
158		2.2.1.3.5	Demonstrate enzyme cost contribution of <$0.10 per gallon of ethanol in model converson process
159		2.2.2	NBC CRADA with Genencor
160		**2.3**	**Sugar Platform Integration**
161		**2.3.1**	**NBC Sugar Platform Integration**
162		**2.3.1.1**	**Enzyme Sugar Platform**
163		**2.3.1.1.1**	**Feedstock Variability**
164		2.3.1.1.1.1	Investigate corn stover variability
165		2.3.1.1.1.2	Supply corn stover to project and industry
166		2.3.1.1.1.3	Investigate other feedstocks (e.g, wheat straw)
167		**2.3.1.1.2**	**Solid/Liquid Separations**
168		2.3.1.1.2.1	Evaluate suitable solid/liquid separation equipment
169		2.3.1.1.2.2	Achieve 95% sugar recovery in solid/liquid separation steps
170		**2.3.1.1.3**	**Process Integration (Corn Stover)**
171		2.3.1.1.3.1	High solids pretreatment (dilute acid)
172		2.3.1.1.3.2	Achieve 85% sugar yield, 90% digestibility
173		2.3.1.1.3.3	High solids saccharification (bench)
174		2.3.1.1.3.4	Achieve 80% cellulose conversion, > 10 solids
175		2.3.1.1.3.5	High yield saccharification
176		2.3.1.1.3.6	Achieve 90% cellulose conversion, >18% solids
177		2.3.1.1.3.7	Residue combustion test
178		2.3.1.1.3.8	Integrated processing demonstration
179		2.3.1.1.3.9	Limited 1 week operation, residue for combustion and wastewater te
180		2.3.1.1.3.10	Process Integration (New Feedstock)

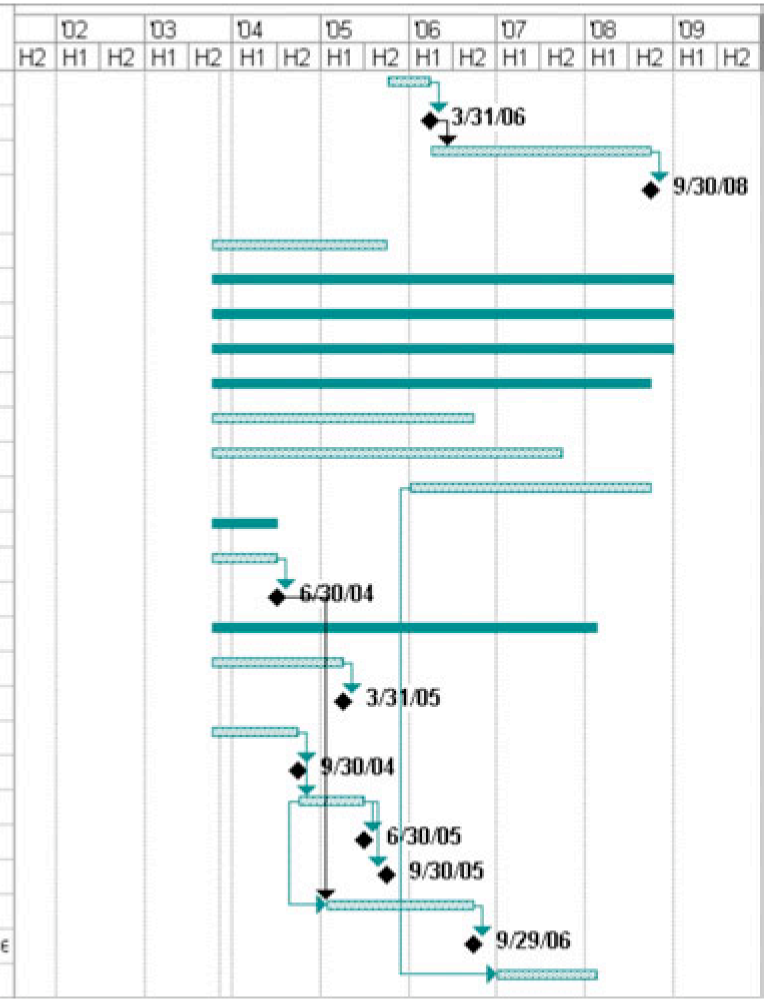


Figure 17: Biomass Program Activities Addressing the Barriers for Deployment of the Sugar Platform

ID		WBS	Task Name
181		**2.3.1.1.4**	**Biomass Analytical Methods Support (Corn Stover)**
182		2.3.1.1.4.1	Rapid analysis
183		2.3.1.1.4.2	Methods development
184		2.3.1.1.4.3	Instrument support
185		2.3.1.1.4.4	Biomass Methods Support
186		**2.4**	**Fundamentals and New Concepts**
187		**2.4.1**	**NBC Fundamentals and New Concepts**
188		**2.4.1.1**	**Biomass Structure**
189		2.4.1.1.1	Feedstock Cellular Structure
190		2.4.1.1.2	Characterize composition and ultrastructure of selected fractions of
191		2.4.1.1.3	Characterize gross physical and chemical properties o diverse varieties of corn
192		2.4.1.1.4	Correlate pretreatment performance with physical and chemical characteristics of diverse varieties of corn
193		**2.4.1.2**	**Chemical Processing Fundamentals**
194		2.4.1.2.1	Chemical Processing Research Task
195		2.4.1.2.2	Decide if ultrastructural characteriation techniques can elucidate the factors influencing enzyme hydrolysis
196		2.4.1.2.3	Determine which ultrastructural properties of dilute acid pretreated biomass have the greatest impact on the susceptibility of cellulose
197		2.4.1.2.4	Initial molecular mechanics computer model to quantify the boundary layer energetics at the cellulose interface using a flowing bulk water mode
198		2.4.1.2.5	Quantify the rate determining steps in dilute acid mediated cellulose hydrolysis through molecular modeling
199		2.4.1.2.6	Determine macroscopic properties of dilute acid pretreated biomass that have the greatest impact on the susceptibility of cellulose to chemical and enzymatic hydrolysis
200		2.4.1.2.7	Determine affect of dilute acid pretreatment on lignin/enzyme interaction and degree of irreversibly bound enzyme on

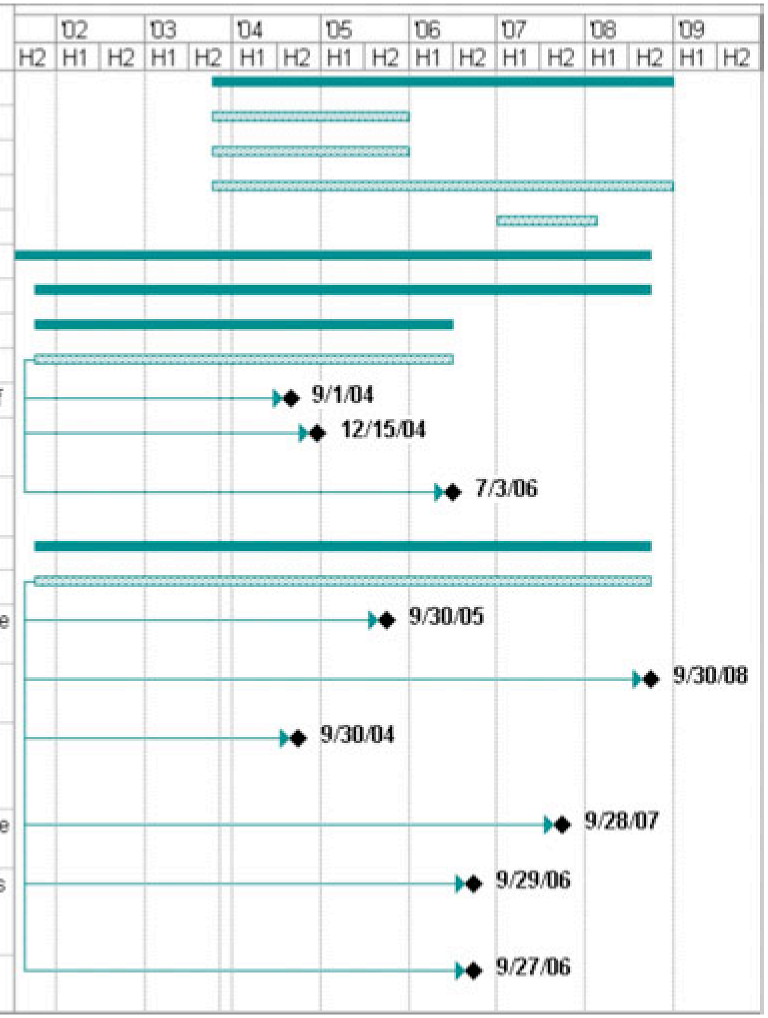


Figure 17: Biomass Program Activities Addressing the Barriers for Deployment of the Sugar Platform

ID	WBS	Task Name
201	2.4.1.3	**Biological Processing Fundamentals**
202	2.4.1.3.1	Biological Processing Research Task
203	2.4.1.3.2	Use molecular mechanics modeling to simulate enzyme action on cellulose at elevated temperatures
204	2.4.1.3.3	Understand how temperature effects cellulases, cellulose, and their interaction
205	2.4.1.3.4	Determine the apparent enzymatic targets in pretreated biomass using surface analysis
206	2.4.1.3.5	Determine the preferred cellulosic substrate for fungal and bacterial cellulases
207	2.4.1.3.6	Propose the role of N-linked glycosylation on the stability and processive action of selected Cel7A enzymes.
208	2.4.1.3.7	Understand the enzymatic decrystallization process mediated by CBH I
209	2.4.1.3.8	Understand the mode of action of cellulases in kinetic and thermodynamic terms
210	2.4.1.4	**New Concepts**
211	2.4.1.4.1	**Enzyme-mediated Pretreatment**
212	2.4.1.4.1.1	Enzyme-mediated Pretreatment Task
213	2.4.1.4.1.2	Decrease enzyme costs through complementation of cellulase action with hemicellulases
214	2.4.1.4.1.3	Maintain digestibility of lower-severity pretreated corn stover through addition of non-cellulase enzymes
215	2.4.1.4.1.4	Determine the potential cost decrease associated with the use of hemicellulase enzymes
216	2.4.1.5	**Biomass Surface Characterization**
217	2.4.1.5.1	Complete installation of AFM, NSOM, eSEM and TEM
218	2.4.1.5.2	Demonstrate ultrastructure characterization of Biomass
219	2.4.2	**GO Dilute Acid Total Hydrolysis (Auburn)**
220	2.4.2.1	Dilute Acid Total Hydrolysis (contract)
221	2.4.2.2	Evaluate effect of intra-particle acid diffusion in dilute acid hydrolysis of pretreated biomass
222	2.4.3	**GO Complementation of Endoxylanase with a Glucuronidase Beta Xylosidase (U. FL)**
223	2.4.3.1	U Florida Endoxylanse contract
224	2.4.3.2	Modify pretreatment protocols to maximize the release of fermentable sugars from hemicellulose
225	2.5	NBC Sugar Platform Analysis

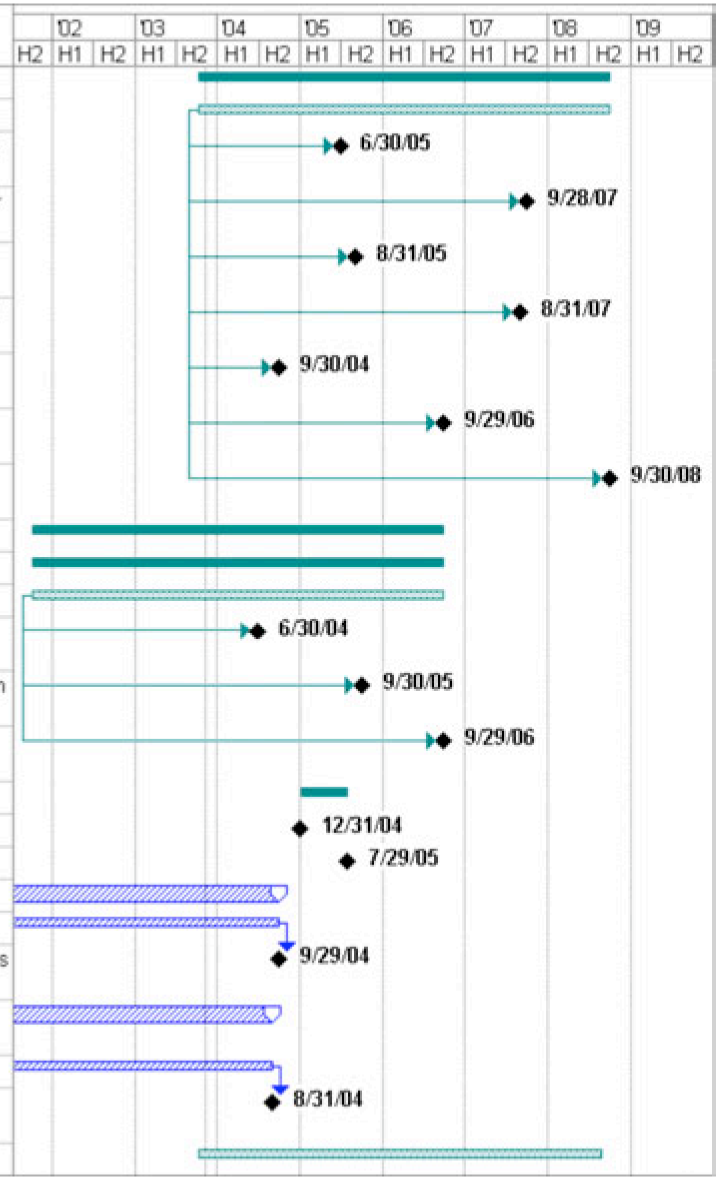


Figure 17: Biomass Program Activities Addressing the Barriers for Deployment of the Sugar Platform

2.2.4.3 Sugar Platform Analysis Support

Analysis is performed under this task to support the ongoing research in the Sugar Platform. Analysis helps to provide direction and focus to the research by evaluating the technical, economic, and environmental aspects of biomass sugar production and conversion. This analysis also supports OBP's goals and feeds into the Multi-Year Analysis Plan (MYAP).

Much of the analysis work to be done is a continuation and elaboration of past efforts to model and understand the economic factors and key uncertainties related to the sugars route to ethanol from lignocellulosic biomass. The process to produce ethanol still will be used as a base case process to evaluate the economic impacts of technology developments. However, increasingly greater emphasis will be given to the production of additional products from the sugar streams in addition to ethanol.

2.2.5 Resource Allocation Plan

Figure 18 and Table 4 provide a high-level summary of the proposed costs for projects included in the Sugar Platform core R&D area of the Program.

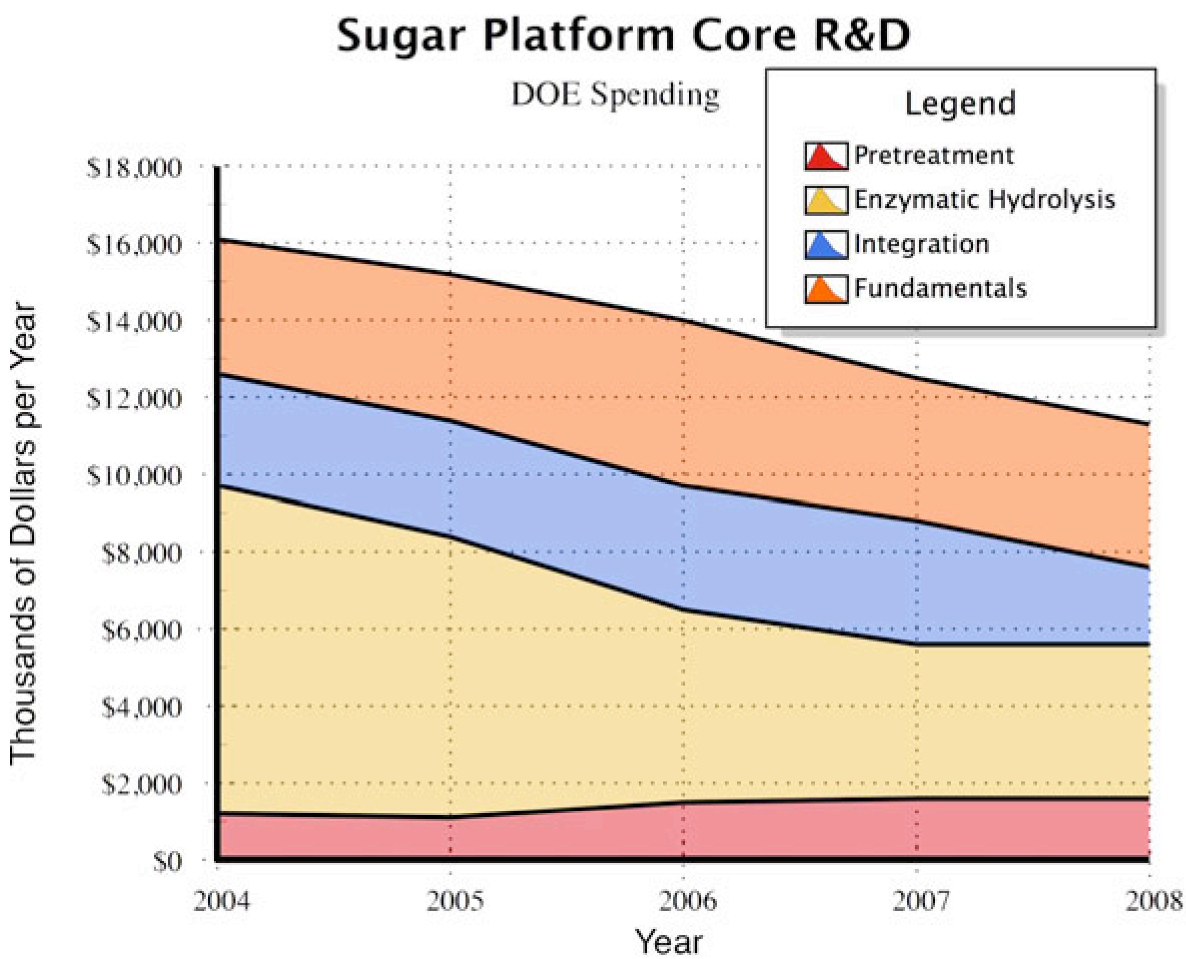


Figure 18: Sugar Platform Core R&D Resource Plan

The research in this area is leveraged with partnership cost share, as shown in Figure 9. This chart includes ongoing projects that have been funded prior to FY 04 that included some cost share.

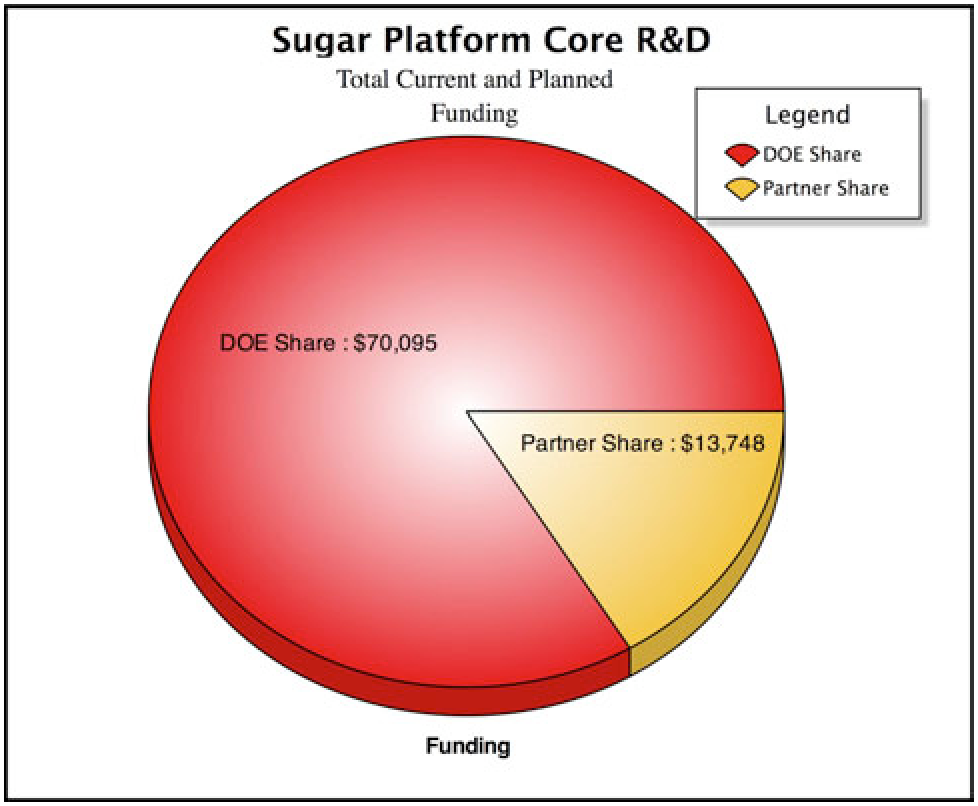


Figure 19: Total DOE and Partnership Cost Sharing for the Sugar Platform[5]

2.2.6 Overview of Projects and Milestones

Table 5 summarizes all projects that support core R&D for the Sugar Platform, along with their major milestones (or outputs). The projects are organized into the technical barrier areas identified previously. For each project, technical barriers specifically addressed within the broader technical barrier are identified.

[5] Includes pre-FY 2004 dollars from DOE and partners for ongoing projects started prior to the start of this plan. See funding details in Table 7

Table 4: Sugar Platform Core R&D Resource Plan *Fully Funded Prior to FY04

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
2	**Sugar Platform Core R&D**	**$1,463**	**$18,140**	**$16,940**	**$19,000**	**$16,500**	**$15,300**
	DOE Share	***$1,015***	***$16,090***	***$15,190***	***$14,000***	***$12,500***	***$11,300***
	Partner Share	***$448***	***$2,050***	***$1,750***	***$5,000***	***$4,000***	***$4,000***
2.1	Pretreatment Technical Barrier	$832	$1,200	$1,100	$1,500	$1,600	$1,600
	DOE Share	*$546*	*$1,200*	*$1,100*	*$1,500*	*$1,600*	*$1,600*
	Partner Share	*$286*	*$0*	*$0*	*$0*	*$0*	*$0*
2.1.1	NBC Pretreatment Core R&D	$0	$1,200	$1,100	$1,500	$1,600	$1,600
	DOE Share	*$0*	*$1,200*	*$1,100*	*$1,500*	*$1,600*	*$1,600*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.1.1.1	Emerging Pretreatment Options	$0	$1,100	$1,050	$1,500	$1,600	$1,600
	DOE Share	*$0*	*$1,100*	*$1,050*	*$1,500*	*$1,600*	*$1,600*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.1.1.2	Pretreatment Applications for Corn Mills	$0	$100	$50	$0	$0	$0
	DOE Share	*$0*	*$100*	*$50*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.1.2*	GO CAFI Fundamentals of Biomass Hydrolysis at low pH (Dartmouth)	$832	$0	$0	$0	$0	$0
	DOE Share	*$546*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$286*	*$0*	*$0*	*$0*	*$0*	*$0*
2.1.3	Go Enzymatic Digestion and Hydrolyzate Fermentation (Dartmouth)	TBD					
	DOE Share	*TBD*					
	Partner Share	*TBD*					
2.2	Enzymatic Hydrolysis	$0	$10,540	$9,040	$10,000	$8,000	$8,000
	DOE Share	*$0*	*$8,490*	*$7,290*	*$5,000*	*$4,000*	*$4,000*
	Partner Share	*$0*	*$2,050*	*$1,750*	*$5,000*	*$4,000*	*$4,000*
2.2.1	NBC Enzymatic Hydrolysis	$0	$10,250	$8,750	$10,000	$8,000	$8,000
	DOE Share	*$0*	*$8,200*	*$7,000*	*$5,000*	*$4,000*	*$4,000*
	Partner Share	*$0*	*$2,050*	*$1,750*	*$5,000*	*$4,000*	*$4,000*

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
2.2.2	NBC CRADA with Genencor	$0	$290	$290	$0	$0	$0
	DOE Share	*$0*	*$290*	*$290*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.3	Sugar Platform Integration	$0	$2,900	$3,000	$3,200	$3,200	$2,000
	DOE Share	*$0*	*$2,900*	*$3,000*	*$3,200*	*$3,200*	*$2,000*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.3.1	NBC Sugar Platform Integration	$0	$2,900	$3,000	$3,200	$3,200	$2,000
	DOE Share	*$0*	*$2,900*	*$3,000*	*$3,200*	*$3,200*	*$2,000*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.4	Fundamentals and New Concepts	$631	$3,500	$3,800	$4,300	$3,700	$3,700
	DOE Share	*$469*	*$3,500*	*$3,800*	*$4,300*	*$3,700*	*$3,700*
	Partner Share	*$162*	*$0*	*$0*	*$0*	*$0*	*$0*
2.4.1	NBC Fundamentals and New Concepts	$0	$3,500	$3,800	$4,300	$3,700	$3,700
	DOE Share	*$0*	*$3,500*	*$3,800*	*$4,300*	*$3,700*	*$3,700*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.4.1.1	Biomass Structure	$0	$500	$500	$600	$0	$0
	DOE Share	*$0*	*$500*	*$500*	*$600*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.4.1.2	Chemical Processing Fundamentals	$0	$700	$800	$800	$900	$900
	DOE Share	*$0*	*$700*	*$800*	*$800*	*$900*	*$900*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.4.1.3	Biological Processing Fundamentals	$0	$1,300	$1,500	$2,000	$1,900	$1,900
	DOE Share	*$0*	*$1,300*	*$1,500*	*$2,000*	*$1,900*	*$1,900*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.4.1.4	New Concepts	$0	$500	$500	$600	$600	$600
	DOE Share	*$0*	*$500*	*$500*	*$600*	*$600*	*$600*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.4.1.4.1	Enzyme-mediated Pretreatment	$0	$500	$500	$600	$600	$600
	DOE Share	*$0*	*$500*	*$500*	*$600*	*$600*	*$600*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
2.4.1.5	Biomass Surface Characterization	$0	$500	$500	$300	$300	$300
	DOE Share	*$0*	*$500*	*$500*	*$300*	*$300*	*$300*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
2.4.2*	GO Dilute Acid Total Hydrolysis (Auburn)	$188	$0	$0	$0	$0	$0
	DOE Share	*$130*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$58*	*$0*	*$0*	*$0*	*$0*	*$0*
2.4.3*	GO Complement Endoxylanase w/ Glucuronidase ß Xylosidase (U. FL)	$443	$0	$0	$0	$0	$0
	DOE Share	*339*	*0*	*0*	*0*	*0*	*0*
	Partner Share	*$104*	*$0*	*$0*	*$0*	*$0*	*$0*

Table 5: Alignment of Projects and Milestones in the Sugar Platform Core R&D Area

Biomass Program Goal: To develop the capability for using lignocellulosic biomass to produce inexpensive sugar streams that can be used for the production of fuels, other chemicals, and materials.

Objective: By 2010 reduce the cost of a mixed, dilute sugar stream suitable for fermentation to ethanol, in a mature biochemical plant, from $0.14/lb in 2003 to $0.07/lb.

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
Pretreatment GO/NBC	2.1.1 Pretreatment	• Lack of experience with pretreatment as an option for releasing hemicellulosic sugars in existing corn grain processing • Lack of consistent, comparative technical characterization of emerging technology options • Lack of consistent economic evaluation of emerging pretreatment technology options	08/2004: Comparative evaluation of AFEX and dilute acid/hot water pretreatment of corn fiber 09/2007: Technical review of pretreatment alternatives
Enzymes GO/NBC	2.2.1 Enzyme Hydrolysis	• Low reactivity of current commercial enzymes • High cost of enzyme production • Enzyme biochemistry • Process integration	03/2004: Novozymes biotech achieves tenfold cost reduction for cellulase in ethanol production 09/2008: Validate performance of $0.10/gallon ethanol new generation cellulase enzymes
Fermentation (Existing and Emerging Technology Applications)	See projects in the "Products" area	• See projects in the "Products" area 4.1.1.2.1 Arabinose Yeast CRADA, 4.1.1.2.2, Ethanologen Research 4.1.2 GO Develop Yeast for Chemicals (Cargill Dow Polymers)	See projects in the "Products" area of the plan

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
Integration GO/NBC	2.3.1 Sugar Platform Integration	• Unproven use of residues for combustion, heat, and power • Unproven integrated performance of high solids processing (30% in pretreatment, 20% in saccharification) anticipated for large scale operations	09/2005: Validate combustion of process residues for heat and power generation 9/30/06: Integrated pilot-scale demonstration, 24/7 for one week, pretreatment, saccharification, and fermentation, at high solids. 09/2008: Validate integrated pretreatment, saccharification and fermentation of biomass using improved enzymes and fermentation organisms
Fundamentals and New Concepts GO/NBC	2.4.1 NBC Fundamentals and New Concepts	• Biomass structure • Chemical processing fundamentals • Biological processing fundamentals • Conversion concepts	09/2004: Proof-of-concept for consolidated bioprocessing (CBP) via heterologous cellulase expression (Dartmouth) 12/2004: Demonstration of ultrastructural characterization of biomass samples 09/2005: Determine whether non-cellulase enzymes can reduce required pretreatment severity 07/2006: Achieve a better understanding of the physical, chemical and ultrastructural features of corn plants that affect process performance 09/2007: Understand how temperature effects cellulases, cellulose, and their interaction 09/2008: Determine ultrastructural properties of pretreated biomass with impact on cellulase susceptibility
NBC Sugar Platform Analysis	2.5 Analysis Support of the Sugar Platform	• Linkage between research goals and economic and environmental impacts	Ongoing life cycle and technoeconomic analysis

2.3 The Thermochemical Platform

The Thermochemical Platform involves use of elevated temperature 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 produce fuels and products that are interchangeable with existing commercial commodities. Intermediate products include clean syngas (a mixture of primarily hydrogen and carbon monoxide), pyrolysis oil, hydrothermal oils, and gases rich in hydrogen or methane. These intermediate products can be used directly for heat and electric power generation, or may be upgraded by various processing technologies to products such as crude oil, gasoline, diesel, alcohols, olefins, oxo chemicals, synthetic natural gas, and high-purity hydrogen.

Gasification and pyrolysis involve the conversion of solid or liquid organic matter to gases (CO, CO_2, H_2, and CH_4), organic vapors, water, and residual solids at elevated temperature. A strict technical definition is that pyrolysis takes place through the application of elevated temperatures in the absence of any reactive compounds or oxidants. Gasification is the reaction of any carbonaceous feedstocks with air, oxygen, steam, carbon dioxide, or mixtures of these, to yield a gaseous product that is suitable for use either as a source of energy or as a raw material for the synthesis of chemicals, liquid fuels, or other gaseous fuels. A practical definition that covers most biomass conversion processes states that the primary difference between pyrolysis and gasification is that pyrolysis takes place at temperatures (ca. 400–650°C; 750–1,200ºF) at which the primary product is a liquid (pyrolysis oil), whereas gasification takes place at higher temperatures (ca. 650–900°C; 1,200–1,650ºF) at which the primary products are permanent gases (CO, CO_2, H_2, CH_4). A third term seen frequently is steam reforming. In the context of the thermal conversion of solid biomass, this refers to high-temperature (650–900°C; 1,200– 1,650ºF) pyrolysis (absence of oxygen) in the presence of steam to produce primarily permanent gases.

A third alternative (apart from gasification and pyrolysis) is hydrothermal processing with excess water and/or organic solvent at medium temperatures (300–350°C; 570–660ºF) and sufficient pressure (16 MPa; ca. 2,300 psia) to maintain the water or solvent in the liquid phase. The primary products are complex hydrocarbon liquids including long aliphatic chains, some cyclic compounds containing carbonyl groups, and a few hydroxyl groups, ether linkages, and carboxylic acid groups. Hydrothermal processing in the presence of a heterogeneous catalyst (e.g. Ni-Ru) produces primarily methane or hydrogen and is referred to as wet gasification.

Thermochemical conversion provides an efficient approach for producing fuels and products from a wide variety of biomasses. Thermal processes readily convert all major components of biomass including lignin, which is currently resistant to biological conversion, to intermediate building blocks. Use of the lignin, which is typically 25%-30% of the biomass, is essential to achieve high efficiencies in the biorefinery. Thermal processes are "omnivorous" in this regard and can convert most biomass feedstocks or residues to a raw synthesis gas. Cleanup and conditioning of the raw gas results in a clean synthesis gas. It is then possible to access and leverage the extensive process technology developed in the petroleum and chemicals industry to produce a wide range of liquid fuels and chemicals.

Biomass gasification is important in providing a source of fuel for electricity and heat generation for the integrated biorefinery. Virtually all other conversion processes, whether physical, chemical, or biological, produce residue that are not currently or cannot be converted to the primary products. To avoid a waste stream from the refinery and to maximize the efficiency of the biorefinery, these residues can be used for combined heat and power production (CHP). In existing facilities, these residues are combusted to produce steam for power generation. Gasification offers the potential to use higher-efficiency power generation technologies such as combined cycle gas turbines or, in the future, fuel cells. Gas turbine systems offer potential electrical conversion efficiencies approximately double that of steam-cycle processes, with fuels cells being nearly three times as efficient.

2.3.1 Technical Goals and Objectives

The Thermochemical Platform R&D efforts will ensure that biomass gasification technologies are compatible with the production of fuels and chemicals based on technologies currently available through the petroleum industry. This will provide near-term opportunities for biomass while also leveraging the extensive related experience of industry. In the mid to long term, the Program will ensure that biomass syngas technologies are compatible with advanced utilization technologies. These will include hydrogen-related technologies as well as advanced utilization technologies better suited to the scale at which biomass is available. These development efforts will directly support and contribute to achieving the hydrogen-from-biomass targets set by the Office of Hydrogen, Fuel Cells and Infrastructure Technologies (OHFCIT)

The Program will develop reliable gasification-based combined heat and power systems for integration with all types of biorefineries. These gasification technologies will include those for "conventional" biomass and biomass residues as well as for black liquor (a combination of lignin residue and the spent pulping chemicals used in a paper mill). It is important to determine the scales and applications at which biorefineries are economic and will be developed and to have appropriate gasifier systems available at those scales. The Platform will address short-term technologies such as gas turbines as well as long-term options such as advanced fuels cells.

The Thermochemical R&D efforts of the Program also address other thermochemical conversion approaches, particularly pyrolysis and hydrothermal gasification. Pyrolysis converts biomass primarily to liquid products, with smaller amounts of syngas and char also being produced. The liquid "biocrude" is superficially similar to fuel oil but is chemically quite different. Like gasification, pyrolysis is "omnivorous" and converts all major fractions of the biomass resource. The liquid can be used as an intermediate to produce fuels, products, or electricity. The relatively high energy density of the pyrolysis liquids also potentially allows them to be economically transported to a central site for processing into fuels and chemicals. In this area, the objectives of the Platform are to ensure that the liquid and gaseous products from pyrolysis products can successfully be used in a thermochemically based biorefinery.

In certain areas of the Thermochemical Platform, it may be possible to leverage efforts, developments, and accomplishments from the Office of Fossil Energy (FE). This is most likely in the areas of gas cleanup and conditioning. Coal gasifiers have generally been developed for much larger scale operation, and coal is physically and chemically very different from biomass. In fact, the most widely applied commercial coal gasifiers all use a coal slurry feed, an approach that is not feasible with biomass from an energy and efficiency perspective.

2.3.2 Programmatic Status

The Thermochemical Platform was started in FY2003 with the development of a multi-year program plan that forms the basis of this MYTP. The program is in transition from an emphasis on power systems to an emphasis on fuels and chemicals systems. Because the Thermochemical Platform is in its first year, the effort involves existing projects with DOE's national laboratories, NETL, GO, and existing subcontractors. Some of these "legacy" projects may represent a good fit with new program priorities; however, this will be the subject of investigation and alignment in FY04. The existing efforts include:

Thermochemical Processing

- Wet gasification using a modular reactor system (PNNL)
- Congressionally mandated research projects managed by GO at the Southern Research Institute (SRI), Gas Research Institute (GTI), and Iowa State University (ISU)
- Fuel chemistry and bed performance in a black liquor reformer (University of Utah)

- Black liquor gasification materials support R&D placed via competitive solicitation and managed by NETL
- Research to support integration of gasification with pulp and paper mills managed by NETL

Cleanup and Conditioning

- Continuation of laboratory efforts in gas cleanup and conditioning with an emphasis on catalytic tar cracking (performed at NREL using Ni-based catalysts in a 2” reactor and an 8” fluid bed reactor that will be installed by December 2003)
- Evaluation of RVS-1 sorbent for removal of sulfur from black liquor gasification (NETL)

Thermochemical Platform Analysis

- Preliminary technoeconomic analyses of fuels and chemicals synthesis processes (NREL)

Products-Related Projects (discussed in Section 2.4 of this document)

- Completion of laboratory investigations of the use of syngas for electricity generation in internal combustion engines and microturbines (performed at NREL using an electrically heated gasifier at the 15-20 kWe scale)
- Pyrolysis oil upgrading (performed by PNNL using Ru catalysts in batch experiments)
- Initiation of evaluations of the suitability of syngas as a catalytic synthesis feed (performed at NREL in a fixed-bed microreactor)

Integrated Biorefinery-Related Projects (discussed in Section 2.5 of this document)

- Carbona Corporation, gasification-based CHP (5.4 MWe, 11 MWt) using a fluid bed gasifier, catalytic tar cracking, and internal combustion engines
- Community Power Corporation, gasification-based CHP (15 kWe) using a downdraft gasifier, particulate separation, and internal combustion engines
- Flex Energy, gasification/anaerobic digester gas/landfill gas use in a catalytic microturbine
- Georgia-Pacific Corporation, full-scale demonstration of black liquor gasification at the Big Island pulp and paper mill

Anticipated additional efforts in the near future include:

Thermochemical Processing

- A solicitation for breakthrough concepts to improve the efficiency or reduce the costs of thermal processing

Cleanup and Conditioning

- Investigations of reliable, cost-effective methods for catalytic, condensing, and non-condensing gas cleanup using existing facilities
- Research on handling and blending characteristics of thermally derived biomass oils

Products-related projects

- Survey of potential roles for biomass-derived products or intermediates in petroleum refineries and petrochemical plants

Integrated Biorefinery-Related Projects

- Industry partnerships under the Integrated Biorefinery area of the Program will be sought to help move the above processes and concepts into the commercial marketplace.

2.3.3 Technical Barriers

As with the Sugar Platform, the overarching barrier to deployment of the Thermochemical Platform is its inability to compete with fossil fuel in most applications. Barriers that contribute to the cost barrier have been identified (**Figure 20**). As an example, in the case of gasification, studies have shown that generation of a clean syngas suitable for fuel or product synthesis represents over 60% of the total capital cost to produce an example product (**Figure 21**). For this reason, and since the technology to convert a synthesis gas (regardless of source) to fuels or chemicals is largely mature, the Program will concentrate the majority of it's R&D effort and dollars on the processes that lead to clean intermediates (e.g. syngas, pyrolysis oils etc.)

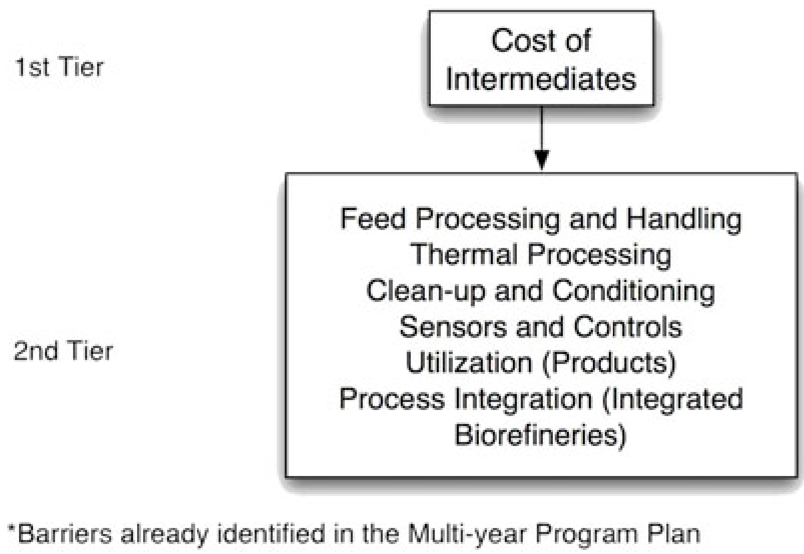


Figure 20: Hierarchy of Barriers to the Deployment of Thermochemical Platform Technology

The relative priority of each of the second tier barrier areas is listed along with the potential of each are to reduce final product cost is listed in Table 1. All areas are considered necessary, but with limited resources the priority ratings provide a consensus of their relative importance.

The priority assigned takes several factors into account. Perhaps the most obvious is the potential impact on cost of the final product. In addition, the state of the art with respect to required commercial performance was evaluated. As an example, the state of the art in gasification (thermal processing) is relatively advanced with respect to the cleanup systems that would be needed to couple to today's product synthesis processes. Similarly, although advanced sensors and controls might improve process operating and maintenance costs, a number of biomass plants currently operate with conventional instrumentation. Also considered was the degree to which an area is an absolute barrier i.e. feeder development may not realize significant cost reductions but reliable feed systems are critical to any biorefinery. In some cases the relative priority is driven as much by what is needed first as by ultimate importance to the success of eventual biorefinery demonstration.

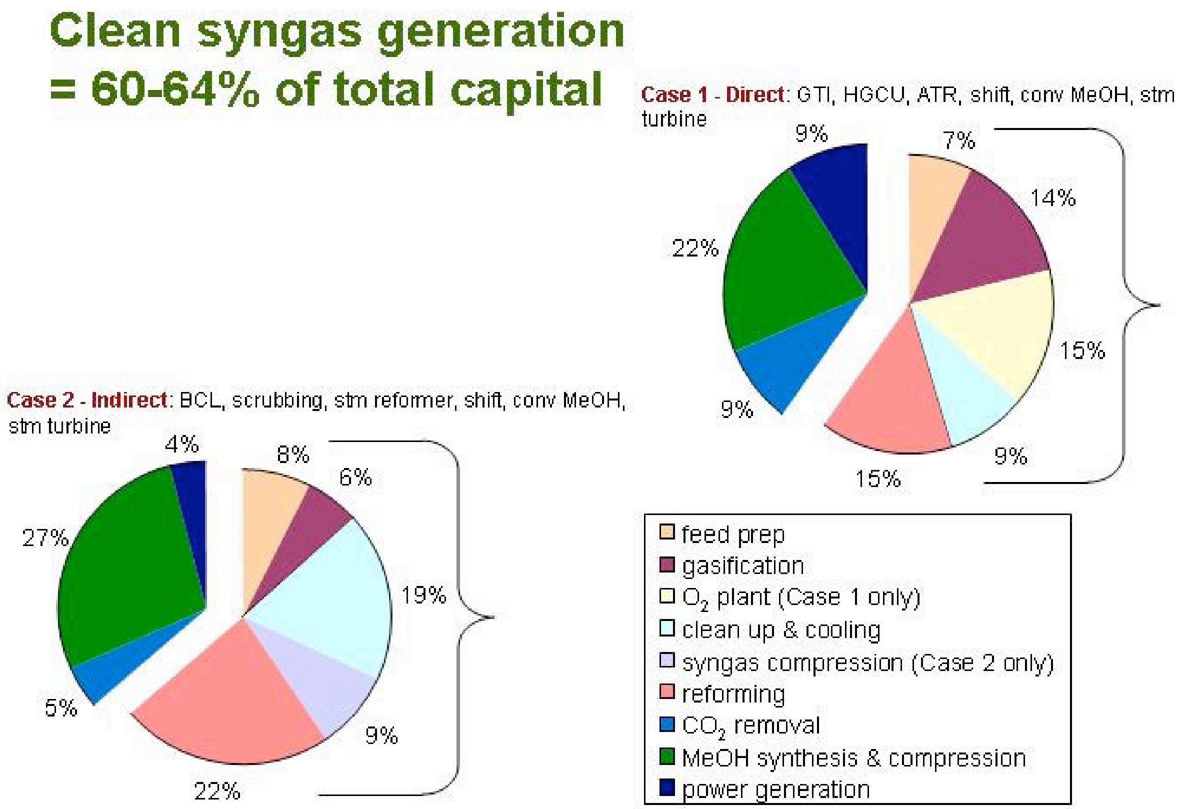


Figure 21 - Cost Components of an example biomass to methanol plant

It should be recognized that the relative priority of each area will change as the barriers are overcome and this research plan evolves. Note also that development efforts in the areas of utilization and process integration are dealt with in the Products and Integrated Biorefineries sections of this plan respectively.

Table 6: Potential Impact of Overcoming Barriers for the Thermochemical Platform

Barrier	Priority	Potential Cost Reduction (%)
Cleanup & Conditioning	High	15-25
Thermal Processing	Medium	5-10
Feed Processing & Handling	Low	5-10
Sensors & Controls	Low	5-10
Syngas Utilization (Products)	High	10-15
Process Integration (Integrated Biorefineries)	High	5-10

Below is a brief description of each barrier area and a list of specific needs within the area rated as high, medium, or low.

Feed processing and handling

Thermochemical platforms require a supply of uniform feedstock and reliable feed preparation, storage, and handling systems. The history of biomass project development has shown that reliable feeders are key to any successful project or system. A number of feed systems function reliably using feedstocks within a narrow range of physical properties (size, moisture, etc.). However, the diverse feedstocks that will be needed for a broad-based bioeconomy have a wide range of properties.

One approach for dealing with this diversity is for commercial operators to have quality control (QC) procedures that ensure uniformity in biomass feedstocks in addition to long-term fuel supply contracts that ensure this uniformity.

An alternate approach is to develop in-plant feedstock handling that can economically convert a wide range of feedstocks to a consistent form that existing feeders need to function reliably. The task of adapting existing feed systems to handle the variety and complexity of a wide range of biomass feedstocks is daunting and has not yet been accomplished.

These approaches (pre-plant and in-plant) need to be balanced to arrive at the lowest cost feed delivered to the thermal conversion device. Areas of higher priority for investigation that have been identified include densification and removal chemical bad-actors (e.g. alkali species) while novel drying and process feed systems are less urgently needed.

Thermochemical Processing

Biomass and black liquor gasification have developed to the point of large-scale demonstration. In the case of biomass gasifiers producing a low heat content fuel gas, this has largely been accomplished by the private sector. Black liquor gasification has enjoyed support from both public and private entities and a small number of demonstrations have occurred or are imminent.

However, widespread commercial availability of gasifier systems suitable for integration with fuels synthesis or hydrogen separation technologies has not yet been realized. This is due in part to areas of fuels chemistry that require additional investigation to support the commercial demonstration program and facilitate the development and scale-up of advanced gasifiers and gas cleanup systems.

A directed gasification chemistry technical support effort that provides usable results will maximize the chances of successful demonstrations. Gasification chemistry encompasses all chemical reactions, fluid dynamics, and phase equilibria behavior associated with the fuel, other reactants, transport gas, and gasification products. It also includes potential interactions with vessel refractories, reactor bed, and heat transfer media.

The technical community generally agrees that there is good understanding of global gasification and pyrolytic gasification chemistry. Historical development has concentrated on this area with less effort applied to understanding the fuel chemistry of minor products and residual solids. Better technical understanding of the formation and destruction of tars (condensable organic compounds heavier than benzene) and their ultimate impact on downstream unit operations will be required for commercial success. Tar destruction efforts may include catalytic and non-catalytic methods.

The potential impact of gasification catalysts, both added catalysts and alkali compounds in the fuel, on tars and residual carbon needs to be understood. An understanding of residual carbon age distribution and composition is needed to optimize reactor design. The management of impurities such as sulfur, halogens, nitrogen, and alkalis needs to be understood for process operability, for use of the product gas, and for environmental impact minimization. For complete understanding of how fuel chemistry affects commercial viability, reaction chemistry, fluid mechanics, and phase behavior should be incorporated into both rigorous and engineering computational fluid dynamic models for use in design and process control. Better understanding of fuel chemistry can also be applied to optimization of specific fuel throughput (i.e., $kg/m^2/s$) to minimize capital cost. Table 3 shows a prioritized list of fuel chemistry technical support areas.

Pyrolysis process development faces a number of challenges in producing oil with properties suitable for commercial use. Instability of the oil, aging due to reactive components, phase separation, acidity, and environmental safety and health issues associated with long-term exposure need to be addressed. Because pyrolysis oil properties are significantly different than existing petroleum-based oils, new product specification and standards (e.g., ASTM standards) will need to be developed. This is a multi-year effort. To a large extent, these yet-to-be-determined standards will define additional technical developments for product cleanup (e.g., particulate and alkali removal).

Also included in this barrier area is the supporting R&D and science needed in support of black liquor gasifiers in the areas of containment materials and pulp mill integration. Experience with black liquor gasifier systems in low-temperature and, more particularly, high-temperature reactors clearly indicates that the reactions occurring in the gasification process are difficult to contain and that long-term and economically acceptable approaches are yet to develop. Solutions to the containment issue are seen to involve metals used for reactor shells and internally, refractory materials used to line the containment vessels, the vessel design itself, and significantly increased knowledge about bed behavior and agglomeration. Whereas the ideal solution may ultimately be materials that are unaffected by the fuel and reaction chemistry, innovative combinations of refractory, metals, and vessel design may be necessary to provide acceptable operating up-time and maintenance cost. Modeling and model verification of bed behavior is also seen as extremely important in enabling optimum reactor design and the prevention of catastrophic failure.

Use gasification instead of combustion for pulping chemical recovery increases the load on the causiticization area of the plant. Therefore, novel causticization methods are also seen as an important component of black liquor gasifier deployment.

Technical challenges associated with hydrothermal treating of biomass include the normal issues associated with feeding and pressure let-down of high-pressure slurries, defining the properties of "bio-oils," demonstrating the effectiveness of separation techniques, and demonstrating the commercial use of products. For wet gasification, a major challenge is demonstrating long-term catalyst effectiveness when using fixed-bed catalysts in the presence of inorganic particulates.

Hydrothermal conversion and pyrolysis processes are a relatively recent addition (or re-introduction in the case of pyrolysis) to the OBP portfolio, resulting from new EERE and Program priorities. In FY04, their technical and economic benefits will be defined and a prioritized list of technical barriers developed similar to those for the gasification and area.

Cleanup and conditioning

The raw gases from biomass gasification systems do not meet strict quality standards for downstream fuel or chemical synthesis catalysts or those for some power technologies (fuel cells or fuel cell/turbine hybrids). They will require gas cleaning and conditioning to remove contaminants such as tar, particulates, alkali, ammonia, chlorine, and sulfur. Available cleanup technologies do not meet the needed cost, performance, or environmental criteria needed to achieve the Program goals or commercial implementation. In the pyrolysis arena, research has shown that the stability and properties of pyrolysis oil are greatly enhanced if solids and inorganic contaminants can be rapidly removed after formation of the pyrolysis vapors and before condensation of the desired oil products. Significant progress has been made in this area; however, addition development leading to a commercial process will be required if analysis indicates that this is a fruitful area for continued R&D. Similarly, treating and upgrading of pyrolysis oils will require novel approaches; this is discussed in the Products section of this document. Areas with high priority for activity include catalytic cleanup and related aspects such as lifetime and regenearation as well as issues surrounding particulate removal and condensing cleanup.

Sensors and Controls

Effective process control will be needed to maintain plant performance and emissions at target levels with varying load, fuel properties, and atmospheric conditions. Development of new sensors and analytical instruments is needed to optimize control systems for thermochemical systems. Prioritized areas requiring sensor development appear in

Utilization

In the near term, efforts will focus on integrating the intermediates produced from thermochemical processing with existing synthesis and other processes (e.g. refineries and chemical plants). Development of new products or development of new processes that are more suited to biomass feeds is addressed in Section 4 (Products) of this plan.

Process Integration

As with all new process technologies, demonstrating sustained integrated performance that meets technical, environmental, and safety requirements at sufficiently large scales is essential to supporting commercialization. Black liquor mill integration has the added complexity of being attached to an existing commercial process in which the unit operations associated with steam production, power, pulping, and chemical recovery must all be integrated.

Because most of these issues can only be addressed in the operation of a fully integrated process plant, this barrier is addressed in Section 5 (Integrated Biorefineries) of this plan. This includes R&D that is specific to integration of bioenergy processes with existing biorefineries and R&D required to provide increased efficiency to existing, emerging, and advanced biorefineries (e.g., integrating biomass gasification with combined cycle heat and power production).

The Role of Analysis

Published analyses suggest that the combined effect of addressing the four barriers shown in Figure 22 represents a reduction of 44% in cost of a syngas intermediate.

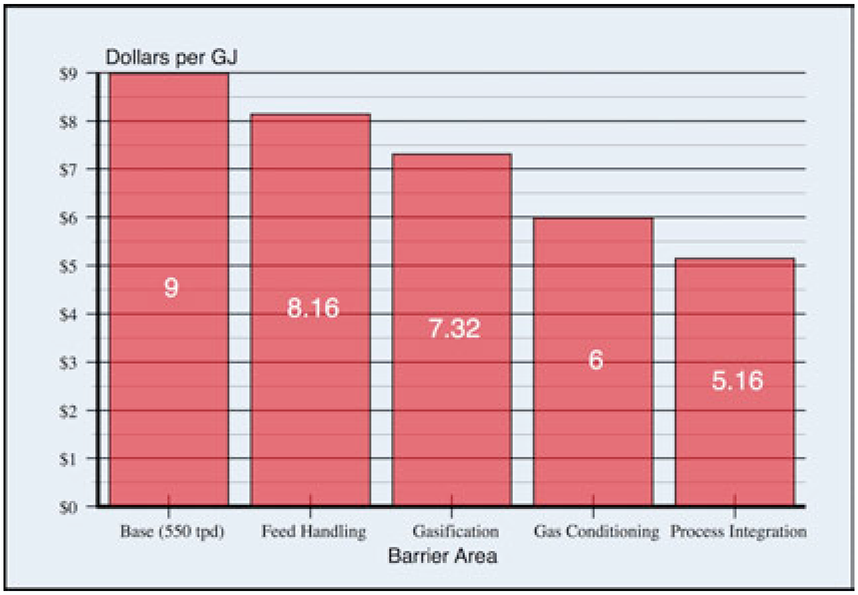


Figure 22: Translating Barrier Reductions to Cost Impacts for Syngas Intermediate

Figure 23 translates these cost reductions into their impact on example products in comparison to their fossil-based counterparts. In these ways, analysis helps to guide development efforts, set performance and efficiency targets, and measure progress toward goals.

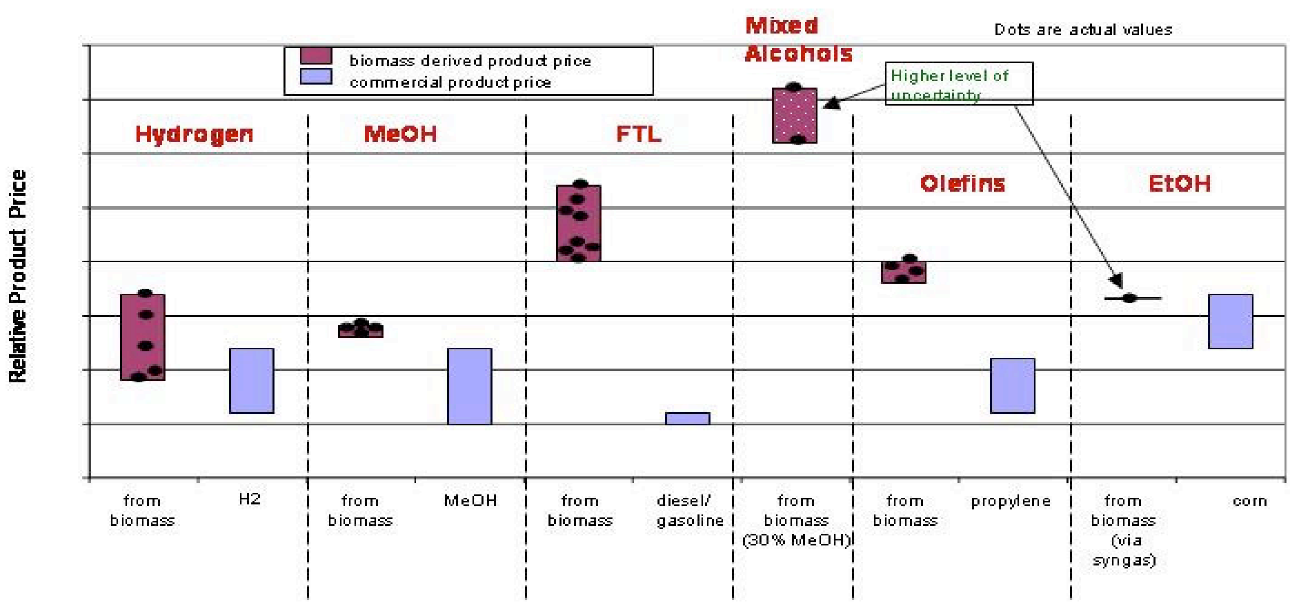


Figure 23 - Cost of Example Products from Biomass and Fossil Sources

2.3.4 Technical Approach

To facilitate the development of advanced thermochemical conversion systems, OBP will conduct advanced R&D to address the technical barriers related to ensuring that the syngas product can be reliably produced and is compatible with requirements for converting it to fuels and chemicals. R&D activities will be conducted in the four barrier areas plus supporting/guiding analysis: Feed Processing and Handling, Thermochemical Processing, Clean-up and Conditioning, Sensors and Controls.

The technical approach for the Thermochemical Platform involves core research addressing the technical barriers to development and integrated industrial biorefinery demonstration projects addressing integration and system scale-up issues. The work breakdown structure for core research on the Thermochemical Platform is shown in Figure 24. Details of the activities associated with each project in the Thermochemical Platform area are shown in Gantt chart format in Figure 27.

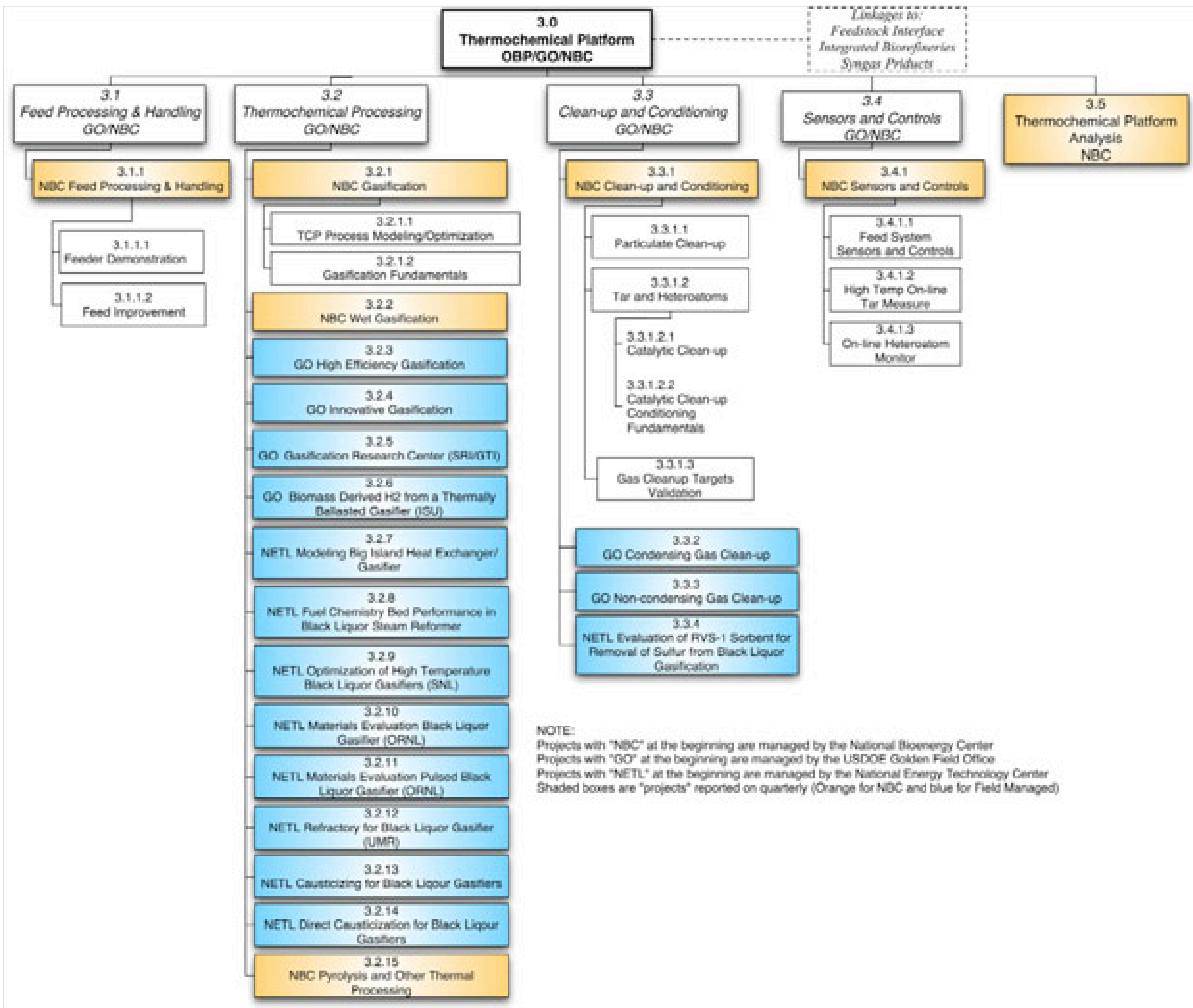


Figure 24: Work Breakdown Structure for the Thermochemical Platform Core R&D Area

National laboratories, industry, and universities will perform the core technical research. The industry and university projects will be selected through a solicitation targeting specific technical issues. Technoeconomic and life cycle analysis will be used to quantify the benefits of research targets as well as to recommend targets for research. In addition, the Program will explore facilities, capabilities and technologies developed under DOE/Fossil Energy's coal gasification research program and these will be used and leveraged wherever practical and applicable.

The majority of supporting core research will be completed by 2009. Note that this plan and approach include the process elements and schemes that are apparent today and does not include advanced process ideas or technology developments that may form the basis for new R&D areas in the future.

Industrial biorefinery (process integration) demonstration projects will be selected through competitive solicitations in the following areas: distributed fuels and chemicals systems; syngas production systems at existing petroleum, chemical, and forest products facilities; and integrated biorefinery systems. These projects will form the core of moving enabling systems and technologies from the platform research area into commercial biorefineries and will address the critical process integration (heat integration, waste minimization, etc.) issues that can be examined only in a truly integrated plant. Although these activities will be closely coupled to the platform research area, they will be managed as part of the Integrated Biorefinery activity (Section 2.5 of this document).

2.3.4.1 Feed process handling

The Program will conduct R&D activities to ensure that biomass feedstocks can be effectively supplied to biomass thermochemical conversion systems. The feedstock-related activities within the Thermochemical Conversion research area will focus on handling, processing and feeding that takes place within the biorefinery plant boundaries.

The overall objective of the Program's feedstock work will be to develop methodologies that allow biomass to be collected, prepared, and converted in a cost-effective manner. For biorefineries, it is important that the feedstock requirements of the conversion technology be met while also minimizing preparation of the biomass material in order to reduce costs. This will require optimization between the cost of plant-gate feedstock (and therefore coordination with the Feedstock area) with the handling and processing required to ensure reliable operation of the feeder. This optimization will have as a goal the minimum cost of feedstock as fed to the conversion device (e.g., gasifier). The specific minimum feasible feedstock cost has yet to be determined, but will be the result of this optimization study. With significant industry involvement, OBP will also conduct R&D to ensure that appropriate biomass feeder systems are available, particularly for pressurized gasification systems that have previously been shown to be a critical technology barrier.

2.3.4.2 Thermal Processing

OBP will conduct R&D activities to ensure that appropriate biomass thermal conversion processes are available to convert a variety of biomass materials to suitable intermediates. The gasification step is one crucial first step in producing fuels and chemicals using this thermochemical conversion pathway.

Working in partnership with industry, OBP will assist in resolving technical questions related to the operability and reliability of biomass and black liquor gasification systems. OBP will conduct R&D necessary for integration of biomass gasifiers into biorefineries. The goal of this work will be to ensure that gasification technologies are shown to be technically feasible in longer-term applications that have the potential for ongoing economic feasibility. The focus will be on addressing key technology barriers and fundamental information needs (such as tar formation mechanisms, kinetics, or chemical recovery).

OBP will also conduct R&D on advanced gasification technologies to develop more efficient, cleaner gasification systems appropriate for a wide variety of biomass feedstocks. This work will include fundamental gasification studies, process modeling, and similar work to identify opportunities for technology improvements.

Partners in this work will include national laboratories, universities, and others. OBP will build on the base of biomass gasification information developed over two decades by the previous Biomass Power

Program, the Black Liquor Gasification Program, DOE/Fossil's coal gasification program and other related activities.

During FY2004, the Program will also evaluate other thermal processes (including Pyrolysis and Hydrothermal gasification) to determine their relative merit and impact on OBP goals. Appropriate goals, targets and detailed schedules will be developed for these technologies as are outlined for gasification below.

2.3.4.3 Cleanup and Conditioning

The recent expansion of this part of the program to include thermochemical processing in general means that a scope and approach for other types of thermal processing must be developed. The bulk of the work included in this MYTP for cleanup and conditioning is related to gasification technology. Significant advances in syngas cleaning and conditioning are required for the raw gasification product to be used in downstream processes. Syngas cleaning involves removal of material such as tars or particulates from the gas stream, and conditioning involves further treatment of syngas to achieve a product containing mostly CO and H_2 that is suitable for synthesis to fuels and chemicals. The key activities in the plan related to cleanup and conditioning of intermediates from thermal processing of biomass include:

- Analyzing hot gas particulate removal
- Examining use of catalytic reforming for tar cracking
- Analyzing large-scale gas conditioning with catalysts
- Evaluating the chemistry and kinetics of biomass gasifier tar formation and removal
- Evaluating advanced desulfurization adsorbents that remove reduced sulfur species from black liquor gasification products for reuse in the paper mill
- Developing novel methods for cleaning, stabilization, and upgrading of pyrolysis oils

OBP will evaluate advanced concepts for particulate and tar removal in existing test-bed facilities and will explore options for new thermal and catalytic removal and treatment technologies and materials. Specific targets are outlined in Table 8 or will be determined based on analysis completed in FY2004. Research is expected to improve gas cleaning and conditioning to allow biomass syngas to be effectively used for fuels and power production. Efforts will include work with biomass and biomass residues as well as black liquor. R&D in the area of improving capture of biomass pyrolysis liquids from gas stream will also be conducted.

2.3.4.4 Process control and optimization

OBP will conduct R&D to facilitate the development of sensors and controls necessary for thermochemical systems. Better monitoring sensors are needed for biomass feed systems to ensure reliable feed supplies. Thermal conversion of biomass also creates unique gas impurities such as heteroatom tars and alkali for which there are currently no adequate on-line sensors. OBP will partner with national laboratories, universities, and instrumentation developers to establish concepts for monitoring these and other gas-phase species during system operation. Development of such sensors and automated controlling systems is expected to improve the operability and reliability of biorefineries.

2.3.4.5 Thermochemical Platform Analysis

OBP will conduct analysis activities on the Thermochemical Platform to provide information to decision makers. Technoeconomic analyses will be performed to determine the costs of producing biofuels and chemicals using currently available technologies. The analyses will also evaluate major process steps and determine those areas in which technical progress will be most successful in reducing project product costs. Life-cycle analysis will be conducted to determine the sustainability of syngas pathways.

Comparative analyses of the syngas pathways with those of other platforms will be conducted to compare the relative advantages of each. This work will build upon extensive past efforts by the national laboratories and universities in building various analysis tools.

2.3.5 Resource Allocation Plan

Figure 25 and Table 7 summarize the resource allocation plan for the Thermochemical Platform Core R&D area. Note that this plan details only the bringing to fruition of the first thermochemical biorefinery demonstration. It is expected during this development path that new ideas and avenues for investigation will be identified for next-generation biorefineries. No attempt is made to project the development path or resources for these novels areas at this time.

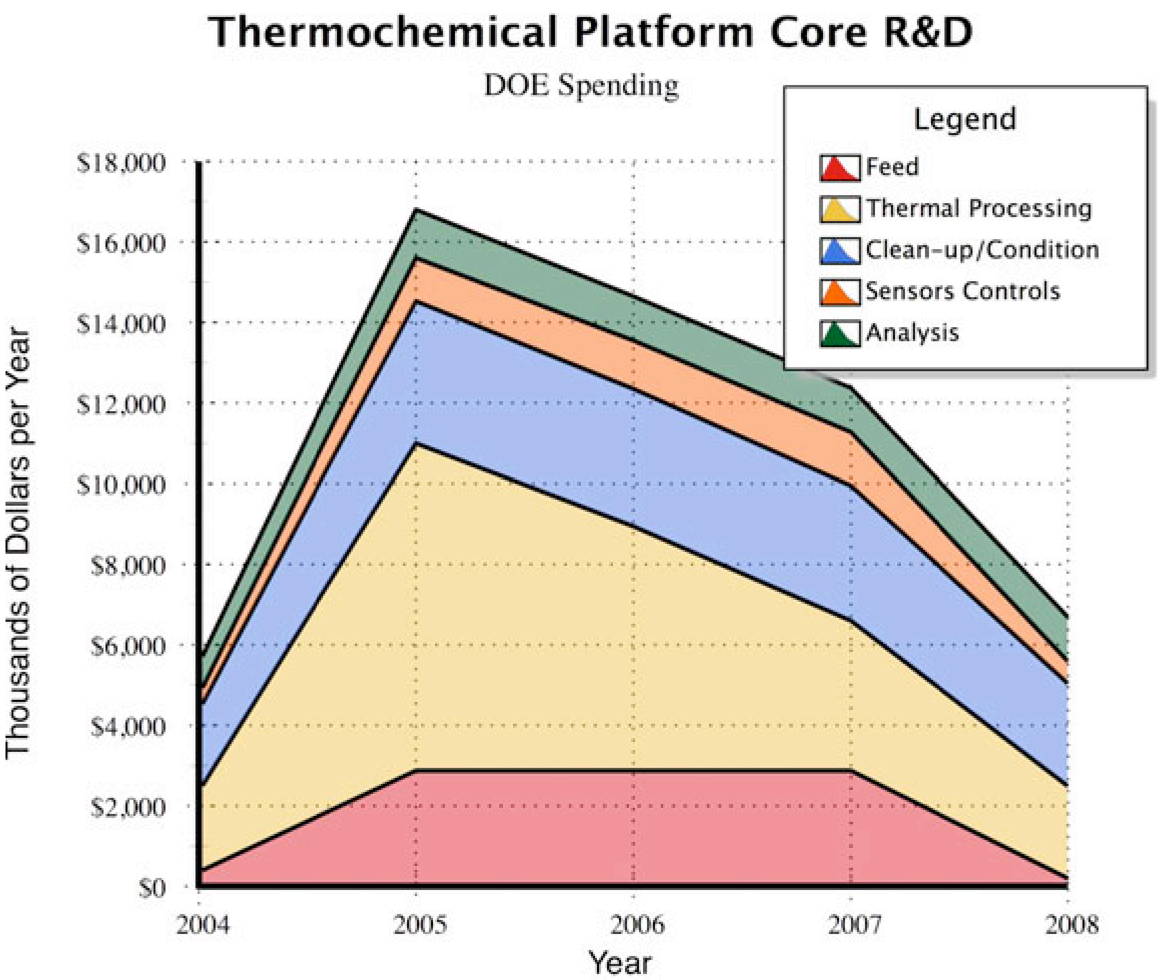


Figure 25: Thermochemical Core R&D Resource Plan

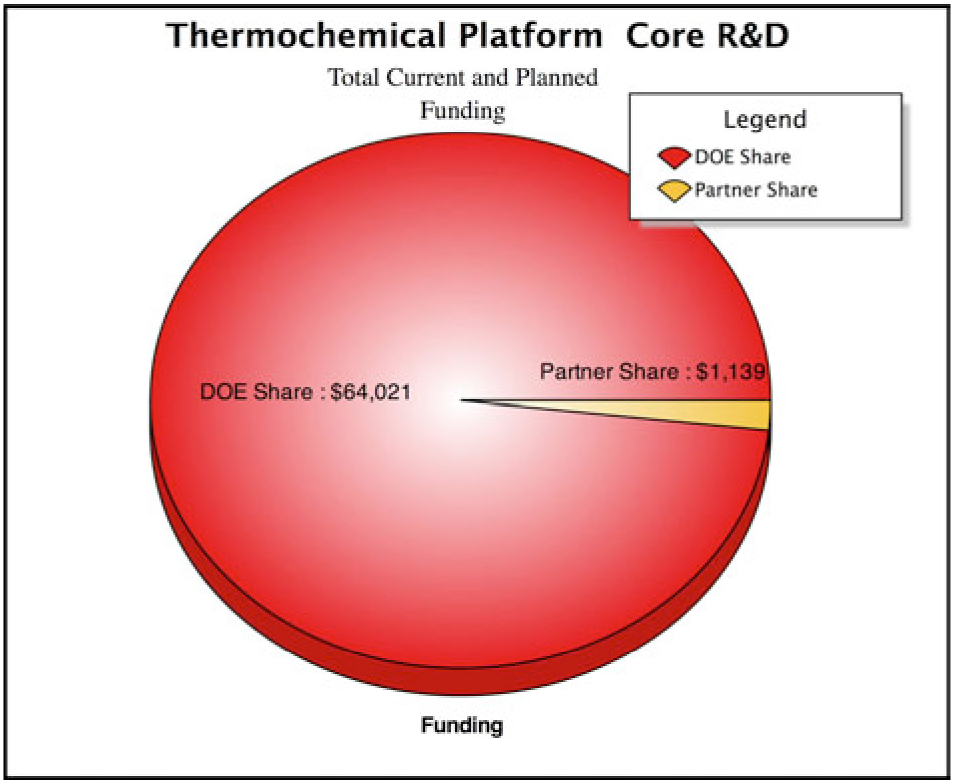


Figure 26: Total DOE and Partnership Funding for Thermochemical Platform[6]

2.3.6 Thermochemical Platform Projects and Milestones

Table 8 summarizes all of the projects included in the Thermochemical Platform, organized according to major barrier areas for the platform. Information is also included on the specific barriers addressed by each project and their milestones.

[6] Includes pre-FY 2004 dollars from DOE and partners for ongoing projects started prior to the start of this plan. See funding details in Table 7

ID		WBS	Task Name
226		**3**	**Thermochemical Platform Core R&D**
227		**3.1**	**Feedstock Processing and Handling**
228		**3.1.1**	**NBC Feed Processing and Handling**
229		**3.1.1.1**	**Feeder Demonstration**
230		3.1.1.1.1	Industry Feeder Demonstration (Woody feedstock)
231		3.1.1.1.2	Industry Feeder Demonstration (Herbaceous Feedstock)
232		3.1.1.1.3	Industry/PNNL Feeder Demonstration (Wet Feedstock)
233		3.1.1.1.4	Complete pilot testing of at least one feeder system
234		**3.1.1.2**	**Feedstock Improvement**
235		3.1.1.2.1	Industry/University Feed Improvement Idrying)
236		3.1.1.2.2	Complete feedstock drying system polot testing
237		3.1.1.2.3	Industry/University Feed Imprvement (Densification)
238		3.1.1.2.4	Complete pilot testing of one feedstock densification system
239		3.1.1.2.5	Industry/Univeristy Feed Improvement (Chemical Modification)
240		3.1.1.2.6	Complete pilot testing of one feedstock chemical modification system
241		**3.2**	**Thermal Processing**
242		**3.2.1**	**NBC Gasification Core Barrier R&D**
243		**3.2.1.1**	**Gasification process modeling and optimization**
244		3.2.1.1.1	Gate Placement Review for Gasification Process Modeling and Optimization
245		3.2.1.1.2	ASPEN Model for TCPDU
246		3.2.1.1.3	CFD model for NREL gasifier
247		3.2.1.1.4	Parametric TCPDU studies
248		3.2.1.1.5	Biorefinery residue (lignin) conversion
249		3.2.1.1.6	Complete 600 hours of TCPDU parametric testing
250		3.2.1.1.7	Stage Gate Decision on Gasification Modeling and Optimization

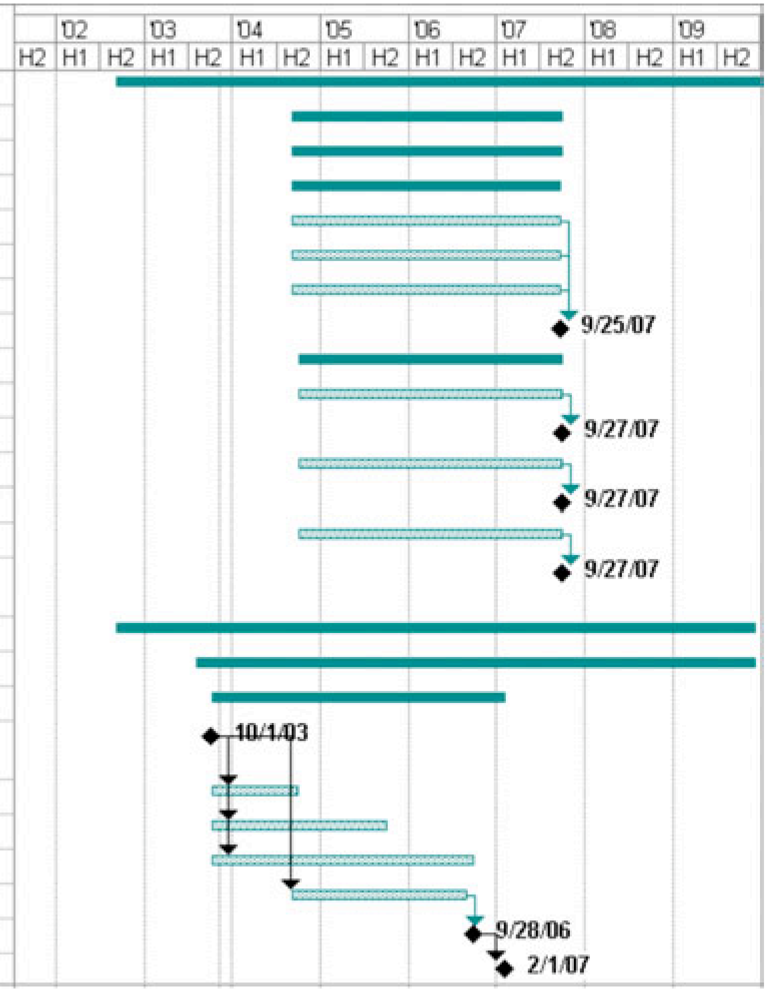


Figure 27: Key Activities in Support of the Thermochemical Platform

ID	WBS	Task Name
251	**3.2.1.2**	**Gasification Fundamentals**
252	3.2.1.2.1	Gate Placement Decision for Gasification Chemistry Fundamentals
253	3.2.1.2.2	Model compound studies
254	3.2.1.2.3	Global kinetics
255	3.2.1.2.4	Tar formation/destruction kinetics
256	3.2.1.2.5	Heteroatom compound formation/destruction
257	3.2.1.2.6	Complete global kinetics models for gasification
258	3.2.1.2.7	Stage Gate Decision on Gasification Chemistry Fundamentals
259	3.2.1.2.8	Mechanistic models development for Gasification Chemistry Fundamentals
260	3.2.1.2.9	Fundamentals of molecular weight growth (soot)
261	3.2.1.2.10	Containment Issues for Non-BLG
262	3.2.1.2.11	Complete mechanistic models
263	3.2.1.2.12	Stage Gate Decision for Gasification Chemistry Fundamentals
264	3.2.1.2.13	Gate Placement Review for Application of Gasification Models to Gasifiers and Biorefinery Residues
265	3.2.1.2.14	Application to pilot gasifiers
266	3.2.1.2.15	Application to biorefinery residues
267	3.2.1.2.16	Complete testing of kinetic /models in one pilot gasifier
268	3.2.1.2.17	Stage Gate Decision on Modeling of Gasifiers

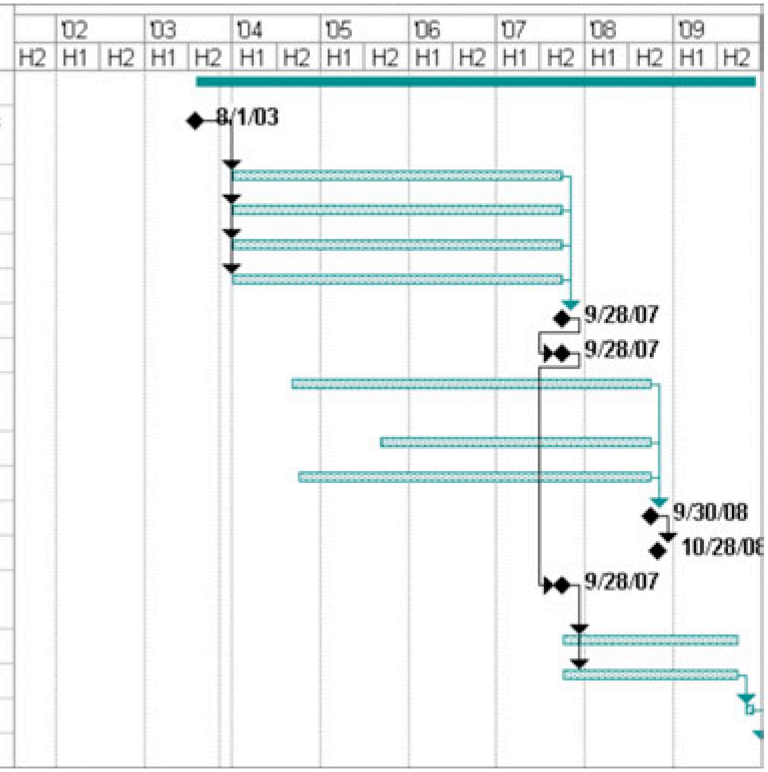


Figure 27: Key Activities in Support of the Thermochemical Platform

ID		WBS	Task Name
269		**3.2.2**	**Wet Gasification**
270		3.2.2.1	Parametric studies on methane
271		3.2.2.2	Stage Gate Decision for Wet Gasification Industry led R&D
272		3.2.2.3	Industry led R&D for Wet Gasification
273		3.2.2.4	Complete industry testing of wet gasification
274		3.2.2.5	Stage Gate Decision on Commercialization of Wet Gasification
275		3.2.2.6	Parametric studies on hydrogen
276		3.2.2.7	Complete 100 hours of scale-up reactor testing of wet gasification for H2 production
277		3.2.2.8	Gate Placement Decision on Wet Gasification H2 Production
278		3.2.2.9	Industry cooperative agreement
279		3.2.2.10	Complete industry testing of wet gasification for H2 production
280		3.2.2.11	Stage Gate Decision on Commercialization Wet Gasification for H2 Production
281		**3.2.3**	**GO High-efficiency gasification systems**
282		3.2.3.1	Fuels and chemicals synthesis
283		3.2.3.2	Biorefinery utilities
284		3.2.3.3	Complete testing one high-efficiency gasifier system
285		**3.2.4**	**GO Innovative gasification opportunities**
286		3.2.4.1	Non-traditional feeds
287		3.2.4.2	Pressurized indirect gasification
288		3.2.4.3	Enriched air gasification
289		3.2.4.4	Complete testing one innovative gasification concept
290		**3.2.5**	**GO Gasification Research Center (SRI)**
291		3.2.5.1	GO Gasification Research Center (contract)
292		3.2.5.2	Integrate and evaluate syngas clean-up and treatment technologies for synthesis gas from biomass gasification
293		**3.2.6**	**GO Biomass H2 from a Thermally Ballasted Gasifier (Iowa State University)**
294		3.2.6.1	Gasification of Switchgrass (contract)
295		3.2.6.2	Optimize performance of an indirectly heated gasification system th

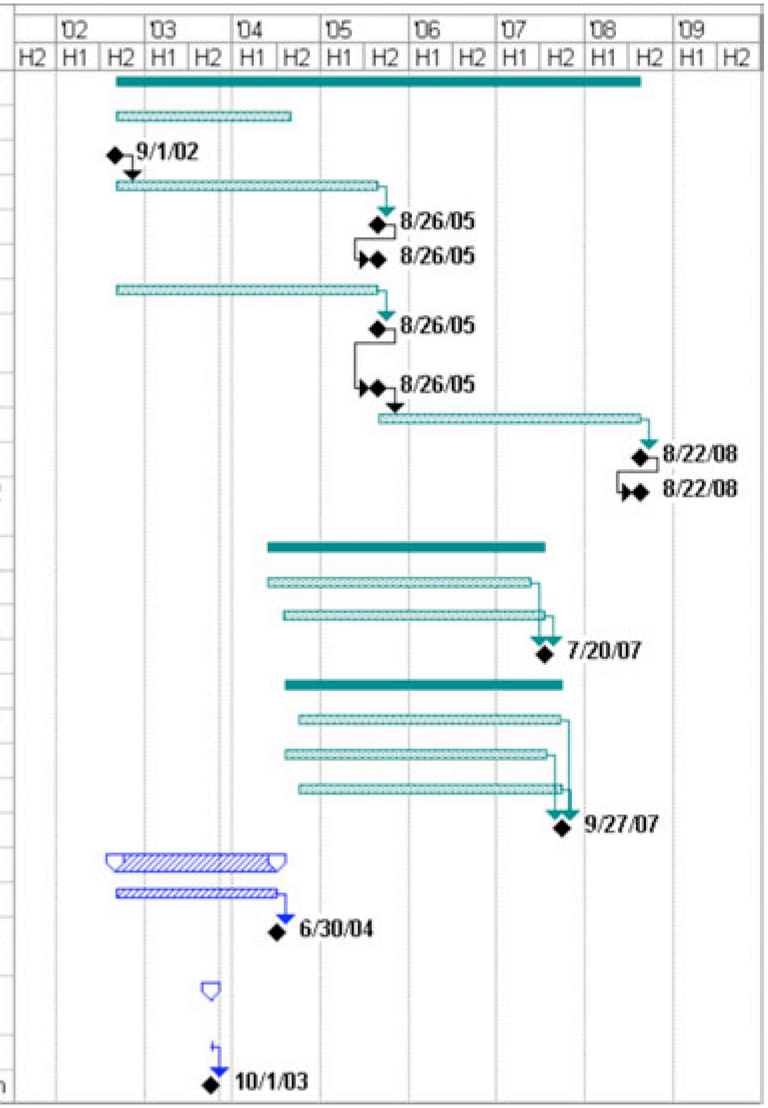


Figure 27: Key Activities in Support of the Thermochemical Platform

ID		WBS	Task Name
296		**3.2.7**	**NETL Modeling Big Island Heat Exchanger/Gasifier**
297		3.2.7.1	NETL Modeling Big Island
298		3.2.7.2	Validate CFD models of Georgia-Pacific BL Gasifier
299		**3.2.8**	**NETL Fuel Chemistry Bed Performance in Black Liquor Steam Reformer**
300		3.2.8.1	NETL Fuel Chem Black Liquor Work
301		3.2.8.2	Validate CFD models of low and high-temperature gasifier
302		**3.2.9**	**NETL Optimization of High Temperature Black Liquor Gasifiers (SNL)**
303		3.2.9.1	NETL Opt Hi Temp BL Gasifiers (SNL) work
304		3.2.9.2	Generate database of algorithms/CFD calculations that predict commercial scale gasifier performance
305		**3.2.10**	**Materials Evaluation Black Liquor Gasifier (ORNL)**
306		3.2.10.1	Materials Evaln BL Gasifier ORNL work
307		3.2.10.2	Characterize exposure samples of metallic and refractory materials
308		**3.2.11**	**Materials Evaluation Pulsed Black Liquor Gasifier (ORNL)**
309		3.2.11.1	Materials Evaln Pulsed BL Gasifier ORNL work
310		3.2.11.2	Complete long-term tests of metallic and refractory samples in PDU
311		**3.2.12**	**Refractory for Black Liquor Gasifier (U.MO Rolla)**
312		3.2.12.1	Select Refractory fpr BL Gasifier U. MO Rolla work
313		3.2.12.2	Subit satisfactory refractory materials for industrial trial
314		3.2.13	Causticizing for Black Liquor Gasifiers
315		3.2.14	Direct Causticization for Black Liquor Gasification
316		3.2.15	NBC Pyrolysis and Other Thermal Processing PLACEHOLDER

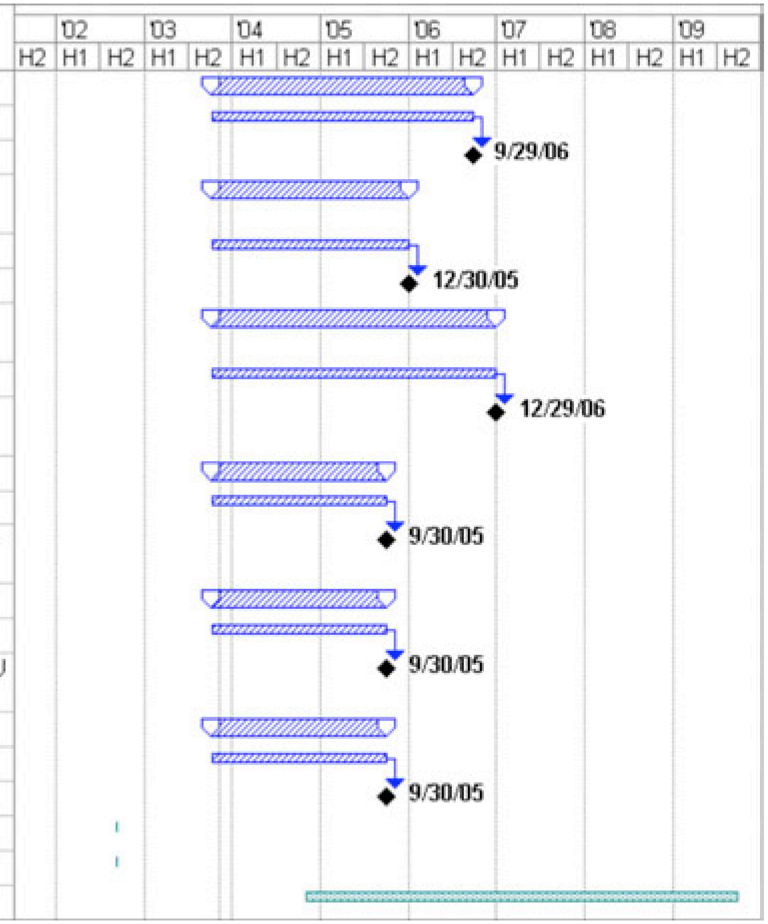


Figure 27: Key Activities in Support of the Thermochemical Platform

ID		WBS	Task Name
317		**3.3**	**Clean up and Conditioning**
318		**3.3.1**	**NBC Clean-up and Conditioning**
319		**3.3.1.1**	**Particulate Clean-up**
320		**3.3.1.1.1**	**Particulate Measurements**
321		**3.3.1.1.1.1**	**Design and fabricate particle measurement system**
322		3.3.1.1.1.1.1	Design system
323		3.3.1.1.1.1.2	isokinetic sampling protocols
324		**3.3.1.1.1.2**	**Particle size characterization**
325		3.3.1.1.1.2.1	Filter media evaluation
326		**3.3.1.1.2**	**Attrition/Agglomeration of Catalyst & Gasifier Solids**
327		3.3.1.1.2.1	Gasifier particle agglomeration
328		3.3.1.1.2.2	Aerosol formation and growth
329		3.3.1.1.2.3	Tar catalyst attrition measurements
330		3.3.1.1.2.4	Catalyst particle agglomeration
331		3.3.1.1.2.5	Achieve greater than 95% removal of +5 micron solids
332		3.3.1.1.2.6	Stage Gate Decision on Attrition/Agglomeration of Catalyst and Gasifer Solids R&D
333		3.3.1.1.2.7	Define tar catalyst attrition/agglomeration characteristics
334		3.3.1.1.2.8	Stage gate Decision on Attrition/Agglomeration of Catalyst and Gasifier Solids R&D
335		3.3.1.1.2.9	Novel Hot gas Clean-up

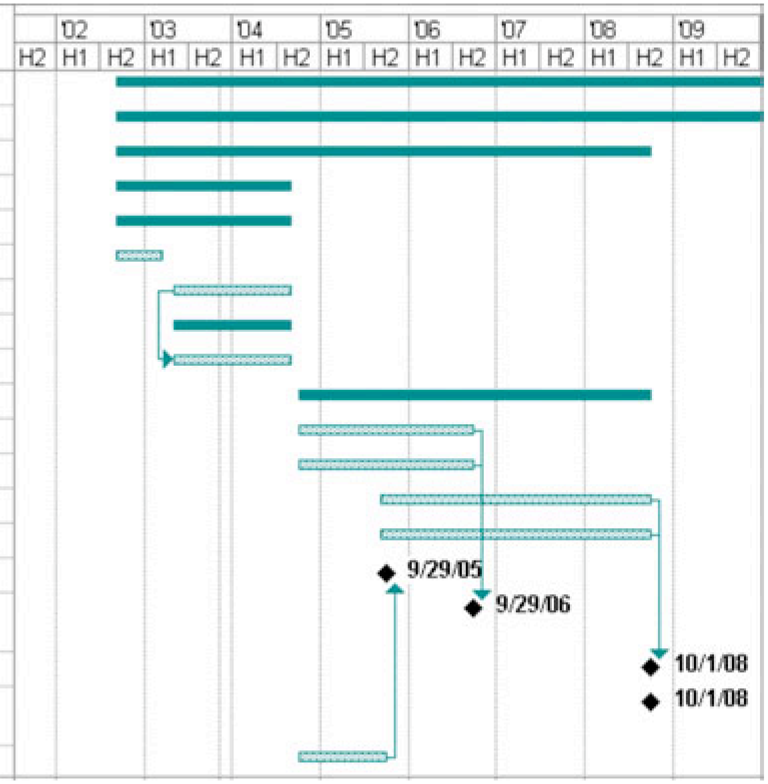


Figure 27: Key Activities in Support of the Thermochemical Platform

ID		WBS	Task Name
336		**3.3.1.2**	**Tar and Heteroatoms**
337		**3.3.1.2.1**	**Catalytic Clean-up**
338		**3.3.1.2.1.1**	**Pilot Slipstream Catalytic Cleanup**
339		3.3.1.2.1.1.1	Preliminary catalyst screening (2"FBR)
340		3.3.1.2.1.1.2	Catalyst life time testing
341		3.3.1.2.1.1.3	Complete 200 hours of catalyst testing
342		**3.3.1.2.1.2**	**Pilot catalytic cleanup**
343		3.3.1.2.1.2.1	Tar reformer installation
344		3.3.1.2.1.2.2	Catalyst testing in tar reformer
345		3.3.1.2.1.2.3	Catalyst lifetime determination
346		3.3.1.2.1.2.4	Catalyst deactivation - poisons and sintering
347		3.3.1.2.1.2.5	Interim Gate review for Pilot Catalytic Clean-up
348		**3.3.1.2.1.3**	**Catalyst Regeneration**
349		3.3.1.2.1.3.1	Stage Gate Decision on Catalyst Regeneration for Gas Clean-up
350		3.3.1.2.1.3.2	Regeneration - slip stream testing, Xytel system
351		3.3.1.2.1.3.3	Design, installation, tar cracker regenerator
352		3.3.1.2.1.3.4	Parametric testing
353		3.3.1.2.1.3.5	Achieve greater than 99% tar destruction
354		3.3.1.2.1.3.6	Stage Gate Decision on Catalyst Regeneration for Gas Clean-up
355		**3.3.1.2.1.4**	**Industrial catalyst testing**
356		3.3.1.2.1.4.1	Stage Gate Decision on Industrial Catalyst Testing
357		3.3.1.2.1.4.2	Industrial testing
358		3.3.1.2.1.4.3	Complete industrial testing
359		3.3.1.2.1.4.4	Stage Gate Decsion on Industrial Catalyst Testing

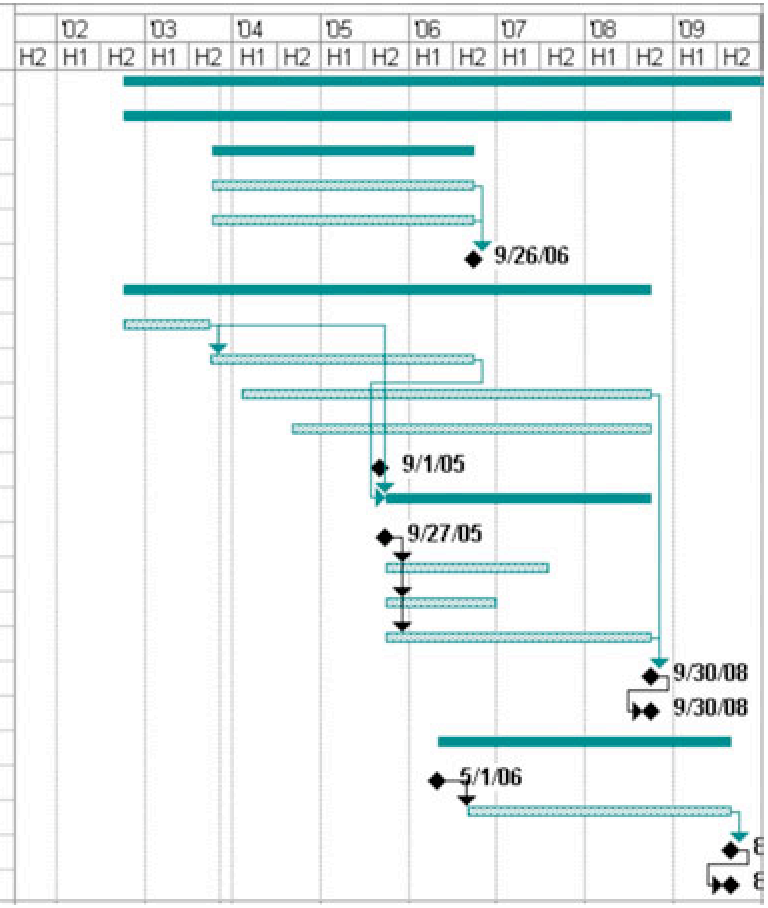


Figure 27: Key Activities in Support of the Thermochemical Platform

ID		WBS	Task Name
360		**3.3.1.2.2**	**Catalytic Clean-up and Conditioning Fundamentals**
361		3.3.1.2.2.1	Design and fabrication of microreactor system
362		3.3.1.2.2.2	Rapid catalyst screening
363		**3.3.1.2.2.3**	**Kinetic model of tar destruction**
364		3.3.1.2.2.3.1	steam reforming rates
365		3.3.1.2.2.3.2	coke formation mechanisms
366		3.3.1.2.2.3.3	Selective poisoning studies
367		3.3.1.2.2.3.4	Develop fluidizable tar reforming catalysts and supports
368		3.3.1.2.2.3.5	catalyst surface characterization
369		3.3.1.2.2.4	Complete development of one catalyst for gas clean-up
370		3.3.1.2.2.5	Stage Gate Decision on Catalytic Clean-up and Conditioning Fundamentals
371		3.3.1.3	Gas Clean-up Targets Validation
372		**3.3.2**	**Condensing gas cleanup**
373		3.3.2.1	water/organics separation
374		3.3.2.2	Organics utilization
375		3.3.2.3	Ammonia separation and use
376		3.3.2.4	Complete one condensing cleanup study
377		3.3.2.5	Stage Gate Decision for Condensing Gas Clean-up
378		**3.3.3**	**Non-condensing gas cleanup**
379		3.3.3.1	Residual carbon utilization
380		3.3.3.2	Alkali control
381		3.3.3.3	Other - tars, chlorides, nitrogen compounds, sulfur
382		3.3.3.4	Complete one non-condensing cleanup study
383		3.3.3.5	Stage Gate Decision on Non-condensing Gas Clean-up

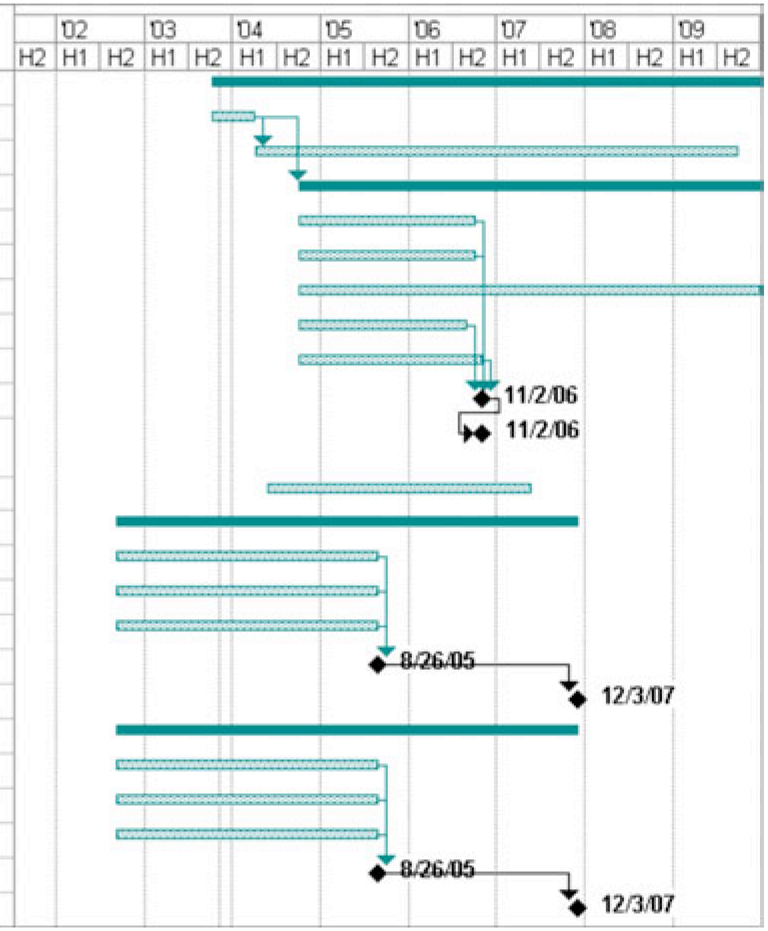


Figure 27: Key Activities in Support of the Thermochemical Platform

ID		WBS	Task Name
384		**3.3.4**	**NETL Black Liquor Evaluation RVS-1 Sorbent for Sulfur Removal**
385		3.3.4.1	NETL BL RVS-1 Sorbent for Sulfur Removal work
386		3.3.4.2	Complete BL gasifier with hot gas cleanup process flow concept for commercial integration into paper mill
387		**3.4**	**Sensors and Controls**
388		**3.4.1**	**NBC Sensors and Controls**
389		**3.4.1.1**	**Feeding System Sensors and Controls**
390		3.4.1.1.1	On line sensor development and testing
391		3.4.1.1.2	Complete development of one sensor
392		3.4.1.1.3	Stage Gate Decision On-line Sensor Feeding Systems
393		**3.4.1.2**	**High Temperature On-line Tar Measure**
394		3.4.1.2.1	Gate Placement Review
395		3.4.1.2.2	Development of high temperature sampling interface
396		3.4.1.2.3	Analytical instrument vendor partnership
397		3.4.1.2.4	Correlation of existing and developing tar measurements
398		3.4.1.2.5	Surrogate or representative tar measurements
399		3.4.1.2.6	Gate review
400		3.4.1.2.7	Host site testing
401		3.4.1.2.8	process monitoring and control
402		3.4.1.2.9	Complete development of on-line tar sensor
403		3.4.1.2.10	Stage Gate Decision for High Temperature On-line Tar Measure

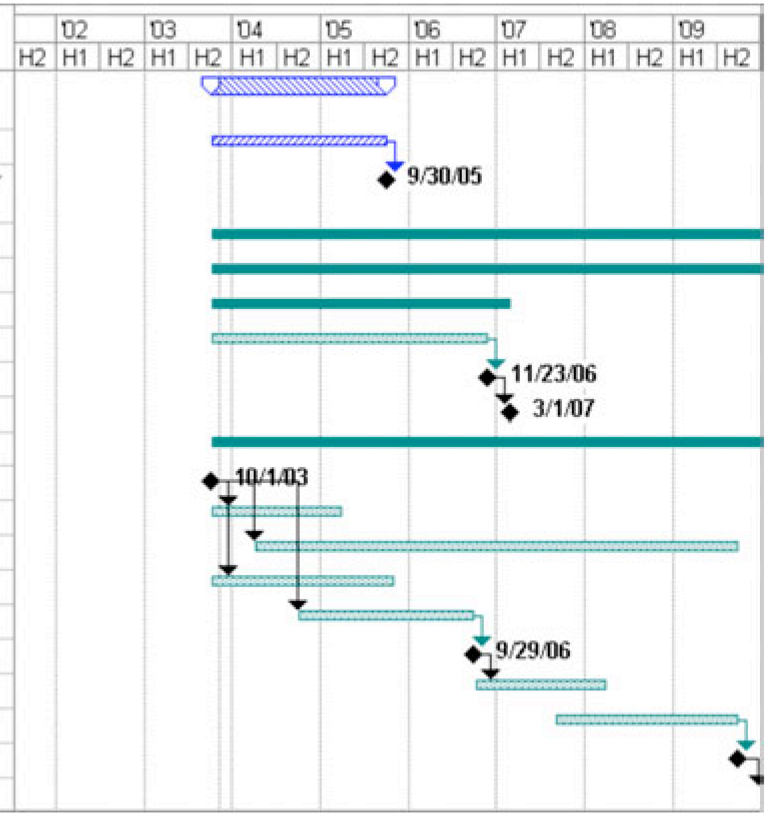


Figure 27: Key Activities in Support of the Thermochemical Platform

ID		WBS	Task Name
404		**3.4.1.3**	**On-line Heteroatom Monitor**
405		3.4.1.3.1	Gate review
406		3.4.1.3.2	Total and species sulfur
407		3.4.1.3.3	Nitrogen compounds (total and species)
408		3.4.1.3.4	Alkali monitors (PSI partnership)
409		3.4.1.3.5	Halides
410		3.4.1.3.6	Complete development of alkali monitor
411		3.4.1.3.7	Interim Gate Review for On-line Heteroatom Monitor
412		3.4.1.3.8	Complete lab development of halide monitor
413		3.4.1.3.9	Stage Gate Decision for On-line Heteroatom Monitor
414		**3.5**	**Thermochemical Platform Analysis**
415		**3.5.1**	**Biomass feed systems**
416		3.5.1.1	State of the Art
417		3.5.1.2	Updates
418		3.5.1.3	Complete state of the art review of Biomass Feeder Systems
419		3.5.2	Feedstock Program coordination
420		**3.5.3**	**NREL Analysis**
421		**3.5.3.1**	**Gas Cleanup**
422		3.5.3.1.1	Detailed Equipment Costs
423		3.5.3.1.2	Incorporate into ASPEN & cost models
424		3.5.3.1.3	Updates
425		**3.5.3.2**	**Oxygen and fuel synthesis as a function of O2 purity**
426		3.5.3.2.1	ASU Detailed Equipment Costs
427		3.5.3.2.2	Incorporate into ASPEN and cost models
428		3.5.3.2.3	Other/emerging technologies

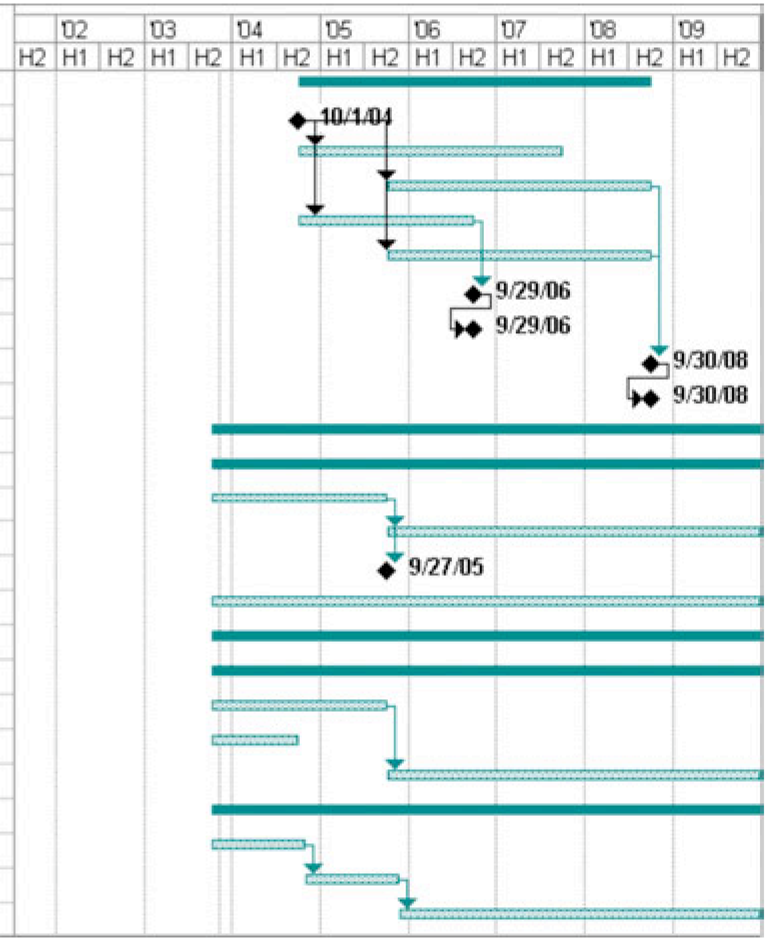


Figure 27: Key Activities in Support of the Thermochemical Platform

ID		WBS	Task Name
429		3.5.3.3	Merchant syngas opportunities
430		3.5.3.4	Complete market review of merchant syngas opportunities
431		**3.5.3.5**	**Fuel Synthesis**
432		3.5.3.5.1	Mixed alcohols
433		3.5.3.5.2	Other fuels/future studies
434		3.5.3.6	Biorefinery utilities
435		**3.5.3.7**	**Pyrolysis**
436		3.5.3.7.1	State of the art
437		3.5.3.7.2	ASPEN Modeling
438		3.5.3.7.3	Complete ASPEN Model
439		3.5.3.7.4	Updates
440		**3.5.3.8**	**Lifecycle assessment/Environmental analysis**
441		3.5.3.8.1	Biomass to hydrogen
442		3.5.3.8.2	Multilab biomass/H2 LCA Study
443		3.5.3.8.3	Future work
444		3.5.3.9	Distributed fuels and chemicals systems
445		3.5.3.10	Future Studies
446		3.5.3.11	Biorefinery residues characterization
447		**4**	**Products**

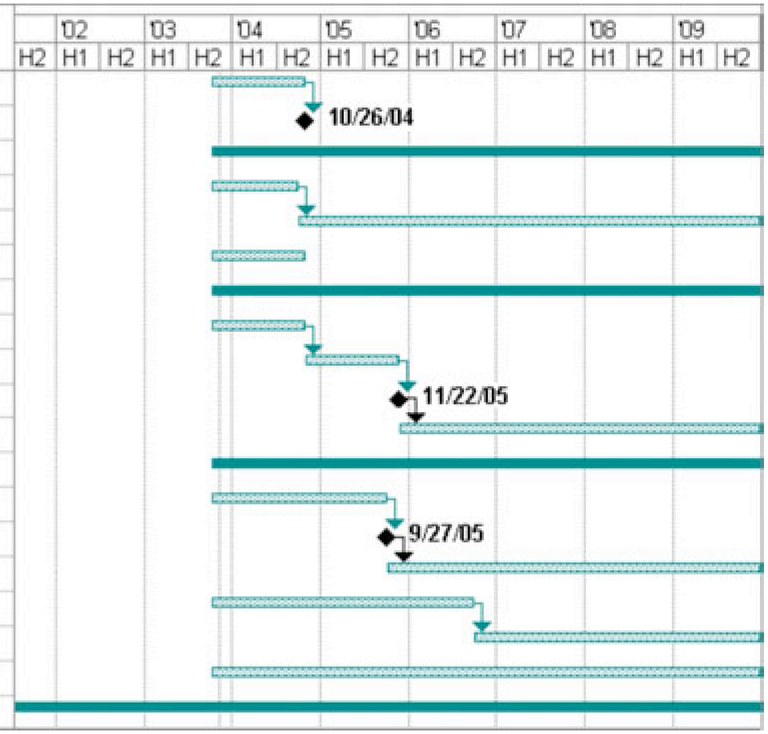


Figure 27: Key Activities in Support of the Thermochemical Platform

Table 7: Thermochemical Platform Core R&D Resource Plan

WBS	Title	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
3	**Thermochemical Platform Core R&D**	**$5,663**	**$5,860**	**$18,372**	**$15,400**	**$13,125**	**$6,740**
	DOE Share	***$4,524***	***$5,860***	***$18,372***	***$15,400***	***$13,125***	***$6,740***
	Partner Share	***$1,139***	***$0***	***$0***	***$0***	***$0***	***$0***
3.1	Feedstock Processing and Handling	$0	$400	$2,875	$2,875	$2,875	$200
3.1.1	NBC Feed Processing and Handling	$0	$400	$2,875	$2,875	$2,875	$200
	DOE Share	*$0*	*$400*	*$2,875*	*$2,875*	*$2,875*	*$200*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.1.1.1	Feeder Demonstration	$0	$150	$1,375	$1,375	$1,375	$50
	DOE Share	*$0*	*$150*	*$1,375*	*$1,375*	*$1,375*	*$50*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.1.1.2	Feedstock Improvement	$0	$250	$1,500	$1,500	$1,500	$150
	DOE Share	*$0*	*$250*	*$1,500*	*$1,500*	*$1,500*	*$150*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2	Thermal Processing	$5,663	$2,100	$8,352	$6,070	$3,725	$2,290
	DOE Share	*$4,524*	*$2,100*	*$8,352*	*$6,070*	*$3,725*	*$2,290*
	Partner Share	*$1,139*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.1	NBC Gasification Core Barrier R&D	$0	$650	$1,655	$1,520	$2,625	$1,740
	DOE Share	*$0*	*$650*	*$1,655*	*$1,520*	*$2,625*	*$1,740*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.1.1	NBC TCP Process Modeling and Optimization Task	$0	$400	$860	$625	$700	$50
	DOE Share	*$0*	*$400*	*$860*	*$625*	*$700*	*$50*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*

WBS	Title	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
3.2.1.2	NBC Gasification Fundamentals	$0	$250	$795	$895	$1,925	$1,690
	DOE Share	*$0*	*$250*	*$795*	*$895*	*$1,925*	*$1,690*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.2	NBC Wet Gasification	$0	$500	$2,000	$2,050	$1,000	$550
	DOE Share	*$0*	*$500*	*$2,000*	*$2,050*	*$1,000*	*$550*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.3	GO High Efficiency Gasification	$0	$100	$1,000	$1,000	$50	$0
	DOE Share	*$0*	*$100*	*$1,000*	*$1,000*	*$50*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.4	GO Innovative Gasification	$0	$150	$1,500	$1,500	$50	$0
	DOE Share	*$0*	*$150*	*$1,500*	*$1,500*	*$50*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.5*	GO Gasification Research Center	$3,394	$0	$0	$0	$0	$0
	DOE Share	*$2,711*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$683*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.6*	GO Biomass Derived Hydrogen from Thermally Ballasted Gasifier	$620	$0	$0	$0	$0	$0
	DOE Share	*$500*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$120*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.7*	NETL Modeling Big Island Heat Exchanger/Gasifier	$0	$0	$500	$0	$0	$0
	DOE Share	*$0*	*$0*	*$500*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.8	NETL Fuel Chemistry and Bed Performance Black Liquor Steam Reformer	$0	$0	$90	$0	$0	$0

WBS	Title	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
	Black Liquor Steam Reformer						
	DOE Share	*$0*	*$0*	*$90*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.9	NETL Optimization High Temperature Black Liquor Gasifier	$0	$700	$600	$0	$0	$0
	DOE Share	*$0*	*$700*	*$600*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.10	NETL Materials Evaluation for Black Liquor and Biomass Gasifiers	$0	$0	$778	$0	$0	$0
	DOE Share	*$0*	*$0*	*$778*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.11	NETL Pulsed Black Liquor Reformed Materials Evaluation	$0	$0	$229	$0	$0	$0
	DOE Share	*$0*	*$0*	*$229*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.12	NETL Refractory for Black Liquor Gasifiers	$0	$0	$0	$0	$0	$0
	DOE Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.13*	NETL Causticizing for Black Liquor Gasifiers	$600	$0	$0	$0	$0	$0
	DOE Share	*$480*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$120*	*$0*	*$0*	*$0*	*$0*	*$0*

WBS	Title	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
3.2.14*	NETL Direct Causticization for Black Liquor Gasifiers	$1,049	$0	$0	$0	$0	$0
	DOE Share	*$833*	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$216*	*$0*	*$0*	*$0*	*$0*	*$0*
3.2.15	GO/NBC Pyrolysis and Other Thermal Processing	$0	$0	$0	$0	$0	$0
	DOE Share						
	Partner Share						
3.3	Clean up and Conditioning	$0	$2,180	$4,870	$4,155	$4,100	$2,600
	DOE Share	*$0*	*$2,180*	*$4,870*	*$4,155*	*$4,100*	*$2,600*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.3.1	NBC Cleanup and Conditioning	$0	$1,880	$2,780	$2,655	$2,600	$2,500
	DOE Share	*$0*	*$1,880*	*$2,780*	*$2,655*	*$2,600*	*$2,500*
	Partner Share		*$0*	*$0*	*$0*	*$0*	*$0*
3.3.1.1	Particulate Cleanup	$0	$430	$430	$230	$0	$0
	DOE Share	*$0*	*$430*	*$430*	*$230*	*$0*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*

WBS	Title	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
3.3.1.2	Tar and Heteroatoms	$0	$1,100	$1,600	$1,950	$2,125	$2,450
	DOE Share	*$0*	*$1,100*	*$1,600*	*$1,950*	*$2,125*	*$2,450*
	Partner Share		*$0*	*$0*	*$0*	*$0*	*$0*
3.3.1.2.1	NBC Catalytic Cleanup	$0	$750	$1,050	$1,350	$1,625	$1,975
	DOE Share	*$0*	*$750*	*$1,050*	*$1,350*	*$1,625*	*$1,975*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.3.1.2.2	NBC Catalytic Cleanup Conditioning Fundamentals	$0	$350	$550	$600	$500	$475
	DOE Share	*$0*	*$350*	*$550*	*$600*	*$500*	*$475*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.3.1.3	NBC Gas Cleanup Targets Validation	$0	$350	$750	$475	$475	$50
	DOE Share	*$0*	*$350*	*$750*	*$475*	*$475*	*$50*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.3.2	GO Condensing Gas Cleanup	$0	$150	$750	$750	$750	$50
	DOE Share	*$0*	*$150*	*$750*	*$750*	*$750*	*$50*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*

WBS	Title	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
3.3.3	GO Non Condensing Gas Cleanup	$0	$150	$750	$750	$750	$50
	DOE Share	*$0*	*$150*	*$750*	*$750*	*$750*	*$50*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.3.4	NETL Evaluationof RVS-1 Sorbent Removal of Sulfur From Black Liquor Gasification	$0	$0	$590	$0	$0	$0
3.4	Sensors and Controls	$0	$400	$1,075	$1,200	$1,325	$550
	DOE Share	*$0*	*$400*	*$1,075*	*$1,200*	*$1,325*	*$550*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.4.1	NBC Sensors and Controls	$0	$400	$1,075	$1,200	$1,325	$550
	DOE Share	*$0*	*$400*	*$1,075*	*$1,200*	*$1,325*	*$550*
	Partner	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.4.1.1	Feeding System Sensors and Controls	$0	$50	$250	$250	$175	$0
	DOE Share	*$0*	*$50*	*$250*	*$250*	*$175*	*$0*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.4.1.2	High-Temperature On-line Tar Measure	$0	$350	$375	$400	$600	$400
	DOE Share	*$0*	*$350*	*$375*	*$400*	*$600*	*$400*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.4.1.3	On-line Heteroatom Monitor	$0	$0	$450	$550	$550	$150
	DOE Share	*$0*	*$0*	*$450*	*$550*	*$550*	*$150*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
3.5	Thermochemical Platform Analysis	$0	$780	$1,200	$1,100	$1,100	$1,100
	DOE Share	*0*	*780*	*1200*	*1100*	*1100*	*1100*
	Partner Share	*0*	*0*	*0*	*0*	*0*	*0*

Table 8 - Thermochemical Platform Projects and Milestones

Biomass Program Goal: To produce a clean syngas from a range of biomass feedstocks that is compatible with existing and advance processes for the production of fuels, chemicals, and power (MYPP & MYTP)

OBP Milestones presented by Garman

- By 2005 complete validation of a process for continuous biomass gasification, tar cracking and syngas reforming.
- By 2007 complete validation of a condensing, gas cleanup system.
- By 2009 complete validation of a catalytic system for cleaning tar.

Objective: By 2010 reduce the cost of cleaned and reformed biomass-derived synthesis gas produced, from a mature gasification plant, from $9 per million Btu in 2003 to $6 per million Btu. (2005 budget)

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
NBC Feed Processing & Handling NOTE: Proposed topics for FY04 focused R&D solicitation	3.1.1.1 Feeder Demonstration	• Supply a uniform feedstock (MYTP) • Reliable feed preparation (MYTP) • Storage and handling (MYTP) • Improved feeders for high- and low-pressure gasifiers (MYTP task description)	12/2003: Define desired characteristics of commercial feeders 09/2004: Feeder development solicitation, FY04 10/2007: Complete pilot testing of at least one feeder that meets defined specifications
	3.1.1.2 Feedstock Improvement – Drying, Densification, Chemical Modification	• Supply a uniform feedstock (MYTP) • Reliable feed preparation (MYTP) • Storage and handling (MYTP) • Lack of efficient, safe dryers (MYTP task description)	12/2003: Define desired characteristics of thermochemical feedstocks based on optimized pre- and in-plant handling costs 09/2004: Feed improvement solicitation 10/2007: Complete testing of feed improvement system that meets the defined criteria.
Thermochemical Processing GO/NBC	3.2.1 NBC Gasification		
	3.2.1.1 TCP Process Modeling and Optimization	• Insufficient understanding of fuels chemistry for commercialization and process scale-up and optimization (inferred from MYTP barrier description)	10/2006: Identify process variables and conditions that minimize formation of undesired impurities 10/2008: Integrate tar kinetics models in process models

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
	3.2.1.2 Gasification Fundamentals	• Insufficient/inadequate CFD modeling tools to support commercialization (inferred from MYTP task description)	10/2005: Complete evaluation of one tar kinetics model and potential for effecting reduced tar formation 10/2007: Complete comprehensive tar kinetics models 10/2008: Mechanistic models development for heteroatom-containing compound conversions
	3.2.1.3 Innovative Gasification Opportunities	• Perceived need for small syngas to synfuels catalytic conversion processes for distributed refineries (MYPP) •	09/2004: Solicitation for feasibility studies of distributed biorefineries 09/2005: Evaluate results of feasibility studies and issue development solicitation if indicated
	3.2.2 Wet Gasification	• Lack of an effective method to convert wet residues to energy-related products (inferred from MYTP task objective)	09/2004: Complete updated economic analysis and assessment of additional feedstocks 09/2004: Complete 100 hrs of scaled-up reactor testing on methane 10/2007: Complete industry testing for methane generation 09/2008: Complete industry testing for hydrogen
	3.2.3 GO High-Efficiency Gasification (O_2 or Enriched Air) NOTE: Proposed topic for FY04 focused R&D solicitation	• Lack of demonstrated, reliable gasifiers suitable for integration with fuel synthesis or hydrogen production (MYTP)	09/2004: High-efficiency gasification solicitation 10/2007: Complete development of one gasifier suitable for hydrogen, fuels, or chemical production

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
	3.2.5 GO Gasification Research Center (SRI/GTI)	• Understanding gas cleanup for removal of tars, particulate, alkali, ammonia, chlorine, and sulfur (MYTP) • Unproven gas cleanup and conditioning technologies and systems (MYPP) • Removal of sub-micron particles and effect of process conditions on particulate size/capture not well understood (inferred from MYTP task description)	12/2003: Complete Facility Design with ± 10 % cost estimate (SRI) 4/2004: Complete Slipstream Design (GTI) 1/2004: Develop comprehensive Test Plan (GTI) 7/2004: Procurement and Construction (GTI) 12/2004: Installation, Checkout, and Shakedown Testing (GTI) 4/2005: Complete Test Period One (GTI)
	3.2.6 GO Gasification of Switchgrass (ISU)	• Understanding gas cleanup for removal of tars, particulate, alkali, ammonia, chlorine and sulfur (MYTP) • Unproven gas cleanup and conditioning technologies and systems (MYPP) • Removal of sub-micron particles and effect of process conditions on particulate size/capture not well understood (inferred from MYTP task description) • Lack of demonstrated, reliable gasifiers suitable for integration with fuel synthesis or hydrogen production (MYTP)	**?/200?: Improve the overall cold-gas efficiency of the gasifier** ?/200?: Establish methodology for reliable hydrogen chloride (HCl) measurements; ?/200?: Demonstrate a combined particulate matter/trace contaminant control system ?/200?: Evaluate the feasibility of a combined catalytic reaction/carbon dioxide sorbent system; ?/200?: Perform economic assessment of ballasted gasifier system
	3.2.7 NETL Modeling Big Island Heat Exchanger/Gasifier	• Insufficient/inadequate CFD modeling tools to support commercialization (MYTP)	12/2003: Complete 2-D and 3-D CFD hydrodynamics models of G-P BL gasifier 09/2004: Complete 3-D CFD model with chemistry for G-P BL gasifier 9/2006: Validate CFD models of G-P BL gasifier

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
	3.2.8 NETL Fuel Chemistry Bed Performance in Black Liquor Steam Reformer	• Insufficient understanding of fuels chemistry for commercialization and process scale-up and optimization (MYTP) • Insufficient/inadequate CFD modeling tools to support commercialization (MYTP)	09/2004: Using lab-scale reactor, identify process variables & conditions that optimize gasification in low-temperature reformer 09/2005: Identify process variables & conditions that optimize gasification in high-temperature reformer 12/2005: Integrate optimization controls into commercial process models 06/2005: Complete 2-D and 3-D CFD hydrodynamics models of low-and high-temperature gasifier 12/2005: Validate CFD models of low-and high-temperature gasifier
	3.2.9 NETL Optimization of High-Temperature Black Liquor Gasifiers (SNL)	• Insufficient understanding of fuels chemistry for commercialization and process scale-up and optimization (inferred from MYTP barrier description) • Insufficient/inadequate CFD modeling tools to support commercialization (inferred from MYTP task description)	Note: Project is on hold pending FY04 appropriations 09/2004: Complete design on high-pressure, high-temperature gasifier lab-scale unit. 09/2005: Identify mechanisms for black liquor drying & oxidation 12/2005: Identify soot & tar formation mechanisms 06/2006: Develop spray droplet formation and transport & radiative properties database 12/2006: Generate extensive database of algorithms and comprehensive CFD model calculations that demonstrates prediction of commercial scale gasifier operation & performance over a range of practical conditions

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
	3.2.10Materials Evaluation for Black Liquor Gasifier (ORNL)	• Reliability and cost of materials for vessels and refractories (MYPP) • Metals used for shells and internals (MYTP) • Refractory materials to line containment vessels (MYTP)	12/2003: Complete simulated lab-scale tests of chemical, thermal, and mechanical cycling environments of gasifiers 12/2003: Install metallic and refractory samples in fluidized-bed BL gasifier at Georgia-Pacific mill 09/2005: Characterize exposure samples of metallic and refractory materials
	3.2.11 Materials Evaluation for Pulsed Black Liquor Gasifier (ORNL)	• Reliability and cost of materials for vessels and refractories (MYPP) • Metals used for shells and internals (MYTP) • Refractory materials to line containment vessels (MYTP)	12/2003: Complete design of 12-tube bundle PDU of Pulsed-Enhanced steam reformer 09/2004: Complete intermediate-duration tests of metallic and refractory samples in PDU 09/2005: Complete long-term tests of metallic and refractory samples in PDU
	3.2.12 Select/Develop Refractory for Black Liquor Gasifier (University of Missouri – Rolla)	• Reliability and cost of materials for vessels and refractories (MYPP) • Refractory materials to line containment vessels (MYTP)	09/2003: Select suitable refractory materials to meet criteria in BL gasifier environments 09/2004: Investigate refractories with acceptable smelt infiltration and corrosion resistance at elevated temperatures 09/2005: Submit satisfactory materials for industrial trail
	3.2.13 NETL Causticizing for Black Liquor Gasifiers	• Mill Integration	08/15/05: Investigate mill integration requirements for successful causticization processes for both HTBLG and LTBLG, and for both partial and complete in situ causticization. 08/15/05: Assess the economics of all technically successful causticization processes.
	3.2.14 NETL Direct Cauticization for Black Liquor Gasifiers	• Mill Integration	02/15/05: Direct causticization testing

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
	3.2.15 NBC Pyrolysis and Other Thermal Processing		
NBC Cleanup and Conditioning GO/NBC	3.3.1 NBC Cleanup and Conditioning		
	3.3.1.1 Particulate Clean-up	• Understanding gas cleanup for removal of tars, particulate, alkali, ammonia, chlorine and sulfur (MYTP) • Unproven gas cleanup and conditioning technologies and systems (MYPP) • Removal of sub-micron particles and effect of process conditions on particulate size/capture not well understood (inferred from MYTP task description)	10/2005:Demonstrate technology to achieve greater than 95% removal of < 5-micron solids for biorefinery applications
	3.3.1.2 Tar and Heteroatoms	• Understanding gas cleanup for removal of tars, particulate, alkali, ammonia, chlorine and sulfur (MYTP) • Unproven gas cleanup and conditioning technologies and systems (MYPP)	
	3.3.1.2.1 Catalytic Cleanup	• Understanding gas cleanup for removal of tars, particulate, alkali, ammonia, chlorine and sulfur (MYTP) • Unproven gas cleanup and conditioning technologies and system. (MYPP) • Lack of suitable tar cracking catalysts (inferred from MYTP task description)	12/2003: Tar reformer installation 10/2005: Develop a fluidizable tar reforming catalyst for scaled-up testing 01/2006: Complete lifetime testing to identify catalyst for use in full-stream reformer 10/2008: Achieve greater than 99% tar destruction with regenerated catalyst 09/2008: Complete industrial verification of catalyst
	3.3.1.2.2 Catalytic Cleanup Conditioning Fundamentals	• Understanding gas cleanup for removal of tars, particulate, alkali, ammonia, chlorine and sulfur (MYTP)	06/2004: Design and fabrication of microreactor system 09/2008: Selective poisoning studies 09/2006: Develop fluidizable tar reforming catalysts and supports 09/2006: Catalyst surface characterization

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
	3.3.1.3 Gas Cleanliness Verification	• Process integration	09/2004: Benchmark study of two catalysts for fuels synthesis
	3.3.2 GO Condensing Gas Cleanup NOTE: Proposed topic for FY04 focused R&D solicitation	• Removal of ammonia and chlorides and foaming issues in the presence of tars (MYTP)	09/2004: Condensing gas cleanup solicitation, FY04 10/2007: Complete one condensing gas cleanup study
	3.3.3 GO Non-Condensing Gas Cleanup for High-Pressure Gasifiers NOTE: Proposed topic for FY04 focused R&D solicitation	• Lack of suitable high-temperature filter materials (physical strength and chemical attach issues) (MYTP)	09/2004: Non-condensing gas cleanup solicitation, FY04 10/2007: Complete one non-condensing gas cleanup study
	3.3.4 NETL Black Liquor Evaluation RVS-1 Sorbent for Sulfur Removal	• Understanding gas cleanup for removal of tars, particulate, alkali, ammonia, chlorine and sulfur (MYTP)	12/2004: Demonstrate at lab-scale the NETL sorbent to removal sulfur from syngas produced in black liquor gasifiers 09/2005: Complete BL gasifier with hot gas cleanup process flow concept for commercial integration into paper mill

Technical Barrier Area	**Project**	**Specific Technical Barriers Addressed**	**Milestones**
Sensors and Controls	3.4.1 NBC Sensors and Controls		
	3.4.1.1 Feed System Sensors and Controls NOTE: Proposed subject for FY04 focused R&D solicitation	• Inadequate control systems technology for gasifier systems and subsystems (MYPP) • Process control for performance and emissions, fuel properties, atmospheric conditions, (MYTP) • Process technology demonstrating sustained integrated performance that meets environmental and safety requirements (MYTP) • Lack of real-time feed sensor for moisture and composition (from MYTP task description)	09/2004: Feed sensor solicitation, 10/2006: Complete development of real-time feed sensor
	3.4.1.2 High-Temperature On-Line Tar Measurement	• Inadequate control systems technology for gasifier systems and subsystems (MYPP) • Process control for performance and emissions, fuel properties, atmospheric conditions, (MYTP)	10/2006: Complete development of on-line alkali monitor 10/2009: Complete development of on-line tar monitoring instrument
	3.4.1.3 On-Line Heteroatom Monitor	• Inadequate control systems technology for gasifier systems and subsystems (MYPP) • Process control for performance and emissions, fuel properties, atmospheric conditions, (MYTP)	10/2006: Complete development of on-line alkali monitor 10/2009: Complete development of on-line tar monitoring instrument

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
Syngas Platform Analysis	3.5 Syngas Platform Analysis	• Provide direction and focus to R&D by evaluating the technical, economic, and environmental aspects of biomass syngas production and conversion	07/2004: Complete review of merchant syngas market 01/2005: Complete multi-lab biomass to H_2 LCA study 05/2004: Complete ASPEN modeling of pyrolysis system 09/2004: Design study for thermochemical biorefinery

2.4 Products

The broad heading of Products R&D includes work for products in three market sectors: (1) fuels, (2) chemicals and materials, and (3) power. The Products R&D portfolio needs to bridge the gap between technology development and market pull. Products R&D provides customers with an interface to the Biomass Program. It also provides the means for OBP to meet the EERE goals of reducing dependence on foreign oil and helping to create the new, domestic bioindustry. Producing biofuels and biopower will have a significant impact on reducing dependence on foreign oil. Producing biobased products will help create the new, domestic bioindustry and also provide some help in reducing dependence on foreign oil. These three market sectors and examples of products that serve them are listed in Table 9.

Table 9: Market Classes for Products R&D

Biobased Fuels for Transportation Markets:
• Ethanol, alcohol blends, Fischer-Tropsch liquids, bio-oils, biodiesel (methyl and ethyl esters), fuel additives, oxygenates and hydrogen
Biobased Products for Chemicals and Materials Markets:
• Drop-in replacements for existing commodity chemicals, new commodity chemicals for existing or new applications (improved performance, new functions, etc.), building blocks for production of a variety of secondary chemicals
Combined Heat and Power for the Utility Market:
• From centralized plants or distributed systems provide heat and power to the biorefinery and grid.

Products R&D efforts will focus on maximizing the value of all of the components produced by the Sugars and Thermochemical Platforms. For the Sugars Platform, these outputs include mixed C6 and C5 monomeric and oligomeric sugars, lignin, protein, and inorganic residues. Platform outputs from the Thermochemical Platform include syngas with varying amounts of tars and oils with widely varying composition, bio-oils, char, and ash. Depending on the source of the original biomass feedstock and pretreatment processes used by the platforms, there may be other biomass components such as oils, plant extractives, and polymeric carbohydrates such as starch, cellulose, or hemicelluloses, which can be used for direct conversion to products. Many of these polymeric sugars, oils, and extractives already have large-volume, value-added markets.

Biorefinery production of fuels, chemicals, materials, and power should reduce the overall costs of all these products, and increase the commercial viability of the biorefinery. The Products R&D portfolio differs from the Integrated Biorefineries portfolio in that it focuses on the development of specific unit operations, biological and chemical conversion, and separations that enable the low-cost production of fuels, chemicals and materials, and power. The biorefinery will take a series of these specific unit operations and, depending on the feedstock and specific interests of the commercial partner(s), combine them in different ways to create different biorefineries. The Products R&D portfolio will also work to insure that new technology is developed to increase the value of all of the platform outputs, including ones such as lignin, char, and protein residues, that are perceived to be the most complex and lowest value.

For OBP to make a significant contribution to EERE's strategic goals, the Products R&D portfolio must simultaneously advance biobased fuels, chemicals and materials, and biopower. Similarly as for petrochemical refineries, fuels and power are likely to consume the majority of the feedstock and constitute the major product volumes, while biobased chemicals and materials are likely to be the higher value and more profitable stream. The relative amount of biofuels and biopower, compared to bioproducts will vary widely depending on the source and composition of the biomass feedstock and on market needs.

Table 10: Common Biomass Components Produced by the Platforms

Biomass Components from the Sugars Platform	Biomass Components from the Thermochemical Platform
Six-Carbon Sugars (monomers and oligomers)	Permanent gases (CO, CO2, H2, H2O, CH4, etc)
Five-Carbon Sugars (monomers and oligomers)	Condensable bio-oil liquids
Lignin/Ash	Char/Ash
Extractives	
Protein	
Other components that can be isolated from biomass include polymeric sugars such as cellulose, starch, and hemicelluloses, as well as crop oils.	

As described in the MYPP, the Products R&D work has a significant near-term focus on the sugars and thermochemical platforms. It also includes work on oil-based products, technoeconomic and lifecycle analyses, and Congressionally mandated projects. The Products R&D portfolio also includes more fundamental work designed to overcome general barriers.

2.4.1 Technical Goals and Objectives

All R&D in the Products Area focuses on allowing OBP to meet EERE's goals of reducing dependence on foreign oil and helping to create the new, domestic bioindustry.

Specific goals for Products R&D include:

- By 2010, developing technology that allows for production of ethanol at a cost of $1.32/gallon from $0.07/lb sugars
- By 2010, establishing the industrial viability of four commodity-scale chemicals or materials co-produced in an integrated biorefinery.

To meet these goals and to significantly reduce dependence on foreign oil, the Products R&D portfolio includes work on processing and converting biomass components—sugars and lignin, thermochemical outputs—to liquid fuels and petroleum replacements. The R&D activities for production of liquid fuels include advanced fermentation for production of ethanol, catalytic clean-up and conversion of syngas, bio-oil upgrading, and processing for improving the quality of biodiesel made from very low cost feedstocks.

Increasing the value of all the platform outputs— lignin, char, protein residues, and ash—will help the Sugars Platform and Thermochemical Platform meet their respective goals of producing $0.07/lb sugars and $6/MMbtu syngas from lignocellulosics.

In addition, Products R&D supports the creation of the new, domestic bioindustry by working to develop specific unit operations that can be used by industrial partners who have a clear understanding of the performance attributes and dynamics of the market for specific chemicals and materials. To enable the development of additional new products, Products R&D will also work at a more fundamental level to overcome general technology barriers.

To accomplish these goals, OBP's efforts in Products R&D will pursue two strategic pathways. Strategy One includes the majority of the Products R&D work and focuses on RD&D efforts that are cost-shared with industrial partners capable of defining the performance characteristics, market dynamics and cost advantages of biobased products. Strategy Two includes components of pre-competitive R&D activities focused on increasing knowledge and overcoming fundamental barriers in areas such as improved fermentations, biocatalysis/catalysis, and separations, and ensuring complete utilization of all the feedstock components, while minimizing emissions.

2.4.2 Programmatic Status

Activities included in the Products R&D portfolio include a broad array of technologies. In part, this is because prior to creation of OBP, three different EERE Programs conducted work in "products." The Biofuels Program focused on production of ethanol and biodiesel fuels. The Biomass Power Program focused on production of heat and power. Production of chemicals and materials was the focus of the Agriculture Industries of the Future Program within the Office of Industrial Technologies. Now the products activities from all three programs have been merged into the Products R&D activities described here.

Because of this legacy, the work in Products R&D is not yet completely balanced in terms of the emphasis on fuels, chemicals and materials, and combined heat and power. Nor is it completely balanced among the utilization of sugars, thermochemical intermediates, oils, and other biomass components used as feedstocks. Also, no projects focus on utilization of a number of biomass components such as lignin, char, extractives, and protein residues.

To help understand the potential for chemicals and materials to enhance the industrial viability of the biorefinery, OBP recently completed a series of studies that identified a series of chemicals and materials that could be produced from sugars, syngas, and oils. Analyses such as these will be expanded in the coming years and the feedstock components will be widened to include other biomass components such as lignin, extractives, and char. While these studies identified some specific potential target chemicals and materials that could be made from sugars, syngas, and oils, their other main purpose was to identify barriers in unit operations that were common to the production of many of these chemicals and materials. These common barriers will be further defined in future studies and used to help focus the fundamental work conducted under the pre-competitive Strategy Two approach described above.

The following brief summaries describe Products R&D projects that are currently underway or will be initiated early in the MYTP.

Fuels

- *Fuels from the Sugars Platform*

Two projects (Arabinose Yeast CRADA and Consortium for Plant Biotechnology Research) focus on improving the conversion of five-carbon- or mixed-sugar streams to ethanol. One project (E-Diesel) looks at the serious safety issues of ethanol/diesel blends.

- *Fuels from the Thermochemical Platform*

There are no projects focused on production of fuels from thermochemical outputs.

- *Fuels from Oils*

One multi-component project (Renewable Diesel Technology) looks at the performance of biodiesel in engines and at production and use of oils and fats as feedstocks for transportation fuel.

Chemicals and Materials

- *Chemical and Material Products from Sugars Platform Outputs*

Four projects (Development of Yeasts for Production of Chemicals, Biorefinery for Polymers and Fuels, Genomics for Enhanced Bio-Products from Sorghum, Engineering Thermotolerant Biocatalysts for Biomass Conversion to Products) focus on developing improved fermentations or biocatalysts for the production of chemicals and materials. One project (Acid Catalyzed Hydrolysis) focuses on conversion of biomass waste streams to hydrogen.

- *Chemical and Material Products from Thermochemical Platform Outputs*

Two projects (Adhesives from Wood Bark, Pyrolysis Oil Upgrading) focus on production of chemicals and materials from processes that produce condensed bio-oils.

- *Chemical and Material Products from Oils*

Three projects (Chemicals from Oilseeds, Polymer Building Blocks from Vegetable Oils, Platform Chemicals from an Oilseed Biorefinery) focus on production of value-added chemicals and materials from oilseeds. One project (National Ag-based Lubricants Center) is focused on the evaluation of lubricants from crop oils.

Combined Heat and Power

One project (Heat and Power from Biomass) focuses on production of heat and power from thermochemical platform outputs. There are no combined heat and power projects in the sugars or oils areas.

Planning and Analysis for Products

There is one crosscutting analysis project in Products R&D. This project includes a study of the most common barriers inhibiting the production of value-added products from sugars. A second project component looks at market opportunities for biobased products.

2.4.3 Technical Barriers

Products R&D will use the platform outputs and other plant components for production of fuels, chemicals and materials, and power. The fuels and power may be sold directly to consumers. Chemicals and materials, however, will likely require several process steps—from platform outputs to “building blocks,” then to “secondary chemicals,” then finally to industrial or consumer products. The core of the Products R&D work involves processing and conversion technology to enable cost-effective manufacturing of valuable products demanded by the marketplace. The processing and conversion step(s) may involve a number of individual unit operations. In this scenario, each step may contain a number of specific technical barriers. Specific performance targets for measuring progress towards overcoming these barriers will vary depending on the specific process and product. For example, process yields may have to be higher for fuels than for a more valuable chemical.

Researchers for each project must consider the quality and cost of different potential feedstocks. Systems analysis will reveal the cost and performance targets needed to reduce technical risk and speed commercial development. The Products R&D program will use technical and economic analyses across the program and as part of Stage Gate Reviews to guide the R&D projects.

At this time, the impacts of overcoming the specific barriers listed below are being evaluated with both technical and market based analyses. These analyses will allow the program to better define the most critical areas for additional R&D.

2.4.3.1 Processing and Conversion

Robust Fermentations

Fermentation is the heart of most bioprocesses. Traditional fermentation involves aqueous phase microbial processing to convert the substrates into fuels and biobased products. Although there are currently large-scale commercial ethanol production facilities using fermentations to produce fuel-grade ethanol, there are a number of barriers that must be overcome for production of fuels and products from lignocellulosic sugar streams. Many of these barriers are common to both ethanol production and the production of chemicals and materials. Barriers include a need for improvements in yield, rate, complete conversion, and selectivity. To enhance economic viability, new, enhanced, and robust microbes need to be developed that allow fermentation of all five biomass sugars, are efficient at higher temperatures and salt concentrations, and are resistant to inhibitors. Novel bioreactors may offer an opportunity to periodically or continuously remove inhibitors/products from the fermentation. Combinations and assortments of microbes may also be able to carry out multiple-step transformations when such processes are better understood. Bioprocessing of syngas provides a potentially low cost approach to using only moderately clean syngas that may be available at lower cost because bioprocessing may be less sensitive to some types of impurities than common metal catalysts. All of the fermentation work will need to be carefully integrated with the processes used for production of the fermentation substrates.

A number of fundamental issues must be addressed for improved fermentations. Barriers include a lack of fundamental understanding of fermentation behavior in extreme environments (T, P, pH), gas/liquid two-phase processes, and non-aqueous phase milieu. The use of bioprocessing for commodity chemicals and materials will require improving the biocatalysts (enzymes or microbes), understanding the impact of the operating environment on the activity of the biocatalysts, better use of existing and advanced reactor designs, and developing appropriate process control.

Improved Catalytic Conversions

Chemical – Nearly 90% of all chemicals produced in the United States require catalysis. The single most important factor for catalyst performance is selectivity. Yield, which is a product of selectivity and conversion, is also important, but modest conversions can often be managed with recycle.

The Products R&D portfolio will leverage both the fundamentals and the applied aspects of the large body of knowledge of Fischer-Tropsch catalysts. Syngas from biomass has unique aspects in terms of the trade-off between cost and quality of the syngas. Products R&D for the use of biomass syngas will be closely linked to the syngas clean-up work performed under the Thermochemical Platform. Improved catalysts for the selective conversion of complex bio-oil mixtures are also needed.

Aqueous phase catalysis for biobased products is in its infancy. There is great potential for improving the selectivity and lowering the costs of catalysis for biomass-derived feedstocks. General considerations for heterogeneous catalysis include, lifetime, selectivity, conversion, and weight hourly space velocity. In addition to these considerations, homogenous catalysis adds the dimension of catalyst recovery. The following are specific needs for overcoming barriers to using catalytic conversions.

- New catalysts and processes for hydrogenation of sugars and oils
- New catalysts for oxidation, particularly milder, more specific oxidation catalysts

- New acid catalysts for dehydration
- Selective bond cleavage catalysts
- New, selective hydrogenolysis catalysts for the conversion of alcohol sugars.

Fundamental areas of study in chemical catalysis include the development of new catalysts with improved selectivity; understanding catalysis in aqueous systems; knowledge of mass transfer, adsorption, and desorption properties; highly porous functionalized supports; and factors that promote more durable catalysts.

Biocatalysis - Biocatalysts include microbial cells and enzymes. Immobilized microbial cells and enzymes are widely used in the pharmaceutical intermediate industry and have an expanding role in the specialty chemical industry. As of yet, these biocatalysts are used sparingly in the commodity chemical industry.

Biocatalysts have the ability to preserve unique properties of biomass such as chirality and hydroxyl groups that are not easily obtained via petrochemical processing. 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 unfamiliarity of the process chemicals industry with the use of biocatalysts.

Fundamental barriers include limited range of chemical transformations, poor interface with organic solvent systems, and stability in extreme environments.

Efficient, Cost-Effective Separations

Separations can account for a major fraction (greater than 50%) of the overall production costs for certain products (power being excluded from analysis) and often are a critical economic barrier to successful commercialization.

Separations strategies are strongly dependent on the target product as well as feedstock impurities. Byproducts are an issue in both chemical and biological processing, and, for fermentations, the nutrient components add an additional separation barrier.

Biobased products can be liquid phases such as neutral species (alcohols, polyols, etc.) or ionic species (organic acids, amino acids, and other charged species and derivatives) or gaseous or solid products. All combinations of solid, liquid, and gaseous separation technologies will be required for biobased products. Advanced approaches employing membranes or combinations of reactions and separations are needed to address needs, some at high temperature. Separation needs are often product specific and process integration enhances opportunities for cost savings.

Analytical Tools and Sensors

New analytical tools and sensors are needed for process development and process control. They are also needed for fundamental characterization of biomass feedstocks and for understanding the interactions between biomass substrates and enzymes and catalysts at the molecular level. Such needs are magnified by the complex and varying array of biomass feedstocks flowing into and through biorefinery processes. A combination of analytical tools including both hardware and data processing software will be needed. Improved analytical tools are required for process development and process control.

2.4.3.2 Using Programmatic History As A Guide

The long history of DOE's involvement in bioprocessing of lignocellulosics to ethanol identifies several R&D needs that also apply to Products. For example, the previous Biofuels Program engaged in research in developing ethanologens, fuel and chemical uses for lignin, multiple separation approaches, and improving enzymatic biocatalysts. The new Products R&D program will also likely include R&D in these areas. For example, the MYTP envisions that more detailed examination of three specific topics could help achieve Products R&D outcomes: Ethanologens, chemical catalysts, and bioseparative reactors. The ethanologen research would involve development of metabolic model(s) capable of providing accurate guidance in pathway engineering and of optimizing fermentations to substantially reduce the resources required to develop slates of products such as ethanol from mixed sugar hydrolysates of lignocellulosic biomass. Research in chemical catalysts would be directed to achieving a better understanding of the interactions between sugars (with different stereochemistry and functionalities) and heterogeneous and homogeneous catalysts. This includes the formation of both primary and secondary reaction products. The bioseparative reactors research would examine combined conversion and separations technologies to reduce overall processing costs. Other historical and relevant program efforts will be examined for potential reevaluation within the next five years.

2.4.4 Technical Approach

The work breakdown structure for the Products Area is organized into projects that correspond to the use of sugars, thermochemical outputs, and oils for developing fuels, chemicals and materials and heat and power (Figure 28). This WBS contains only existing projects in FY04. Historical program experience, new analyses such as the "top ten," syngas and oils analyses, integrated biorefinery and other new analyses will fill gaps in the portfolio.

A conceptual biorefinery was shown in Section 1.2, Figure 2. There are a number of unit operations that can produce bioproducts, and all of these are part of the Products R&D portfolio. A petrochemical refinery can be used as a conceptual model for the Products R&D portfolio. A biorefinery may produce a wide variety of specific products depending on the feedstock, geographic location, and strategic focus of the organization operating the facility, but there are three major elements that will be common to all biorefineries. First, all biorefineries will produce a significant amount of a fuel product, and process heat and power, and the vast majority will produce biobased chemicals and materials. Second, there will be continuous interest in identifying new processes that allow for the production of more valuable chemicals and materials or that lower the production costs of the current suite of chemicals and materials. These improved processes will serve as the economic driver for the overall profitability of the biorefinery. Changes in the composition, costs and availability of the biomass feedstocks, improvements in the processing and conversion technology, and market changes will dictate how these new processes are incorporated into biorefineries. To provide a balanced portfolio the technical approach involves a two-prong technical strategy. . These two strategic approaches are described in detail in the Program Management section, and are only briefly described here. Strategy One involves highly leveraged interactions with industry characterized by significant cost-share (20-50%) and is typically done with a team of performers. These partnerships will have a clear understanding of the cost and performance requirements of the marketplace. Strategy Two involves pre-competitive R&D to reduce the uncertainty of specific technical barriers and, depending on the ownership of intellectual property, may not require any cost-share.

The technical approach for specific byproducts is summarized below.

Biobased Fuels for Transportation Markets

Production of ethanol from mixed sugars is key for the biobased fuels industry. There are well-developed, commercially available technologies for producing ethanol from high quality glucose streams, but there is no commercially viable technology for producing ethanol from less expensive, more complex lignocellulosic sugar streams. The biorefinery will have to effectively use a mixture of five or more individual sugars, and these streams also contain phenolic and extractive components that can inhibit ethanol fermentation. Integration and use of lignin and protein solid residue streams will be key for the commercial viability of lignocellulosics ethanol biorefineries.

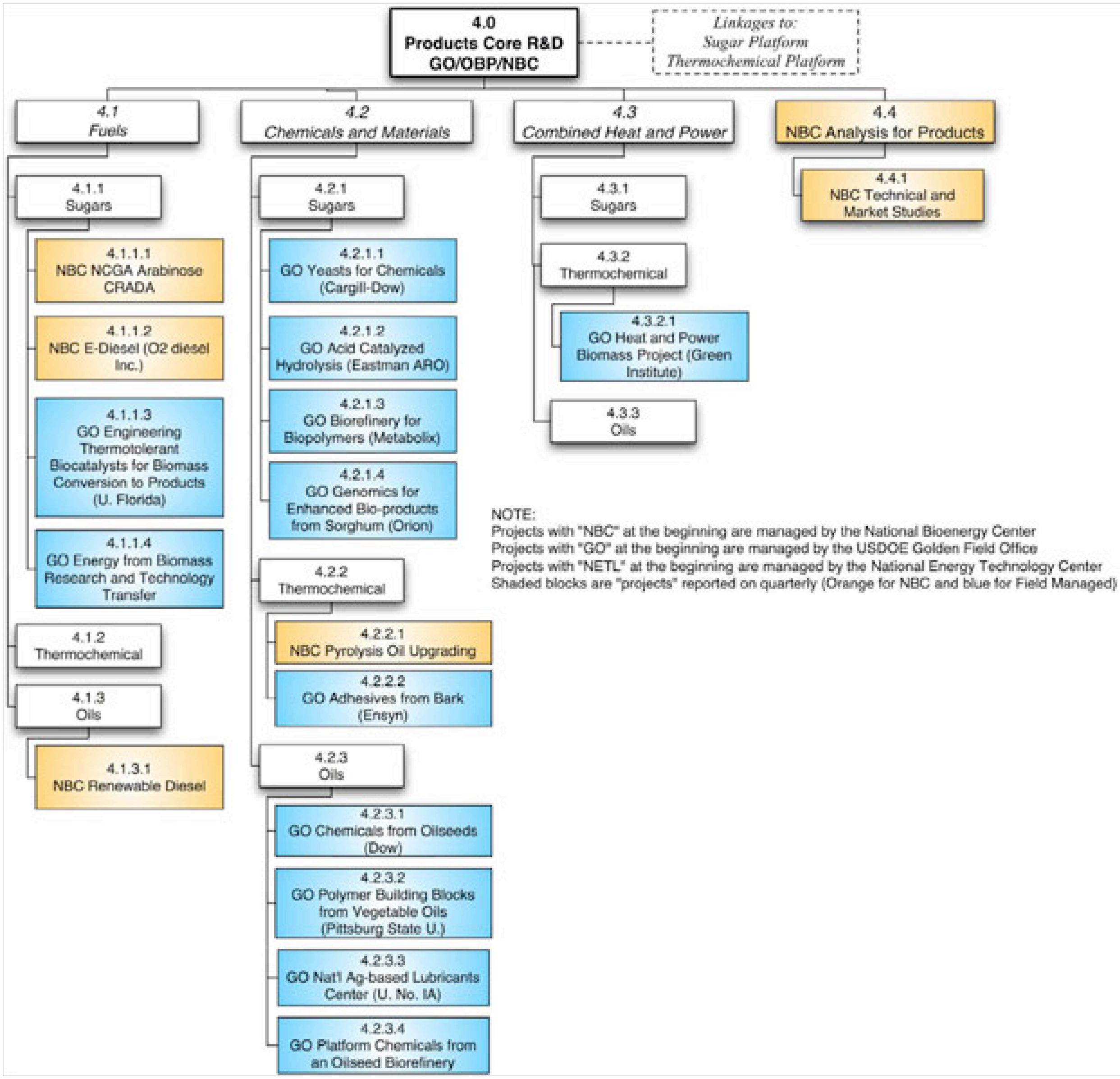


Figure 28: Work Breakdown Structure for Products Core R&D

Similar to production of ethanol from clean glucose, production of Fischer-Tropsch liquids from clean natural gas-derived syngas is a well-developed, commercial technology. But the biorefinery must be able to produce Fischer-Tropsch liquids from more complex, biomass-derived syngas, which is not a commercially viable technology. This is because the tars and impurities contained in biomass-derived syngas will deactivate the catalysts that are required for the conversion of syngas to Fischer-Tropsch liquids. Thermochemical Platform R&D activities focus on evaluating catalysts for the destruction of the tars and other impurities in biomass derived syngas. Products R&D activities in the future may include evaluating commercially available catalysts with biomass-derived syngas streams of varying quality.

Bio-oils are produced by the thermal depolymerization of a variety of biomass sources. Thermal depolymerization processes are very robust, can be conducted under a wide variety of reaction conditions (reaction times, temperatures, pressures), with or without high moisture contents or catalysts, and accommodate a wide variety of feedstocks or process residues. Bio-oils are complex mixtures that can be produced at a low cost and used directly for some fuel application or upgraded into more valuable products. These upgrading processes are of interest for Products R&D.

Production of biodiesel from oilseeds and animal by-products is a well-developed technology. Increasing biodiesel production volumes will require new, value-added uses of the glycerol that is generated during biodiesel production and new technology for production of biodiesel for low cost feedstocks. OBP is interested in both of these barrier areas.

Production of fuel additives, oxygenates and hydrogen will require evaluation of commercially available catalysts with real biomass derived syngas streams.

Biobased Products for Chemicals and Materials Markets

The suite of chemical and material projects in the Products R&D portfolio can be classified by their strategic approach. Industrial partners responding to competitive solicitations will generally define Strategy One projects. Depending on the focus of the competitive solicitation and the technology expertise and market interests of the company(s) the specific processes/projects may vary widely and be derived from any of the biomass components. Thus it is likely that most of these projects will focus on feedstocks and technologies that are nearer to commercialization. As witnessed by the current portfolio of projects these will tend to technologies that use relatively clean sugars, more valuable thermochemical outputs and crop oils.

Strategy Two projects will include precompetitive activities that focus on overcoming barriers that are common to many products. Barrier areas that are common to a number of bioproducts were identified by the "Top Ten" analysis looking at biobased chemicals and materials from sugars and syngas, and the oils products review. The initial phase of the Top Ten analysis has revealed several barrier areas common to products from sugars and syngas. Additional analysis is required for other thermochemical outputs, lignin, and emerging feedstocks. The common barrier areas include a need for improved fermentations and catalysts for conversion of sugars. Projects conducted under this strategy will also focus on the more complex, less attractive biomass components such as lignin, protein, and char. These projects are needed to ensure that advanced biorefineries supported by OBP are commercially competitive, energy efficient, and environmentally benign. Not surprisingly, these areas are consistent with previous work in the program related to the conversion of lignocellulosics to fuels and such historical experience will be enlisted to develop the Products R&D portfolio

Heat and Power for the Biorefinery and Utility Markets

Biorefineries will have significant heat and power requirements. The efficient use of all residue streams can help satisfy some or all of the heat and power requirements. In some cases there will be an opportunity to export heat and power.

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 biomass cofiring in coal-fired power stations, introduction of high-efficiency gasification combined cycle systems, and efficiency improvements in direct combustion systems. Technologies presently at the research and development stage, such as integrated gasification fuel cell systems, and modular systems are expected to be competitive in the future.

Planning and Analysis for Products

Each project will include its own analysis and planning work specific to the technology under development. This activity is crosscutting and supports the entire Products R&D area. Products R&D is somewhat unique in the variety of products that can be produced from biomass feedstocks. In the case of fuels and power, there are a limited number of potential products— ethanol, Fischer-Tropsch liquids, biodiesel, hydrogen, and heat and electricity. But in the case of chemicals and materials, there are hundreds of products that can be made. The key is to identify the products that allow OBP to help EERE met its goals of reducing dependence on foreign oil and helping to create the new, domestic bioindustry. These products should be for, or have the potential to enter into, large volume (greater than 1 billion pounds) chemical markets and serve as the economic driver for the biorefinery. The goal is not to pick the best targets for DOE to pursue; that is industry's role. The goal is to identify processes and unit operations that are common to many of the products for pre-competitive work to support many projects focused on specific products. This first study has been limited to products that can be made from sugars and syngas. Additional studies will evaluate products that can be made from other biomass feedstocks.

In the stage-gate context, the activities conducted under Strategy One are on the "commercial line," and activities conducted under Strategy Two are on the "research line." The stage-gate process can be applied to both strategies and provide a means to address the highest priority technology pathways that will overcome technical barriers. OBP efforts can be leveraged from platform R&D and focus on specific pathways that will yield enabling technologies for both products and platform R&D.

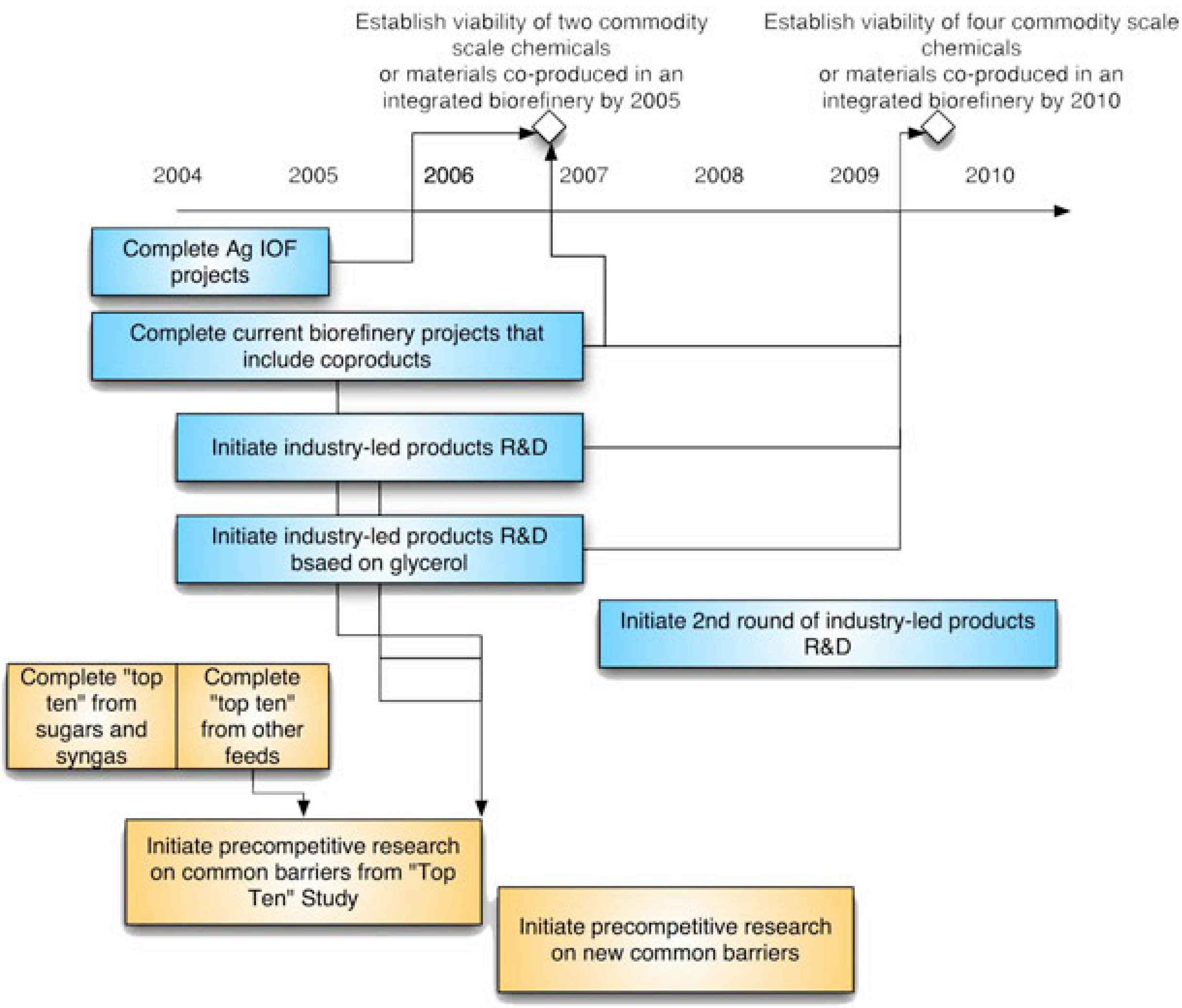


Figure 29: Relationship Between Core Products R&D and Integrated Biorefineries

2.4.5 Resource Allocation Plan

Table 11 summarize the resource allocation plan for the Products Platform Core R&D area. Figure 30 shows proposed spending trends for various elements of the Products Core R&D area. This area of the Program like the Integrated Biorefineries, contains significant partner cost sharing.

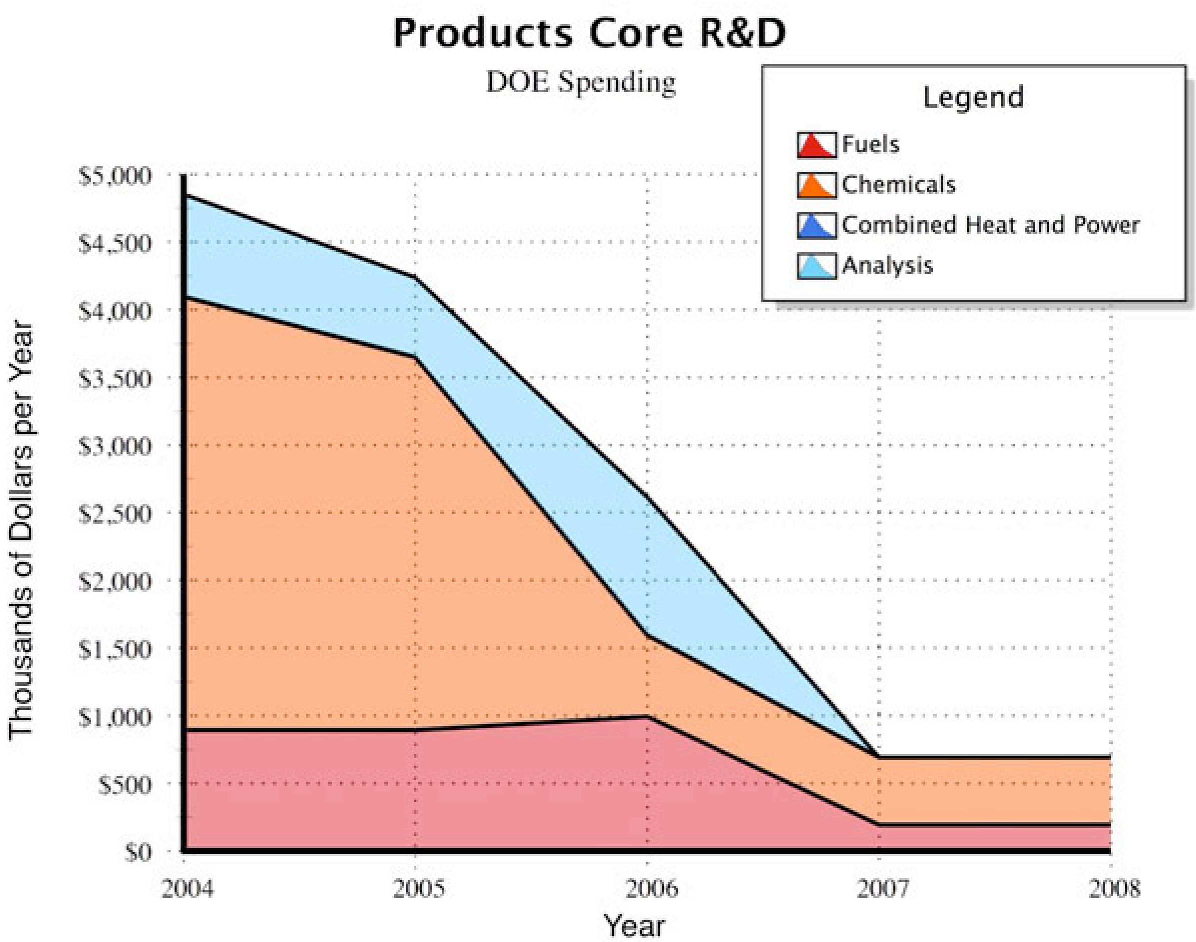


Figure 30: Funding for Key Elements of Products Core R&D

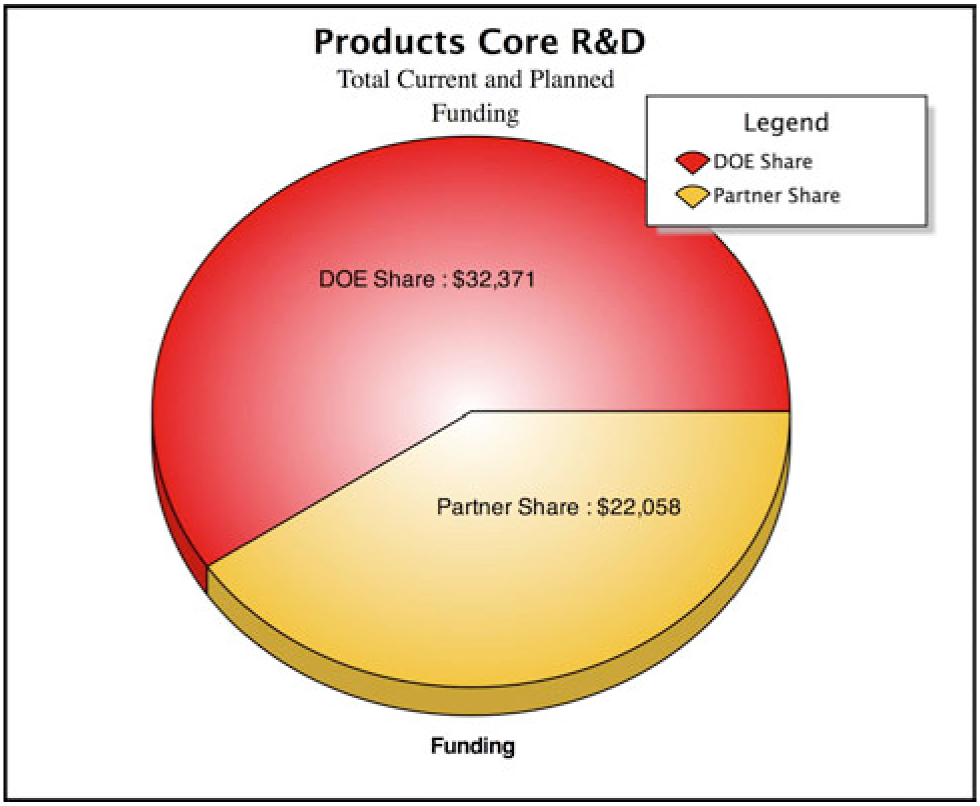


Figure 31: Total DOE and Partner Funding for Products Core R&D[7]

2.4.6 Products Platform Projects and Milestones

Table 12 summarizes all of the projects included in the Products Platform, organized according to major barrier areas for the platform. Information is also included on the specific barriers addressed by each project and their milestones.

[7] Includes funding from Pre-FY04 projects that are still ongoing and that include some portion of partner cost sharing (see Table 11: Products Core R&D Resource Plan)

Table 11: Products Core R&D Resource Plan

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
4	**Products Core R&D**	**$37,897**	**$6,568**	**$5,962**	**$2,614**	**$694**	**$694**
	DOE Share	***$19,285***	***$4,845***	***$4,239***	***$2,614***	***$694***	***$694***
	Partner Share	***$18,612***	***$1,723***	***$1,723***	***$0***	***$0***	***$0***
4.1	Fuels	$4,062	$894	$894	$994	$194	$194
	DOE Share	*$2,867*	*$894*	*$894*	*$994*	*$194*	*$194*
	Partner Share	*$1,195*	*$0*	*$0*	*$0*	*$0*	*$0*
4.1.1	Sugars						
4.1.1.1	NBC Arabinose Yeast CRADA Project (NREL/NCGA)	$0	$700	$700	$800	$0	$0
4.1.1.2	NBC Ethanol-Diesel Blend Evaluation Project						
4.1.1.3	GO Engineering Thermotolerant Biocatalysts for Biomass Conversion to Products Project						
4.1.1.4*	GO Energy from Biomass Research and Technology Transfer Project	$4,062					
	DOE Share	*$2,867*					
	Partner Share	*$1,195*					
4.1.2	Thermochemical						
4.1.3	Oils						
4.1.3.1	NBC Renewable Diesel Technology Project	$0	$194	$194	$194	$194	$194
	DOE Share	*$0*	*$194*	*$194*	*$194*	*$194*	*$194*
	Partner Share	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
4.2	Chemicals and Materials	$29,200	$4,919	$4,478	$600	$500	$500
	DOE Share	*$13,710*	*$3,196*	*$2,755*	*$600*	*$500*	*$500*

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
	Partner Share	*$15,490*	*$1,723*	*$1,723*	*$0*	*$0*	*$0*
4.2.1	Sugars						
4.2.1.1*	GO Develop Yeasts for Chemicals Project (Cargill Dow)	$2,322	$0	$0	$0	$0	$0
	DOE Share	*$1,130*					
	Partner Share	*$1,192*					
4.2.1.2*	GO Acid Catalyzed Hyrdolysis	$900	$0	$0	$0	$0	$0
	DOE Share	*$480*					
	Partner Share	*$420*					
4.2.1.3*	GO Biomass Biorefinery for Polymers and Fuel Project (Metabolix)	$15,470	$0	$0	$0	$0	$0
	DOE Share	*$7,675*					
	Partner Share	*$7,795*					
4.2.1.4*	GO Genomics from Enhanced Bioproducts from Sorghum (Orion)	$8,113	$0	$0	$0	$0	$0
	DOE Share	*$2,987*					
	Partner Share	*$5,126*					
4.2.2	Thermochemical						
4.2.2.1	NBC Pyrolysis Oil Upgrading Project	$0	$700	$500	$600	$500	$500
	DOE Share	*$0*	*$700*	*$500*	*$600*	*$500*	*$500*
	Partner Share						
4.2.2.2*	GO Adhesives from Wood Bark Project (Ensyn)	$2,365	$0	$0	$0	$0	$0
	DOE Share	*$1,408*					
	Partner Share	*$957*					

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
4.2.3	Oils	$0	$0	$0	$0	$0	$0
4.2.3.1*	GO Chemicals from Oilseeds Project (Dow)	$0	$3,978	$3,978	$0	$0	$0
	DOE Share	*$0*	*$2,255*	*$2,255*			
	Partner Share	*$0*	*$1,723*	*$1,723*			
4.2.3.2*	GO Polymer Building Blocks from Vegetable Oil Project	$30	$0	$0	$0	$0	$0
	DOE Share	*$30*					
	Partner Share	*$0*					
4.2.3.3*	GO National Agricultural-Based Lubricants Center Project (Earmark) (Northern Iowa U.)	$0	$241	$0	$0	$0	$0
	DOE Share	*$0*	*$241*				
	Partner Share	*$0*	*$0*				
4.2.3.4	GO Platform Chemicals from an Oilseed Biorefinery Project	TBD					
	DOE Share	*TBD*					
	Partner Share	*TBD*					
4.3	Combined Heat and Power	$3,854	$0	$0	$0	$0	$0
4.3.1	Sugars						
4.3.2	Thermochemical						
4.3.2.1*	GO Heat and Power Biomass Project (Green Institute)	$3,854	$0	$0	$0	$0	$0
	DOE Share	*$1,927*					
	Partner Share	*$1,927*					
4.3.3	Oils	$0	$0	$0	$0	$0	$0
4.4	NBC Analysis for Products	$781	$755	$590	$1,020	$0	$0

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
4.4.1	Technical and Market Analysis	$781	$755	$590	$1,020	$0	$0
	DOE Share	*$781*	*$755*	*$590*	*$1,020*	*$0*	*$0*
	Partner Share	*0*					

Table 12: Products Core R&D Projects and Milestones

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
Fuels	4.1.1.1 Arabinose Yeast CRADA	• Fermentation strain for mixed sugars	8/30/04 Demonstrate arabinose anaerobic fermentation in a yeast. **8/30/05 Develop commercial product yield, production rate, and product titer in yeast fermentation of arabinose.** 9/30/06 Integrate arabinose fermentation with the best available xylose fermentation in yeast.
	4.1.1.2 NBC Ethanol-Diesel Blend Evaluation Project	• Increase the amount of renewable transportation fuels and chemicals to offset the use of petroleum	TBD Increase the amount of renewable transportation fuels and chemicals to offset the use of petroleum
	4.1.1.3 GO Engineering Thermotolerant Biocatalysts for Biomass Conversion to Products Project	• Enzymatic hydrolysis barriers such as low reactivity; optimal environmental conditions; high cost of cellulase enzymes; enzyme biochemistry	TBD
	4.1.1.4 GO Energy from Biomass Research and Technology Transfer Project	•	12/2005 Produce promising basic research investigations that will lead to commercial applications through sub-awards to Universities
	4.1.3.1 NBC Renewable Diesel Technology Project	• Increase the amount of renewable transportation fuels and chemicals to offset the use of petroleum	4/2004 Biodiesel feedstock effects on modern engine NOx emissions

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
		offset the use of petroleum	4/2004 Biodiesel feedstock effects on modern engine NOx emissions 8/2005 Effective stability test methods for B100 and B20 6/2007 Inclusion of stability requirement in biodiesel standards
Chemicals and Materials	4.2.1.1 GO Develop Yeast for Chemicals (Cargill Dow Polymers)	• Products – Fermentation	3/2003 Improve xylose to lactate fermentation of proprietary strain 1 4/2003 Improve xylose to lactate fermentation of proprietary strain 2 11/2002 Conduct rough biochemical characterization of chosen xylose pathway enzymes 6/2003 Utilize tools for genetic engineering of most promising strains 9/2003 Conduct genetic engineering of new host species for xylose to lactate 5/2004 Improve most promising

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
			strains from Tasks 1, 2, 5 or 8
	4.2.1.2 GO Acid Catalyzed Hydrolysis (Eastman ARO)	• Biomass Gasification – Producing Syngas from Biomass	10/2003 Data Analysis 12/2003 Design Commercial Demonstration 6/2004 Build Commercial Demonstration 5/2005 Operate Demonstration 1/2006 Develop Licensing Package 6/2006 Reporting and Project Management Annual Report Commercial Activities
	4.2.1.3 GO Biomass Biorefinery for Polymers and Fuel Project (Metabolix)	• Process, system integration and validation	10/2006 Nuclear Transformation of Plastid Targeted PHB Enzymes into Switchgrass. 10/2003 Develop Plastid Encoded PHB Production Systems. 10/2003 Develop Inducible PHB Production Systems. 10/2003 Introduce Plastid Encoded PHB Production Systems into Switchgrass. 10/2003 Develop PHA Copolymers. 10/2006 Develop Optimized Recovery processes in a

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
			biorefinery context. 10/2006 Life Cycle Analysis -- Investigate Applications for PHAs. 10/2006 Management and Reporting.
	4.2.1.4 GO Genomics from Enhanced Bioproducts from Sorghum (Orion)	• Process, system integration and validation	12/2002 Genomics Program 4/2002 Breeding Program 12/2003 Interact with the renewable resources community; publish non-proprietary results
	4.2.2.1 Pyrolysis Oils Upgrading	• Barrier R&D that is most germane to this effort over the next five years involves employing novel separation technologies to extract products from biocrudes; integration of biocrude fractions with potential new product opportunities; catalytic conversion of biocrude fractions into value-added products; and use of novel analytical tools to assist in process control and measuring processability	9/2005 Hydrogenation evaluation 9/2008 Industrial testing
	4.2.2.2 Adhesives from Bark	• Process, systems integration and validation • Demostrate the performance of adhesives containing biooils derived from bark or forest residues.	12/2003 Complete characterization of Pyrolysis Products 12/2003 Complete Resin Formulation Development

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
		residues.	12/2003 Complete commercial Trial Production Runs of OSB 12/2003 Perform Wood-based Natural Resin & Bark-based Comparison 12/2003 Complete technical feasibility of Bio-Oil Co-Products 12/2003 Complete technical feasibility of Carbon Co-Products
	4.2.3.1 GO Chemicals from Oilseeds (Dow)	• Processing and conversion • Chemical and biocatalysis	10/2005 Plant Science 10/2005 Production 10/2005 Processing 10/2005 Utilization
	4.2.3.2 GO Polymer Building Blocks from Vegetable Oils (Pittsburg hState U)	• Information from this project will help address the inadequate technology for yield value from all components of biomass oil processing systems	12/2001 Establish feasibility of making polyols from soy oil 12/2002 Establish feasibility of making polycarboxylic acid from soy oil 12/2002 Establish feasibility of making polyamines from soy oil established 3/2004 Establish technical and commercial feasibilities, complete pilot scale-ups
	4.2.3.3 GO National Agricultural-Based Lubricants Center Project	•	TBD
	4.2.3.4 GO Platform Chemicals from an Oilseed Biorefinery Project	•	TBD

Technical Barrier Area	Project	Specific Technical Barriers Addressed	Milestones
	Project		
Combined Heat and Power	4.3.2.1 GO Heat and Power Biomass Project	• Process, systems integration and validation	TBD
NBC Analysis for Products	4.4.1 Technical and Market Analysis	• Prioritizing technical barriers that can be overcome with R&D • Establishing technical targets and quantifiable metrics for Products Platform R&D	4/2004 Metrics for barriers related to producing products 6/2004 Market analysis with Top Ten Study 6/2006 Analysis II for products

2.5 Integrated Biorefineries

According to the OBP's MYPP, "a biorefinery processes biomass into value-added product streams." In theory, anything that uses biomass and makes more than one product is a biorefinery. This very simple definition captures a wide range of existing, emerging, and advanced process concepts. Examples of existing biorefineries include corn processors and pulp and paper mills.

The name biorefinery purposely evokes visions of today's petroleum refinery. In a modern petroleum refinery complex, the largest volume product is liquid fuel. However, the key to its profitability lies in the small percentage of value-added petrochemicals that it makes. Similarly a biorefinery will seek to produce the optimum combination of fuels, power, and heat/energy products to produce the greatest financial return.

The following definition of a biorefinery was recently legislated by Congress in the 2002 Farm Bill:

> "The term 'biorefinery' means equipment and processes that—
>
> (A) convert biomass into fuels and chemicals; and
>
> (B) may produce electricity."

For the purposes of this plan, the concept of a biorefinery is expanded to embody a facility that uses biomass to make a slate of fuels and chemicals to maximize the value of the biomass, thereby maximizing the financial return to the producer. The notion of maximizing the value derived from biomass through an optimal slate of products is the key to understanding why the biorefinery is the central strategy for the Biomass Program.

2.5.1 Technical Goals and Objectives

The goal of the Integrated Biorefinery program area is to support the establishment of integrated biorefineries through partnerships with industry and academia. This goal is the culmination of the work being done in the core R&D areas. The Integrated Biorefinery is where the development of the platforms and new capabilities for products is brought together in a fully integrated operation. The objectives of this area reflect four of the six major outcomes defined for the Program in the MYPP:

- Complete technology development necessary to enable start-up demonstration of a biorefinery producing fuels, chemicals, and power by 2007
- Help U.S. industry establish the first large-scale sugar biorefinery based on agricultural residues by 2010

2.5.2 Programmatic Status

In 2002, the OBP awarded funds to six major biorefinery development projects 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-propanediol, polylactic acid, isosorbide, and various other chemicals. Table 1 gives a synopsis of these projects. Milestones for these projects are highlighted in Table 13. A more complete multi-year project description is included in the Appendix.

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, GTI, Manufacturing and Technology Conversion International, Inc. (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 implementation in future biorefineries.

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 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, and SNL); individual chemical, food, and enzyme manufacturers; universities; and trade associations such as the Iowa Corn Promotion Board, United Soybean Board, and the National Corn Growers Association.

Table 13: FY02 Integrated Biorefinery Solicitation Projects

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 biobased 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. DuPont de Nemours & Co., Inc. (DuPont) will build a biobased production facility to convert corn and stover into fermentable sugars for production of value-added chemicals.
Making Industrial Biorefining 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 - Abengoa Bioenergy Corporation, with plants in Kansas, Nebraska, and New Mexico, will develop a novel biomass technology to use distiller's grain 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.

2.5.3 Technical Barriers

The barriers to developing and making this core technology available have largely been addressed in the technical plans related to the specific core technology needs for the Sugar Platform, the Thermochemical Platform, and the conversion of biomass intermediates into products. However, there are barriers peculiar to the goal of demonstrating and deploying commercially successful biorefinery technology:

- The challenge of end-to-end, feed-to-product, process integration
- The risk of pioneer technology
- The high financial investment and proportionally higher return required to attract investors

The Program addresses the issue of the risk of deploying new technology by helping to buy down the high cost of the later stages of commercial development, in particular stage 3 process development and stage 4 commercial demonstration. Typically these stages require 50% or greater recipient cost share. In addition, the Program requires these projects to develop and maintain a “Project Management Plan”. The Project Management Plan (PMP) lays out the detailed work plan, including tasks, milestones, decision points, a schedule, resource requirements, and the identification of role and responsibilities. The PMP is the tool by which the project team and DOE oversee and monitor the project performance.

2.5.4 Technical Approach

The portfolio of projects for this area of the Program, as shown in the work breakdown structure (Figure 34), reflects a range of existing and emerging biorefinery opportunities. These projects include sugar platform-based biorefineries and thermochemical biorefineries.

2.5.5 Resource Allocation Plan

Table 14 and Figure 32 summarize the resource plan for the integrated biorefinery projects. The majority of the funding shown is for Sugar Platform related biorefineries that have begun as a result of recent DOE solicitations. Similar solicitations may occur in the future in support of integrated biorefineries for the Thermochemical Platform. This area of the Program is highly leveraged with partnership cost sharing (see Figure 33

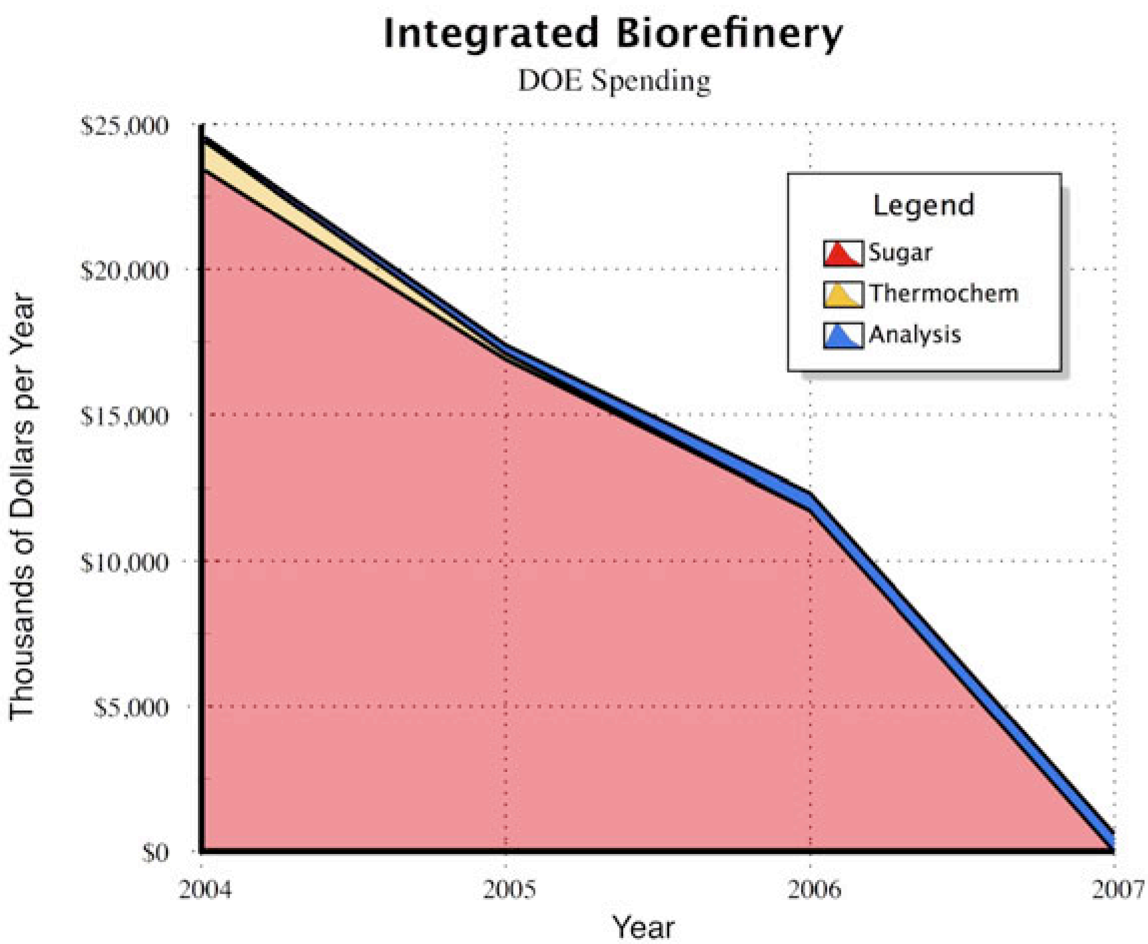


Figure 32: Resource Allocation Plan for Integrated Biorefineries

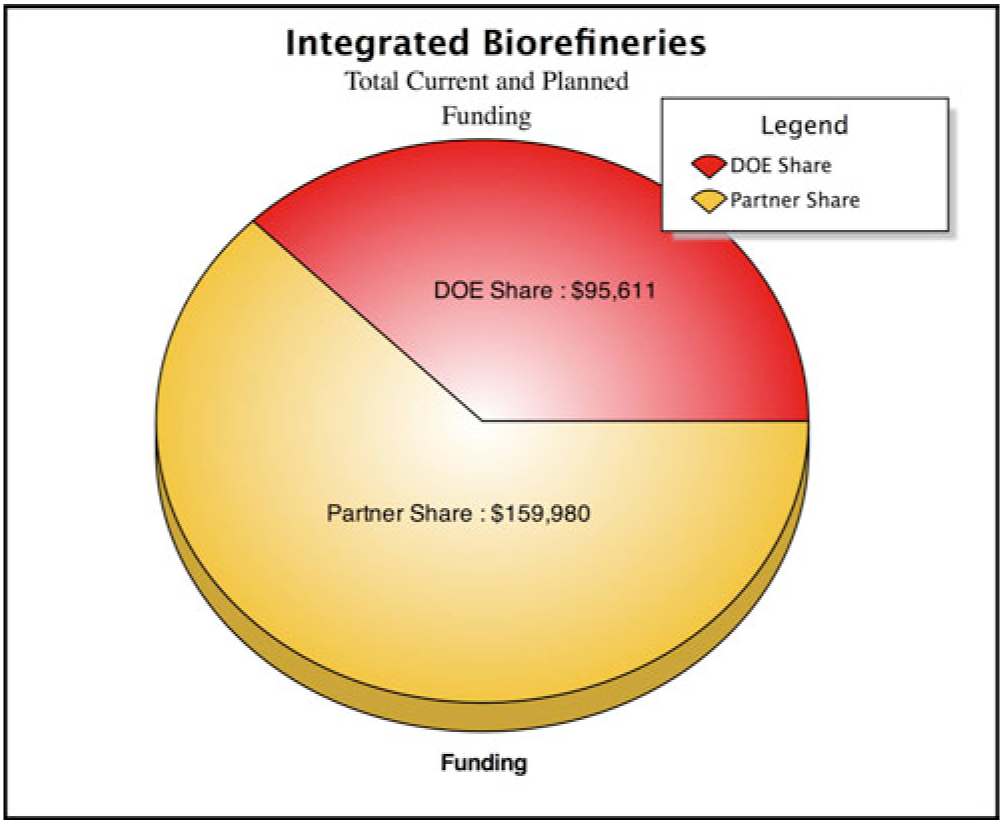


Figure 33: Total DOE and Partner Funding for Integrated Biorefineries

2.5.6 Integrated Biorefineries Projects and Milestones

Table 15 summarizes all of the projects included in the Integrated Biorefinery area, organized according to major barrier areas for the platform. Information is also included on the specific barriers addressed by each project and their milestones.

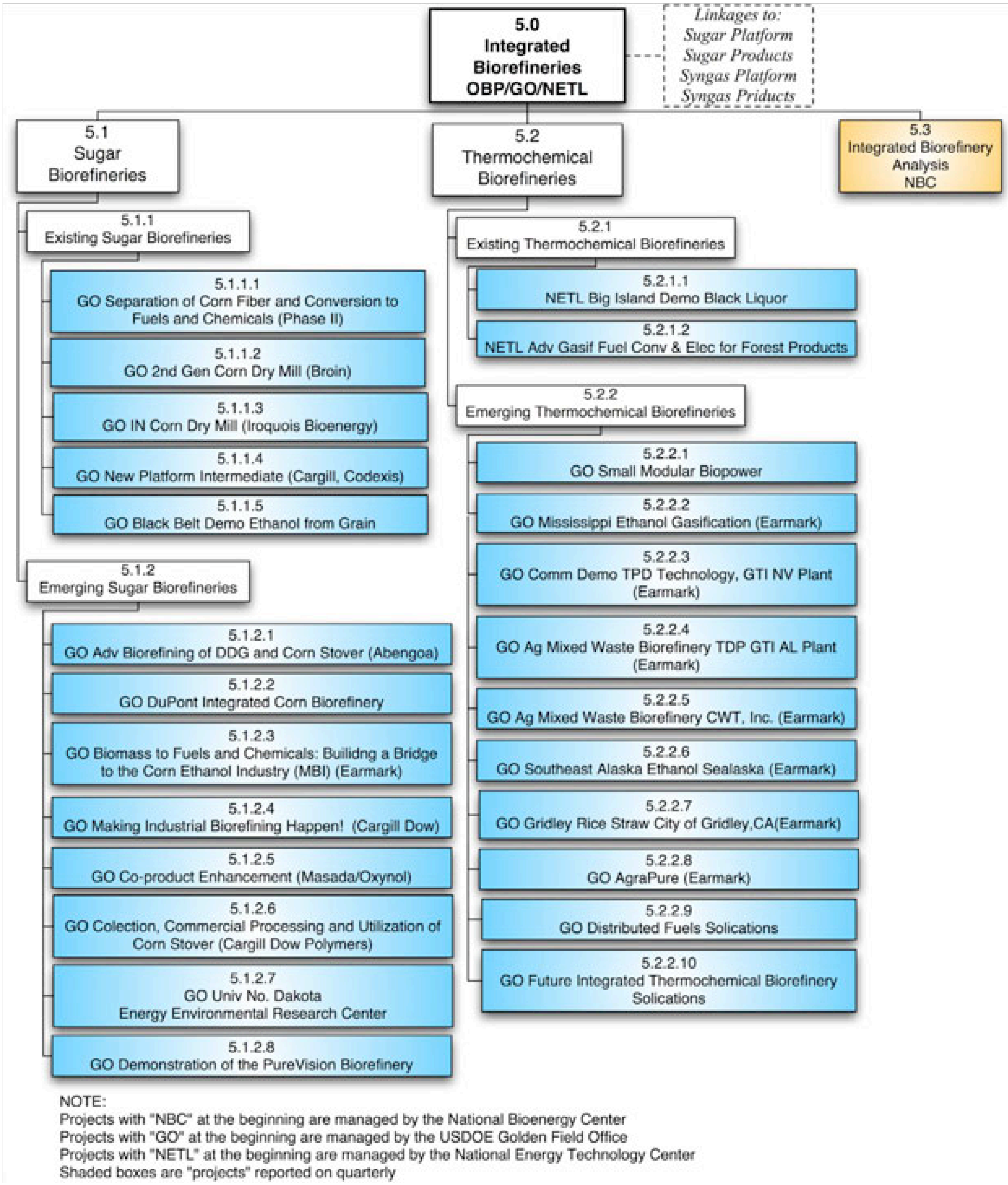
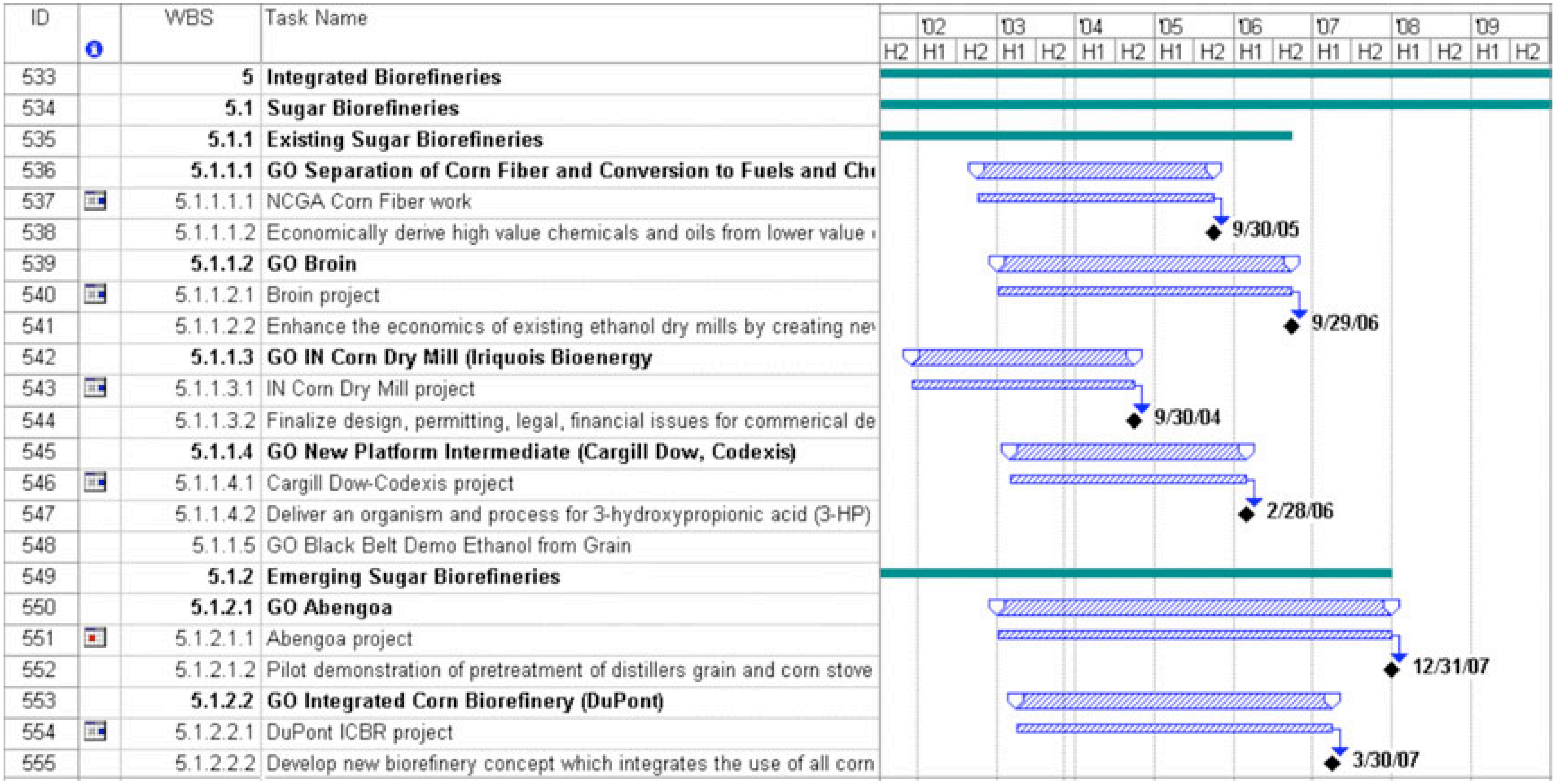
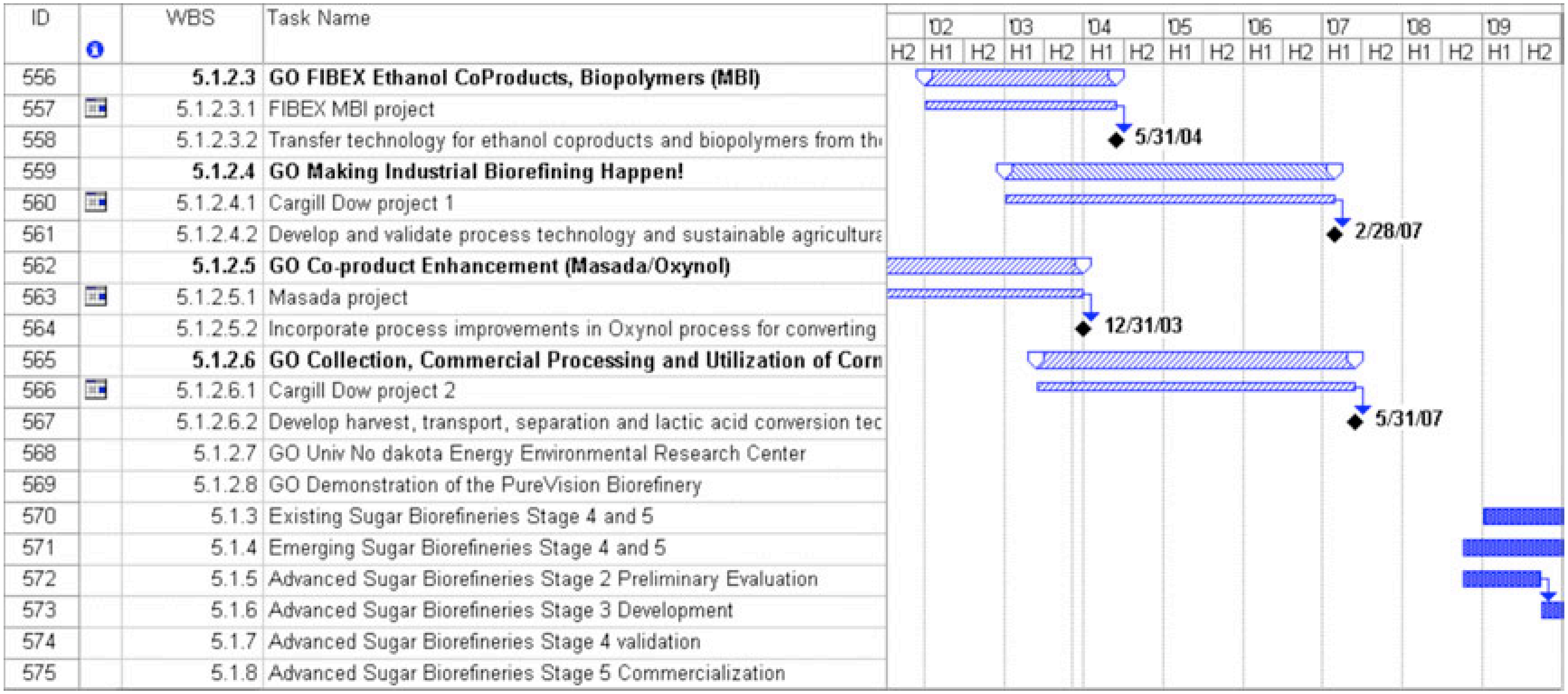


Figure 34: Work Breakdown Structure for the Integrated Biorefineries Area



ID	WBS	Task Name	
533	5	**Integrated Biorefineries**	
534	5.1	**Sugar Biorefineries**	
535	5.1.1	**Existing Sugar Biorefineries**	
536	5.1.1.1	**GO Separation of Corn Fiber and Conversion to Fuels and Ch**	
537	5.1.1.1.1	NCGA Corn Fiber work	
538	5.1.1.1.2	Economically derive high value chemicals and oils from lower value	9/30/05
539	5.1.1.2	**GO Broin**	
540	5.1.1.2.1	Broin project	
541	5.1.1.2.2	Enhance the economics of existing ethanol dry mills by creating ne	9/29/06
542	5.1.1.3	**GO IN Corn Dry Mill (Iriquois Bioenergy**	
543	5.1.1.3.1	IN Corn Dry Mill project	
544	5.1.1.3.2	Finalize design, permitting, legal, financial issues for commerical de	9/30/04
545	5.1.1.4	**GO New Platform Intermediate (Cargill Dow, Codexis)**	
546	5.1.1.4.1	Cargill Dow-Codexis project	
547	5.1.1.4.2	Deliver an organism and process for 3-hydroxypropionic acid (3-HP)	2/28/06
548	5.1.1.5	GO Black Belt Demo Ethanol from Grain	
549	5.1.2	**Emerging Sugar Biorefineries**	
550	5.1.2.1	**GO Abengoa**	
551	5.1.2.1.1	Abengoa project	
552	5.1.2.1.2	Pilot demonstration of pretreatment of distillers grain and corn stove	12/31/07
553	5.1.2.2	**GO Integrated Corn Biorefinery (DuPont)**	
554	5.1.2.2.1	DuPont ICBR project	
555	5.1.2.2.2	Develop new biorefinery concept which integrates the use of all corn	3/30/07

Figure 35: Biomass Program Industry Partnership Activities in Support of Integrated Biorefineries



ID		WBS	Task Name
556		**5.1.2.3**	**GO FIBEX Ethanol CoProducts, Biopolymers (MBI)**
557		5.1.2.3.1	FIBEX MBI project
558		5.1.2.3.2	Transfer technology for ethanol coproducts and biopolymers from th
559		**5.1.2.4**	**GO Making Industrial Biorefining Happen!**
560		5.1.2.4.1	Cargill Dow project 1
561		5.1.2.4.2	Develop and validate process technology and sustainable agricultura
562		**5.1.2.5**	**GO Co-product Enhancement (Masada/Oxynol)**
563		5.1.2.5.1	Masada project
564		5.1.2.5.2	Incorporate process improvements in Oxynol process for converting
565		**5.1.2.6**	**GO Collection, Commercial Processing and Utilization of Corn**
566		5.1.2.6.1	Cargill Dow project 2
567		5.1.2.6.2	Develop harvest, transport, separation and lactic acid conversion tec
568		5.1.2.7	GO Univ No dakota Energy Environmental Research Center
569		5.1.2.8	GO Demonstration of the PureVision Biorefinery
570		5.1.3	Existing Sugar Biorefineries Stage 4 and 5
571		5.1.4	Emerging Sugar Biorefineries Stage 4 and 5
572		5.1.5	Advanced Sugar Biorefineries Stage 2 Preliminary Evaluation
573		5.1.6	Advanced Sugar Biorefineries Stage 3 Development
574		5.1.7	Advanced Sugar Biorefineries Stage 4 validation
575		5.1.8	Advanced Sugar Biorefineries Stage 5 Commercialization

Figure 35: Biomass Program Industry Partnership Activities in Support of Integrated Biorefineries

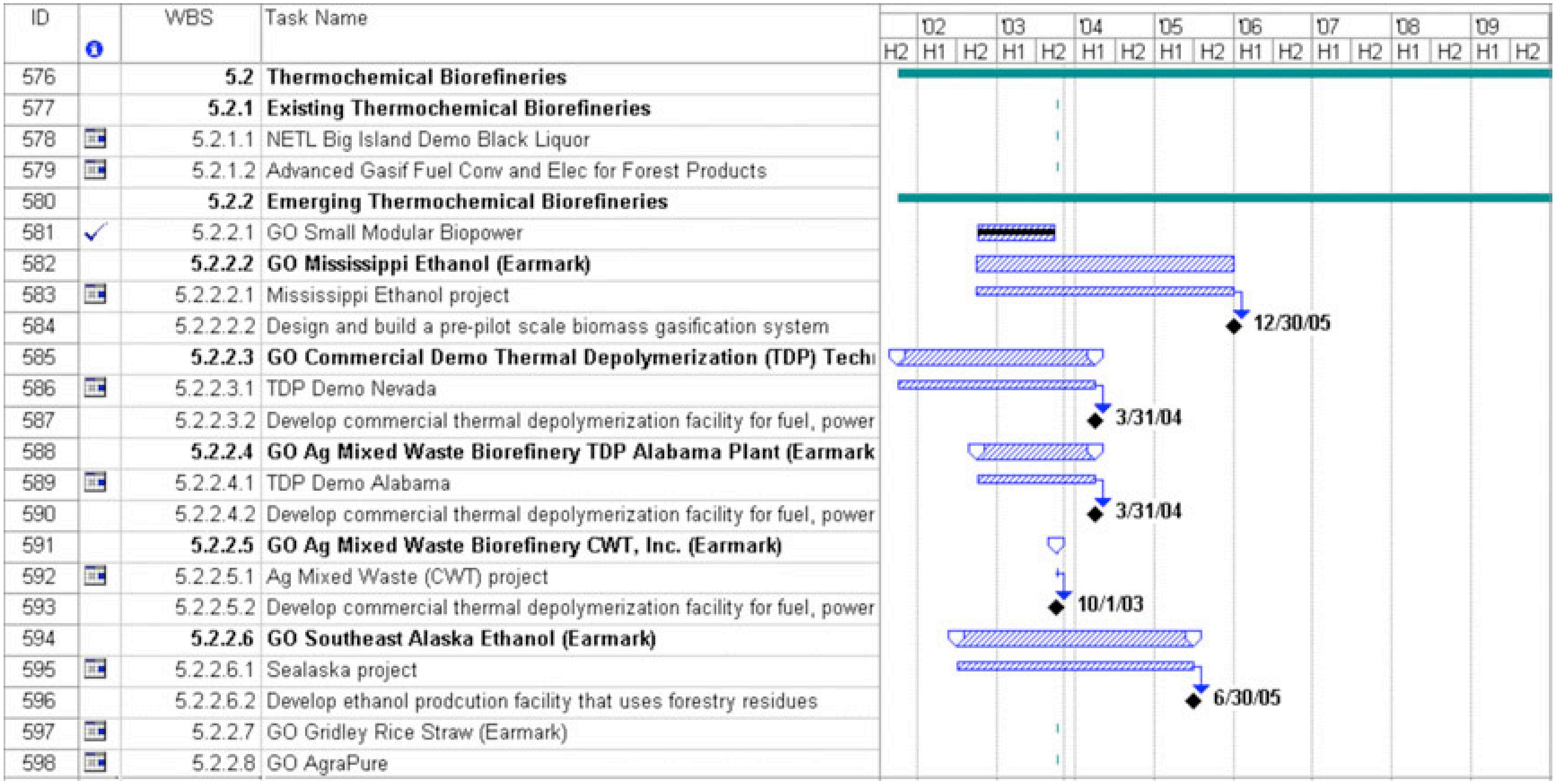


Figure 35: Biomass Program Industry Partnership Activities in Support of Integrated Biorefineries

ID		WBS	Task Name
599		**5.2.2.9**	**Distributed Fuels Solicitation**
600		5.2.2.9.1	Gate Placement Decision for Distributed Fuels Solicitation
601		5.2.2.9.2	Feasibility Solicitation
602		5.2.2.9.3	Feasibility Studies
603		5.2.2.9.4	Demostration Solicitation
604		5.2.2.9.5	Cooperative Agreement Projects
605		5.2.2.9.6	Complete 2 distributed fuels and chemicals projects
606		5.2.2.9.7	Stage Gate Review of Distributed Fuels Demonstrations
607		**5.2.2.10**	**GO Future Integrated Thermochemical Biorefineries**
608		5.2.2.10.1	Gate Placement Review
609		5.2.2.10.2	Future Integrated Thermochemical Biorefineries
610		5.2.2.10.3	Industry led Integrated Thermochemical Biorefinery (1)
611		5.2.2.10.4	Industry led Integrated Thermochemical Biorefinery (2)
612		5.2.2.10.5	Industry led Integrated Thermochemical Biorefinery (3)
613		5.2.2.10.6	Complete 2 integrated thermochemical Biorefineries
614		5.2.2.10.7	Gate Placement Review for Industry led Integrated Thermochemical
615		5.3	Integrated Biorefinery Analysis

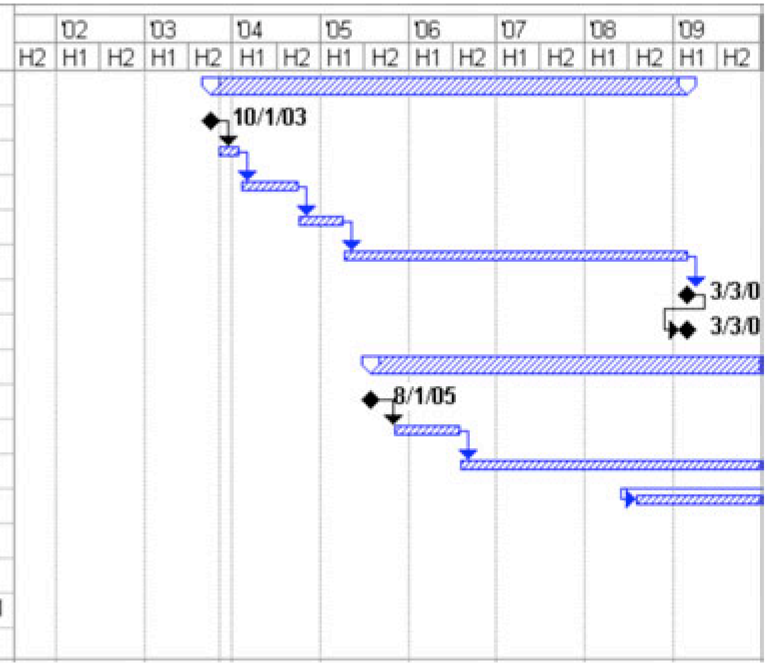


Figure 35: Biomass Program Industry Partnership Activities in Support of Integrated Biorefineries

Table 14: Resource Allocation Plan for Integrated Biorefineries *Fully Funded Prior to FY04

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007
5	**Integrated Biorefineries Projects**	**$127,226**	**$62,519**	**$38,123**	**$26,073**	**$1,650**
	DOE Share	***$40,718***	***$24,564***	***$17,401***	***$12,328***	***$600***
	Partner Share	***$86,508***	***$37,955***	***$20,722***	***$13,745***	***$1,050***
5.1	Sugar Biorefineries	$33,494	$52,779	$33,152	$22,432	$0
	DOE Share	*$19,032*	*$23,414*	*$16,901*	*$11,728*	*$0*
	Partner Share	*$14,462*	*$29,365*	*$16,251*	*$10,704*	*$0*
5.1.1	Existing Sugar Biorefineries	$14,326				
	DOE Share	*$7,161*				
	Partner Share	*$6,334*				
5.1.1.1	GO Separation of Corn Fiber and Conversion to Fuels and Chemicals Phase II	$0	$2,388	$335	$0	$0
	DOE Share	*$0*	*$1,146*	*$163*		
	Partner Share	*$0*	*$1,242*	*$172*		
5.1.1.2	GO A Second Generation Dry Mill Biorefinery Project (Broin)	$0	$4,313	$1,482	$0	$0
	DOE Share	*$0*	*$1,681*	*$829*		
	Partner Share	*$0*	*$2,632*	*$653*		
5.1.1.3*	GO Indiana Corn Dry Mill Project (Iroquois Bioenergy)	$11,418	$0	$0	$0	$0
	DOE Share	*$5,709*				
	Partner Share	*$5,709*				
5.1.1.4	GO New Platform Intermediate Project (Cargill, Codexis)	$0	$3,894	$4,104	$0	$0
	DOE Share	*$0*	*$1,867*	*$2,052*		
	Partner Share	*$0*	*$2,027*	*$2,052*		
5.1.1.5	GO Black Belt Bioenergy Demonstration Project (Earmark)	$2,908	$0	$0	$0	$0
	DOE Share	*$1,452*				
	Partner Share	*$625*				
5.1.2	Emerging Sugar Biorefineries	$19,168	$42,184	$27,231	$22,432	$0
	DOE Share	*$11,871*	*$18,720*	*$13,857*	*$11,728*	*$0*

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007
	Partner Share	*$7,297*	*$23,464*	*$13,37 4*	*$10,70 4*	*$0*
5.1.2.1	GO Advanced Biorefining of Distiller's Grain and Corn Stover Blends: Pre-Commercialization of a Biomass Derived Process Technology Project (Abengoa Bioenergy Corporation)	$0	$15,259	$9,638	$5,185	$0
	DOE Share	*$0*	*$5,851*	*$5,133*	*$3,337*	
	Partner Share	*$0*	*$9,408*	*$4,505*	*$1,848*	
5.1.2.2	GO Integrated Corn-Based Bio Refinery (ICBR) Project (DuPont)	$0	$9,800	$9,223	$9,687	$0
	DOE Share	*$0*	*$4,748*	*$4,539*	*$4,611*	
	Partner Share	*$0*	*$5,052*	*$4,684*	*$5,076*	
5.1.2.3*	GO Biomass to Fuels and Chemicals: Building a Bridge to the Corn Ethanol Industry Project (MBI) (Earmark)	$7,263	$0	$0	$0	$0
	DOE Share	*$5,807*				
	Partner Share	*$1,456*				
5.1.2.4	GO Making It Happen Project!	$0	$17,125	$8,370	$7,560	$0
	DOE Share	*$0*	*$8,121*	*$4,185*	*$3,780*	
	Partner Share	*$0*	*$9,004*	*$4,185*	*$3,780*	
5.1.2.5*	GO Co-product Enhancement (Masada/Oxynol)	$1,250	$0	$0	$0	$0
	DOE Share	*$625*				
	Partner Share	*$625*				
5.1.2.6*	GO Collection, Commercial Processing and Utilization of Corn Stover Project (Cargill Dow Polymers)	$10,137	$0	$0	$0	$0
	DOE Share	*$5,054*				
	Partner Share	*$5,083*				
5.1.2.7*	GO Energy Environmental Research Center (Univ. North Dakota)	$518	$0	$0	$0	$0
	DOE Share	*$385*				
	Partner Share	*$133*				
5.1.2.8	GO Demonstation of the PureVision Technology	TBD				
	DOE Share	*TBD*				
	Partner Share	*TBD*				
5.2	Thermochemical Biorefineries	$93,732	$9,590	$4,671	$3,041	$1,050
	DOE Share	*$0*				

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007
	Partner Share	*$0*				
5.2.1	Existing Thermochemical Biorefineries	$1,328	$7,590	$4,271	$3,041	$1,050
	DOE Share	*$1,028*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$300*	*$7,590*	*$4,271*	*$3,041*	*$1,050*
5.2.1.1	NETL Big Island Demonstration Project - Black Liquor	$0	$7,590	$4,271	$3,041	$1,050
	DOE Share	*$0*	*$0*	*$0*	*$0*	*$0*
	Partner Share	*$0*	*$7,590*	*$4,271*	*$3,041*	*$1,050*
5.2.1.2*	NETL Advanced Gasification-Based Fuel Conversion & Electricity for Forest Products	$1,328	$0	$0	$0	$0
	DOE Share	*$1,028*				
	Partner Share	*$300*				
5.2.2	Emerging Thermochemical Biorefineries	$92,404	$2,000	$400	$0	$0
	DOE Share	*$20,658*	*$1,000*	*$200*	*$0*	*$0*
	Partner Share	*$71,746*	*$1,000*	*$200*	*$0*	*$0*
5.2.2.1	GO Small Modular Biopower Project					
	DOE Share					
	Partner Share					
5.2.2.2*	GO Mississippi Ethanol Gasification Project (Mississippi Ethanol, LLC) (Earmark)	$7,101	$0	$0	$0	$0
	DOE Share	*$5,681*				
	Partner Share	*$1,420*				
5.2.2.3*	GO Commercial Demonstration TDP Technology Plant - Nevada Project (Gas Technology Institute) (Earmark)	$14,252	$0	$0	$0	$0
	DOE Share	*$4,000*				
	Partner Share	*$10,252*				
5.2.2.4*	GO Agricultural Mixed Waste Biorefinery TDP - Alabama Project (Gas Technology Institute) (Earmark)	$9,858	$0	$0	$0	$0
	DOE Share	*$1,861*				
	Partner Share	*$7,997*				
5.2.2.5*	GO Agricultural Mixed Waste Biorefinery - Colorado Project (Changing World Technologies, Inc.) (Earmark)	$21,104	$0	$0	$0	$0
	DOE Share	*$2,408*				
	Partner Share	*$18,696*				
5.2.2.6*	GO Southeast Alaska Ethanol Project (Sealaska) (Earmark)	$5,948	$0	$0	$0	$0

WBS	Title	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007
	DOE Share	*$3,880*				
	Partner Share	*$2,068*				
5.2.2.7*	GO Gridley Rice Straw Project (City of Gridley) (Earmark)	$33,179	$0	$0	$0	$0
	DOE Share	*$2,347*				
	Partner Share	*$30,832*				
5.2.2.8*	GO AgraPure	$962	$0	$0	$0	$0
	DOE Share	*$481*				
	Partner Share	*$481*				
5.2.2.9	GO Distributed Fuels Solicitations Project	$0	$2,000	$400	$0	$0
	DOE Share	*$0*	*$1,000*	*$200*		
	Partner Share	*$0*	*$1,000*	*$200*		
5.2.2.10	GO Future Integrated Thermochemical Biorefinery Solicitations Project	$0	$0	$0	$0	$0
	DOE Share					
	Partner Share					
5.3	NBC Integrated Biorefinery Analysis Project	$0	$150	$300	$600	$600
	DOE Share	*$0*	*$150*	*$300*	*$600*	*$600*
	Partner Share	*$0*				

Table 15: Alignment of Projects, Milestones and Technical Barriers for the Integrated Biorefineries Area

Biomass Program Goal: To support the establishment of integrated biorefineries through partnerships with industry and academia

Objectives:

- Complete analysis of biorefinery options by 2004 that identifies the most promising processes and products
- Complete technology development necessary to enable start-up demonstration of a biorefinery producing fuels, chemicals, and power by 2007
- Demonstrate a fully integrated black liquor gasification system for heat and power production at a commercial pulp mill by 2009
- Help U.S. industry establish the first large-scale sugar biorefinery based on agricultural residues by 2010

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
Sugar Biorefineries GO	5.1.1.1 GO Separation of Corn Fiber and Conversion to Fuels and Chemicals Phase II: Pilot-Scale Operation (National Corn Growers Association)	• Develop and demonstrate an integrated biorefinery	2/2004 Development of Process Economics 2/2004 Finalization of Flowsheet (from Bench-scale Optimization Testing) 2/2004 Pilot Plant Site Selection 5/2004 Completion of Pilot Plant Design Package 2/2005 Completion of Construction/ Installation of Pilot Plant and Supporting Facilities 2/2005 Completion of System Start-up Operating Manual (Draft) 2/2005 Completion of Test Plan and Sampling Plan 2/2005 Completion of Assembly/Shakedown of Analytical Equipment at Pilot Plant Facilities 4/2005 Completion of Start-up/Operating Manual (Final)

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
			4/2005 Completion of System Start-up and Shakedown Testing 10/2005 Completion of Pilot Plant Operations Testing 1/2006 Finalization of Flowsheet (from Pilot Plant Operations Testing) 5/2006 Final Assessment of Corn Fiber Process (Final Report)
	5.1.1.2 GO A Second Generation Dry Mill Biorefinery (Broin)	• Pretreatment, processing, and conversion	12/2004 Detailed investigation 6/2003 Corn degerming and debranning design, construction and startup (PT) 9/2003 Bran pretreatment, conversion and fermentation (PT) 7/2204 Conversion of pretreated bran to ethanol and feed products (C) 12/2004 Conversion of bran to value added products (C) 12/2004 Preliminary economic evaluation of bran conversion (P)
	5.1.1.3 GO Indiana Corn Dry Mill Iroquois Bioenergy	• Develop and demonstrate an integrated biorefinery	Under Development
	5.1.1.4 GO New Platform Intermediate (Cargill, Codexis)	• Products – Fermentation • Products – Catalysis	2/2006 Evolve and improve enzyme activity

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
			using Molecular Breeding technology 12/2003 Screen shuffled libraries 6/2004 Clone and express genes for other enzymes in the pathway 6/2004 Study mechanistic and kinetic attributes of enzymes involved in the pathway 2/2006 Construct pathway and metabolic engineering for production of 3-HP 1/2004 Conduct pathway shuffling 2/2004 Select strain 2/2006 Manipulate strain 9/2005 Optimize microbial physiology 2/2006 Optimize fermentation process 2/2006 Optimize media 2/2006 Conduct pilot trials on the 3-HP fermentation process 7/2003 Convert 3-HP and Sodium 3-HP to acrylic acid and sodium acrylate 10/2003 Convert ammonium 3-HP to acrylamide 2/2006 Demonstrate fermentation-derived 3-HP and sodium 3-HP conversion to acrylic acid and sodium acrylate

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
			conversion to acrylic acid and sodium acrylate 2/2006 Optimize catalyst for the conversion of fermentation-derived 3-HP to acrylic acid 3/2005 Optimize the conversion of fermentation-derived Am-3-HP to acrylamide 2/2006 Integrate Bio/Chemical Processes, Design, and Economics
	5.1.1.5 GO Black Belt Bioenergy Demonstration Project (Earmark)	• Development and demonstration of an integrated biorefinery	9/2002 Market Analysis 11/2002 Agricultural Resource Analysis 2/2003 Site Analysis 3/2003 Energy and Infrastructure Analysis 5/2003 Technology Assessment 7/2003 Economic Impact Study 9/2003 Engineering and Design 9/2003 Contracts, Permits and Concessions 12/2003 Financial Strategy 12/2003 Workforce Development 1/2004 Community Outreach and Public Benefit 2/2004 Project Management Plan
	5.1.2.1 GO Advanced Biorefining of Distiller's Grain and Corn Stover Blends: Pre-Commercialization of a Biomass-Derived Process Technology (Abengoa Bioenergy Corporation)	• Develop and demonstrate an integrated biorefinery	11/2002 Complete Preliminary Mass Balance Analyses and Baseline Performance Evaluation

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
	Commercialization of a Biomass-Derived Process Technology (Abengoa Bioenergy Corporation)		Performance Evaluation 12/2002 Complete Technical Due Diligence 10/2003 Identify Enzyme Technologies to Develop Further Based on Potential Ethanol Yield 1/2004 Completion of Bench Scale Screening of Enzymes in ARBD's Proprietary Cook Process 2/2004 Complete Bench Scale Investigation of Process Improvements for Increasing Ethanol Yield 6/2003 Completion of Pilot Plant Design and Engineering 11/2004 Completion of Pilot Demonstration of High Ethanol Yield Corn Dry Mill Technology 3/2006 Pre-commercialization Demonstration of Step 1 Complete 12/2003 Complete Preliminary Feasibility Study of Pretreatment Options
	5.1.2.2 GO Integrated Corn-Based Bio Refinery (ICBR) Project (DuPont)	• Develop and demonstrate an integrated biorefinery • Pretreatment/enzymatic hydrolysis	4/2004 Process Flowsheets/Economic Evaluation

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
		hydrolysis • Products – fermentation • Develop and demonstrate an integrated biorefinery	4/2005 Test Process Concepts/Obtain Critical Data 4/2006 Process Develop & Optimization/ Cross-site Validations 3/2007 Rigorous Models/Large Scale Equipment Trials 4/2004 Scout Hydrolysis/Cellulase Screening and Discovery 4/2005 Pretreatment Process Develop/ Cellulase Discovery and Evolution 4/2006 Pretreatment Optimization/ Scale-Up 3/2007 Pretreatment Scale-Up/ Strain Development 4/2004 Benchmark Zymomonas mobilis, Xylose Utilization Genome Sequenced 4/2005Rate/Yield/Titer/Tolerance Improved 4/2006 Rate/Yield/Titer/ Tolerance Optimized on Hydrolyzate 3/2007 Fermentation Studies of Optimized Ethanologen 4/2004 Scout Syrup Grain Process

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
			4/2005 Grain Syrup Development & Co-metabolism of Other Sugars 4/2006 Fermentation Studies of Optimized Ethanologen 3/2007 Scale-Up of Grain Process & 10L Fermentation Optimization
	5.1.2.3 GO Biomass to Fuels and Chemicals: Building a Bridge to the Corn Ethanol Industry	• Develop and demonstrate an integrated biorefinery	2/2004 AFEX Pretreatment (details are proprietary) 2/2004 Succinic Acid Production (details are proprietary) 2/2004 Dry Mill Ethanol Process (details are proprietary)

	5.1.2.4 GO Making it Happen! (Cargill Dow)	• Develop and demonstrate an integrated biorefinery
		  • Pretreatment/Enzymatic Hydrolysis
		  • Products - Biocatalyst & Fermentation Technology
		• Develop and demonstrate an integrated biorefinery
			1/2004 Confirm feasibility of biomass processing
			7/2004 Complete pilot plant engineering
			7/2005 Start-up pilot plant
			8/2006 Validate commercial scale design in pilot plant
			12/2006 Complete plant economics
			3/2004 Develop metabolic engineering tools
			1/2005 Develop 2nd generation strain for Xylose conversion
			7/2006 Develop 3rd generation strain for biomass sugar conversion

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
			strain for biomass sugar conversion 12/2006 Select final strain meeting target performance 7/2004 Complete Alpha phase pilot fermentation 12/2006 Complete Beta phase pilot fermentation
	5.1.2.5 GO Co-Product Enhancement (Masada/Oxynol)	• Process Integration	7/2002 Develop detailed test protocol 7/2002 Design hydrolysis system 11/2002 Equipment procurement installation 10/2002 Raw material procurement 11/2002 Biosolids processing 12/2002 Hydrolysis 12/2002 Filtration/lignin residue production 1/2003 Acid/sugar separation 2/2003 Neutralization/gypsum production 2/2003 Sugar concentration 2/2003 Acid concentration 2/2003 Hydrolysis with re-concentrated acid 3/2003 Fermentations 5/2003 Distillation/waste water production 6/2003 Wastewater treatment 9/2003 Evaluation, recommendation and implementation plan

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
			implementation plan
	5.1.2.6 GO Collection, Commercial Processing and Utilization of Corn Stover (Cargill Dow Polymers)	• 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. • Consistency and quality of raw materials. • Impact of weather conditions on raw materials. • fire hazard of stored biomass.	5/2007 Develop improved harvesting/collection/ storage technology at a cost of less than $30/ton delivered 5/2007 Establish benchmarks to improve understanding of Stover inorganic content and areas of concentration, production capabilities, harvest consistency and transport capacities. 5/2007 Eliminate fire hazard and improve preservation of stored biomass by ensiling. 5/2007 Define potential collection center locations for one pass harvest and 'wet storage' 5/2007 Establish benchmarks as to distribution of dry weight and validate most practical Stover storage methods. 5/2007 Determine effects of corn stover bales and processed corn stover pulp storage on fiber quality. 5/2007 Design, build and evaluate a plant part separation system capable of removing contaminates and separating components of the corn plant.

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
			evaluate a plant part separation system capable of removing contaminates and separating components of the corn plant. 5/2007 Automate sampling of the loads of Stover at the delivery scale. 5/2007 Develop fermentation process for converting corn stover to hydrolyzate lactic acid and ethanol using yeast. 5/2007 Develop model business relationships between producers and converters in industrial biobased products supply chains
	5.1.2.7 GO EERC Center for Biomass Utilization 2003	• Feasibility of utilizing products from gasification of treated wood • Reliable methane generation from a waste stream • Dissemination of current technology information • Biodiesel fuel blend optimization • Demonstration of economic viability of a dual-fermentation biorefinery concept	11/2003 Gasification tests in CFBR 1/2004 Data reduction for metal recovery 3/2004 nation of metal recovery costs 6/2004 Presentation of final assessment to industry 8/2003 Design and construction of two-stage reactor 8/2003 Acquisition and preparation of reactor feedstock 10/2003 Acclimation of bacteria

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
			3/2004 Operation at a minimum of three feed rates 9/2003 Sponsor recruitment 12/2003 Send out marketing materials for workshop 3/2004 Hold workshop 9/2003 Completion of biodiesel-jet fuel blend characterization work 12/2003 Completion of test stand work 3/2004 Selection of optimal blend ratio 2/2004 Completion of esterification process optimization work 4/2004 Completion of DFB economic viability assessment 12/2003 Developing and determining the future of integrated biomass cogeneration systems 2/2004 Assessment of collocating ethanol plants near power plant 3/2004 Collecting methane data 5/2004 Performing a universal feasibility study of dilute methane power
	5.1.2.7 GO Demonstration of the PureVision Biorefinery	• Development and demonstration of an integrated biorefinery; process feasibility leading to a commercial biorefinery	TBD

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
		to a commercial biorefinery	
Thermochemical Biorefineries	5.2.1.1NETL Big Island Demonstration Project – Black Liquor	• Lack of demonstrated, reliable gasifiers suitable for integration with the pulp and paper industry	4/2001 Start of Construction 7/2001 Fluor Daniel Conceptual Design 9/2001 DOE Review Period 9/2001 Concrete Demolition 11/2001 Approval to Proceed to Phase 2 7/2002 Foundation Construction 11/2002 Detailed Design & Engineering 12/2002 Procurement and Delivery 4/2003 Building Construction 1/2004 Commissioning 1/2006 Deployment Operation
	5.2.1.2 NETL Black Liquor Gasification Project	• Lack of demonstrated, reliable gasifiers suitable for integration with the pulp and paper industry	8/2001 DOE Cooperative Agreement Executed 9/2001 Demonstration Site Selected 7/2002 Major Subcontracts Finalized 5/2003 Finalize Demonstration System 7/2003 Continuation Application 7/2003 FPI Company and AF&PA 7/2003 AF&PA Energy Performance Task Group Endorsement 8/2003 Project Evaluation Report/Topical Report Submit

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
			Submit
	5.2.2.1 GO Small Modular Biopower		
	5.2.2.2 GO Mississippi Ethanol Gasification Project (Mississippi Ethanol, LLC) (Earmark)	• Products (syngas) process integration, syngas gas cleanup • Products (syngas) fermentation.	12/2003 Complete Gasifier Pre-Pilot Unit (1/10th scale) construction, assembly and testing at MSU-DIAL 12/2003 Complete Gasifier Pilot Unit design and construction 9/204 Complete Gasifier Pilot Unit testing and product gas characterization 9/2004 Complete gas clean-up design, construction and testing at MSU-DIAL 9/2005 Optimize the selection and performance of appropriate fermenting organisms capable of producing ethanol from the ME gasification product gas
	5.2.2.3 GO Commercial Demonstration TDP Technology Plant – Nevada (Gas Technology Institute) (Earmark)	• Develop and demonstrate an integrated biorefinery	22 mo from start Complete Engineering and Design 29 mo from start Complete Site Preparation 25 mo from start Complete Permitting/Legal 29 mo from start TDP Equipment Installed 42 mo from start Shakedown and Plant Operation

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
	5.2.2.4 GO Agricultural Mixed Waste Biorefinery TDP - Alabama (Gas Technology Institute) (Earmark)	• Develop and demonstrate an integrated biorefinery	9 mo from start Complete Engineering and Design 12 mo from start Complete Site Preparation 12 mo from start Complete Permitting/Legal 17 mo from start TDP Equipment Installed 24 mo from start Shakedown and Plant Operation
	5.2.2.5 GO Agricultural Mixed Waste Biorefinery – Colorado (Changing World Technologies) (Earmark)	• Develop and demonstrate an integrated biorefinery	6 mo from start Complete Engineering and Design 12 mo from start Complete Site Preparation 12 mo from start Complete Permitting Activity 17 mo from start TDP Equipment Installed 24 mo from start Shakedown and Plant Operation
	5.2.2.6 GO Southeast Alaska Ethanol Sealaska (Earmark)	• Develop and demonstrate an integrated biorefinery	8/2003 Complete review of technology providers' packages 8/2003 Complete review of cost estimates relative to each provider 8/2003 Select technology provider 7/2003 Complete initial feedstock testing 9/2003 Complete fermentor pilot plant demonstration and scale-up testing

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
			12/2003 Complete bench test with integrated processes 11/2003 Complete pilot plant testing of main technology 2/2004 Complete integrated design data 2/2004 Complete facility cost estimate 4/2004 Stage Gate Review of Phase I
	5.2.2.7 GO Gridley Rice Straw (City of Gridley, CA) (Earmark)	• Develop and demonstrate an integrated biorefinery	TBD
	5.2.2.8 GO AgraPure Mississippi Biomass Project (AgraPure)	• Resource availability • Lack of credible data on price, location, quantity, and quality of biomass • Engineering systems • Handling and transportation challenges due to low bulk-density of biomass	3/2005 Feedstocks assessment 3/2005 Processing options 3/2005 Product market identification 3/2005 Site requirements, location, acquisition 3/2005 Permitting 3/2005 Labor, management & operations requirements 3/2005 Equipment procurement and construction 3/2005 Financing requirements, sources, acquisition 3/2005 Economic analysis 3/2005 Business plan development
	5.2.2.9 Distributed Fuels Solicitation	• The Initiative will address the 1st tier Thermochemical Platform barrier, cost of intermediates. It will also address the 2nd tier barrier on process integration. Phase 2 projects will, by necessity address other relevant 2nd tier technical barriers relevant to a specific technology	3/2005 Issue Distributed Fuels and Chemicals Feasibility Solicitation 7/2004 Make 5 DFC subcontract awards

Technical Barrier Area	Project	Specific Barriers Addressed	Milestones
		address the 2nd tier barrier on process integration. Phase 2 projects will, by necessity address other relevant 2nd tier technical barriers relevant to a specific technology.	subcontract awards 7/2005 Complete feasibility studies 9/2005 Decision Point – Proceed to Phase 2 Projects 1/2006 GO – Issue Phase 2 Solicitation 9/2006 Make 2-3 Phase 2 Awards 3/2009 Complete Phase 2 Projects
	5.2.2.10 Go Future Integrated Thermochemical Biorefinery Solicitations	•	
Integrated Biorefinery Analysis	5.3 NBC Integrated Biorefinery Analysis Project	• Provides measures of success for process integration and identification and documentation of pioneer technology risks.	7/2004 Report on possible methods for quantifying biorefinery projects' progress 1/2005 Develop best method and use on 2 test projects 1/2006 Integrate method into multiple projects

3 Program Management

OBP has overall authority and responsibility for managing DOE research, development, and demonstration activities relating to the use of renewable biomass for fuels, chemicals, materials, and power. OBP provides 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, OBP will build its portfolio based on detailed market and technology analysis, in collaboration with leaders and technology experts from industry, academia, and the national laboratories and in collaboration with other EERE programs. The following are key characteristics of the program management approach:

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

3.1 Program Management Structure and Participants

Figure 1 shows the organizational structure of R&D management for OBP. OBP is one of 11 programs within EERE and under the purview of the Assistant Secretary for EERE. Overall management responsibility and authority for the Program resides with the OBP program manager, who reports directly to the EERE Deputy Assistant Secretary for Technology Development. All personnel within OBP report directly to the Program Manager.

3.1.1 DOE Headquarters—Program Management

OBP is responsible for the routine operations of the office and for formulating strategic and operational plans, justifying and allocating resources, establishing R&D and programmatic priorities and goals, and evaluating the performance of its projects. Management of the overall Program includes consideration of the President's National Energy Policy, EERE's Strategic Plan and priorities, and the EERE Strategic Program Review, and Congressional directives and legislation.

OBP implements agency policies and procedures and reports on progress and activities to senior DOE management. The MYPP, this MYTP, the MYAP, annual operating plans, and communications plans provide the program management framework. Program management includes Program-wide activities such as planning, budgeting, execution, evaluation, technical integration, and analysis, as well as crosscutting activities such as outreach, education, and partnerships.

The Program is composed of five R&D elements or technology areas:

- Biomass Feedstock Interface R&D
- Sugar Platform
- Thermochemical Platform
- Products (including fuels, chemicals, materials, heat, and electricity)

• Integrated Biorefineries

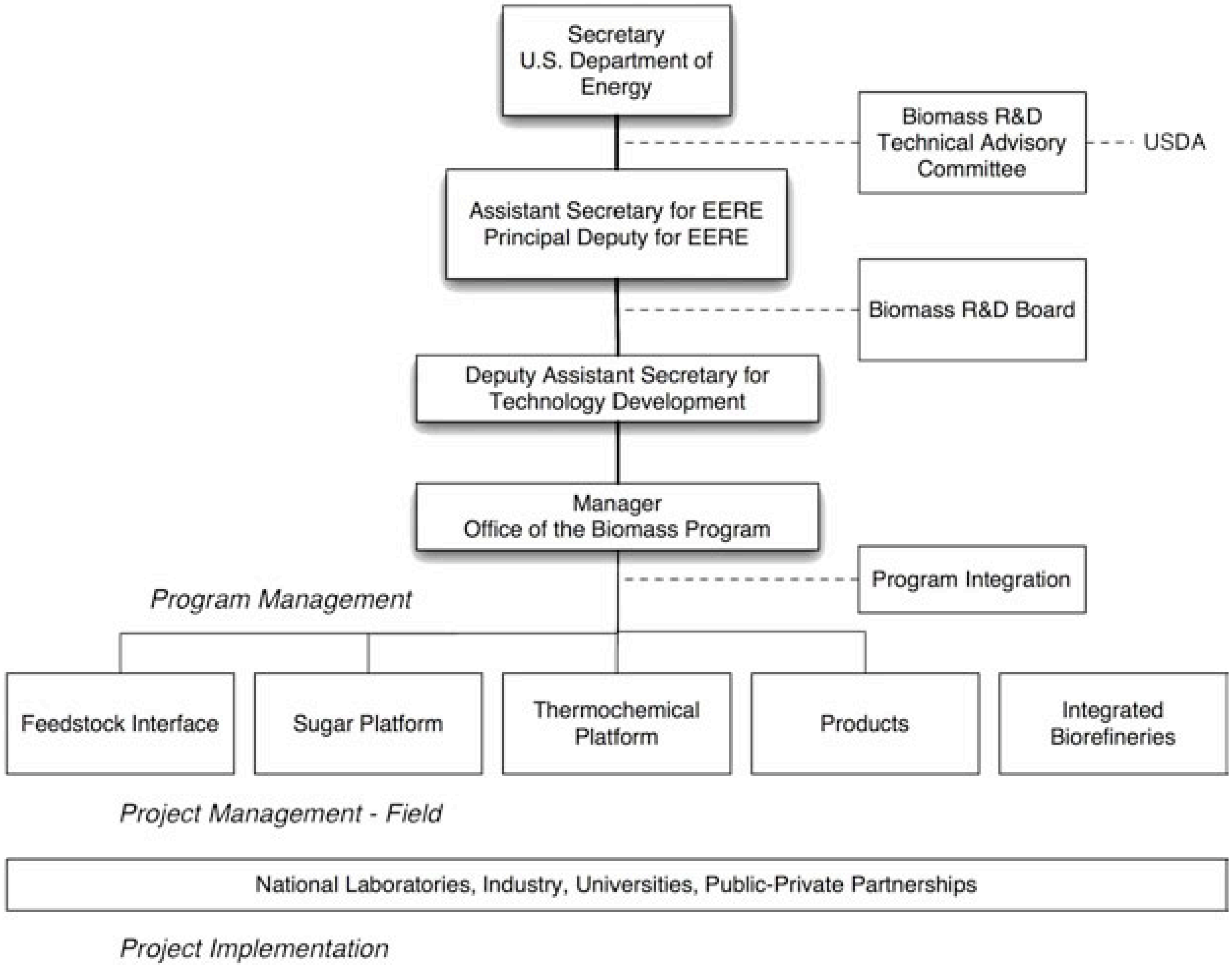


Figure 36: OBP Organization Chart

The OBP organization fosters effective partnerships with its stakeholders in the public and private sectors. In keeping with the President's Management Agenda and the EERE Strategic Program Review, 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 capabilities of headquarters, field and operations offices, and national laboratories are used to optimize the strengths of these organizations and ensure the success of the Program. OBP has established teams responsible for management of technology RD&D and other administrative activities. Team leaders are responsible for keeping the program manager informed of successes and problems and formulating options to maintain progress and schedule.

3.1.2 Coordination with Other EERE Programs and Other DOE Offices

Coordination with other program offices is essential for the success of the Biomass Program and EERE. The following are specific examples of OBP's coordination efforts:

Hydrogen, Fuel Cells & Infrastructure Technologies Program. Biomass is one of the near-term primary energy sources for hydrogen production. The OBP activities in biomass feedstocks interface R&D and elements of the thermochemical, sugar, and products platforms directly support the goals of the HFCIT Program. In the HFCIT Program, a systems analysis approach to hydrogen energy RD&D is used, with exploratory research as the foundation for breakthroughs in technology, while coordinating R&D strategy programs within the EERE and Fossil and Nuclear Energy Offices at DOE.

FreedomCAR and Vehicle Technologies Program. Research on the use of non-petroleum fuels, particularly renewable diesel and E-diesel, are coordinated and co-funded with the FreedomCAR and Vehicle Technologies Program.

Weatherization and Intergovernmental Programs. OBP coordinates with several areas of this Program.

- International Activities: OBP provides technical assistance on international biomass related inquiries and projects.
- Tribal Energy Activities – The Bureau of Indian Affairs of the Department of Interior recognizes biopower as a renewable electricity source that, in small and modular scale, fits in with applications and the culture of many Indian reservations. Although this R&D effort is winding down, OBP will continue to coordinate tribal support activities through the Tribal Program staff.
- Clean Cities: The Clean Cities Program supports public-private partnerships that deploy alternative fuel vehicles and build supporting alternative fuel infrastructure. OBP cooperates with the Clean Cities Program by providing public documents in the Biomass Program's document database to the Alternative Fuels Data Center, which is the primary source of alternative fuels information for Clean Cities stakeholders.
- State Energy: OBP contributes to the State Energy Program (SEP) (See Section 3.5.3.5) and the State Technologies Advancement Collaborative (STAC) Program (see Section 3.5.3.4). RD&D awards from these programs for biofuels, biopower, and bioproducts augment the OBP portfolio.

Federal Energy Management Program (FEMP). The Buy–Bio Initiative, supported by OBP, is implemented through FEMP.

Office of Industrial Technologies (OIT). Biomass-based technologies for fuels, chemical, materials, heat, and electricity are of interest to the OIT Chemical and Forest Products Industries of the Future Programs.

EERE Communications Office. OBP's outreach efforts support and are coordinated with the broader corporate efforts managed by the EERE Communications Office.

EERE Business Administration, Planning, Budget Formulation, and Analysis (PBFA). OBP analysis activities are determined, in part, by the information needed by PBFA to carry out EERE crosscutting corporate analysis.

DOE Office of Science. **OS** supports the basic underpinnings of plant biology and physiology in regulation of metabolic pathways and integration of these multiple pathways for cellular function of constituents. This knowledge can be used to design of accumulation of desired products while enabling to derive a predictive context for these accumulations. Bioconversion and biotechnology activities include molecular mechanisms to convert sunlight into biomass (photosynthesis research), biofuels (fundamentals of enzymes and microbial systems), and bioproducts. Important new imaging tools and methods are being developed to examine metabolic and signaling pathways to visualize the cellular architecture, at both physical-spatial and temporal scales.

Genomics, catalysis, molecular modeling, and nanotechnology are also funded by the Office of Science and constitute cornerstones of the technologies needed for advanced biorefineries

DOE Office of Fossil Energy (FE). FE supports R, D&D and commercial demonstrations in clean coal technologies, which are synergistic with OBP technologies. Past collaborations include the co-firing of biomass and coal to reduce emissions and decrease output of fossil carbon dioxide. Current FE efforts explore FutureGen - tomorrow's "pollution-free power plant" which produces hydrogen, electricity, and carbon dioxide. An industrial consortium representing the coal and power industries, over the next 10 years, is expected to complete a plant that will become a test bed for advanced concepts carbon sequestration projects; results are to be shared among all participants, and the industry as a whole.

3.1.3 DOE Field Offices—Project Management

The DOE Golden Field Office (GO) supports EERE, including OBP, through field project management of R&D partnerships, laboratory contract administration, and a variety of professional, technical, and administrative support functions. GO is also accountable for funds expended under the NREL contract and for funds expended under grant programs administered through the EERE Regional Offices. NETL manages research and demonstration projects on behalf of OBP in the areas of black liquor gasification and biomass gasification in the forest products industry. Competitive solicitations are the primary vehicles for placing R&D partnership projects, although the national laboratories are funded directly for specific core research activities depending on technical capabilities.

3.1.4 National Bioenergy Center—Project Management and Implementation

DOE established the NBC in 2000 as an inclusive center without walls, unifying all of the resources at DOE's relevant national laboratories to advance technology for producing fuels, chemicals, materials, and power from biomass. The NBC provides technical assistance in areas of expertise and is responsible for managing core research activities of the Program. Collaborating with industry, academia, related EERE programs, other DOE offices, as well as other government research, development, and commercialization efforts is central to these responsibilities. The preferred partnering mechanism between industry and DOE laboratories is the CRADA. The CRADA provides for intellectual property rights and patent waivers between DOE laboratories and industrial partners.

The NBC, under direct NREL leadership, includes research and development supported by the OBP and carried out at NREL, ORNL, PNNL, INEEL, and ANL. Tasks or Program areas are assigned based on the capabilities and appropriateness of the organization for performing and/or managing the work. Table 1 shows the capabilities of national laboratories in the NBC employed to support OBP.

Table 1: National Bioenergy Center Capabilities

National Laboratory	Primary Capabilities Supporting OBP
NREL	Biomass Characterization, Biochemical and Thermochemical Conversion, Products, Process Integration, Engineering and Analysis
ORNL	Feedstock Development, Resource Assessment
INEEL	Harvesting Technologies
PNNL	Thermochemical Conversion, Catalysis, Products
ANL	Reaction Engineering and Separations, Life Cycle Assessment

3.1.5 Public-Private Partnerships—Project Implementation

The Biomass Program is leveraging the vast capabilities and experience of its stakeholders through cooperative partnerships. The roles of stakeholder groups vary as do the nature of their collaboration with OBP. In broad terms, the roles of these stakeholder groups are the following:

- Federal Agencies: Partnerships in research and development, environmental and regulatory issues, and coordinating biomass activities through the Biomass R&D Board. Of particular importance are partnerships between DOE/OBP and USDA.
- State and Local Governments: Partnerships in deployment, outreach, and education.
- Industry: Partnerships in research, development, validation, and deployment of biomass technologies.
- Universities: Partnerships in research, analysis, and education.
- International: Partnerships in research and development, outreach, and education.

Many of the technical projects conducted by the Biomass Program partnerships involve industrial and academic partners. Projects that have a relatively clear path to commercialization including near term research and development, pilot scale integrated testing, and larger demonstrations are generally led by industry, have significant private sector cost-share (20-50%), and typically are conducted by a team of performers. These industry lead partnerships will have a clear understanding of the cost and performance requirements of the marketplace. Projects in the Integrated Biorefinery portion of the Program are exclusively industry led. In Stage Gate management parlance (see Section 3.3.1.4) these projects are generally classified as being on the commercial path.

Technical projects that are characterized as longer term, high-risk research generally includes work performed by DOE National Laboratories with appropriate involvement of other technology providers such as universities and industry. Cost share is related to the structure of the project and ownership of intellectual property. These projects will be focused on developing the fundamental understanding and knowledge of barriers that are common to many processes. These projects are generally classified as being on the research path and are subject to industrial review and guidance to insure they are relevant and important.

3.1.5.1 Biomass R&D Board

The Biomass R&D Act of 2000 (Agricultural Risk Protection Act of 2000, Title III) created the Biomass R&D Board (the Board), which is responsible for coordinating biomass activities across federal agencies. With its strategic planning, this cabinet-level board seeks to guide the activities of various participating agencies in terms of federal grants, loans, and assistance and also non-R&D activities.

Membership includes the following agencies:

- USDA (co-chair)
- DOE (co-chair)
- National Science Foundation (NSF)
- Environmental Protection Agency (EPA)
- Department of Interior (DOI)

- Office of Science and Technology Policy (OSTP)
- Office of the Federal Environmental Executive (OFEE)

Official functions of the Board include the following:

- Coordinating programs within and among departments and agencies of the federal government for the purpose of promoting the use of biobased industrial products by
  - Maximizing the benefits deriving from Federal grants and assistance
  - Bringing coherence to federal strategic planning
- Coordinating research and development activities relating to biobased industrial products
  - Between USDA and DOE
  - With other departments and agencies of the federal government
- Providing recommendations to the points of contact concerning administration of the Act

The following are agency representatives to the Board for 2003:

Co-Chairs:

David K. Garman, Assistant Secretary, EERE, DOE
Mark Rey, Under Secretary, Natural Resources and Environment, USDA

Members:

Bruce Hamilton, Director, Bioengineering and Environmental Systems Division, NSF
Jean-Mari Peltier, Counselor to the Administrator, EPA
Jim Tate, Science Advisor, DOI
Kathie Olsen, Associate Director for Science, OSTP
John Howard, Federal Environmental Executive, OFEE

The National Coordination Office, staffed by DOE and USDA, serves as the executive secretariat for the Board, preparing reports and conducting the day-to-day activities. John Ferrell of OBP is the DOE co-chair of the National Coordination Office.

3.1.5.2 Biomass R&D Technical Advisory Committee

The Biomass Act of 2000 also created the Biomass R&D Technical Advisory Committee, an advisory group to the Secretaries of Energy and Agriculture. The Committee includes 30 industrial experts who advise DOE/OBP on technical focus and reviews and evaluate proposals. The Committee also facilitates partnerships among federal and state agencies, producers, consumers, the research community, and other interested groups. The Committee created the "Vision for Bioenergy & Biobased Products in the United States" (October, 2002) and the "Roadmap for Biomass Technologies in the United States" (December, 2002). OBP has embraced the long-range goals set in the vision document:

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

The technical strategies and program goals of OBP, documented in this MYTP, were designed to help meet these targets.

3.1.5.3 Collaboration with USDA

The Biomass R&D Act of 2000 directs the DOE and USDA to integrate technology R&D programs to foster a domestic bioindustry producing fuels, power, and chemicals. OBP works closely with USDA in a number of ways. The technology base for products and energy within 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 Laboratory to address use and resource conservation, including forest management. USDA soil conservation laboratories conduct scientific research on soil and water conservation. DOE/OBP-USDA interagency collaborations include the following:

- Solicitations: The Biomass R&D Initiative within the Farm Bill authorized USDA to spend $5M on bioenergy projects in FY02 and $14M annually for FY2003–FY2007. USDA selected projects from the biorefinery selections made by DOE for the initial funding. A joint solicitation was made in FY03 that resulted in four DOE awards and 15 USDA awards. Additional solicitations are planned for FY04 and beyond.
- Joint research: DOE laboratories, USDA Agricultural Research Centers, and the Forest Products Laboratory are undertaking joint work under interagency agreements, employing capabilities to accomplish biobased products, biofuels, and biopower research, and provide data for life cycle assessments.
- 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 and decrease the risk of forest fires on lands it manages for the Government. The Forest Products Laboratory and DOE's NBC are jointly monitoring the demonstration of five small modular biopower systems located throughout the country.
- 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).

3.1.5.4 State and Local Government

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. Section 3.5.3 describes the specific state and regional partnership projects supported by OBP.

3.1.5.5 Industry

Partnerships with industry exist throughout the OBP portfolio, and the Integrated Biorefinery portion is made up exclusively of industry-led projects. Industry stakeholders also participate in guiding and reviewing the Program through membership on the Biomass R&D Advisory Committee, which is made up primarily of industry stakeholders, and as project gatekeepers in the stage gate management process. 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 consortium 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.

Cost-shared RD&D initiated via competitive solicitations is the preferred method of RD&D and technology transfer because U.S. industry is closely involved from a technical and planning standpoint as well as a financial standpoint (the cost-share). This involvement usually ensures a genuine effort by U.S. industry to commercialize the technology.

3.1.5.6 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.

3.1.5.7 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. International collaboration occurs through participation in International Energy Agency (IEA) activities related to biomass led by the IEA Bioenergy Committee. Doug Kaempf, Manager of OBP, represents the United States on the Executive Committee for IEA Bioenergy. Table 16 shows the IEA Bioenergy tasks currently supported by the United States. The primary value of the IEA is its information-sharing activity. Typically, the United States can access the fruits of other countries' RD&D programs long before they are distilled into reports and literature citations. Site visits offer great value in the area of lessons learned, which rarely if ever reach the open literature. The joint activities provide an outstanding venue for discussion with foreign experts. The work program and task activities within IEA Bioenergy can be accessed at www.ieabioenergy.com/IEABioenergy.php.

Table 16: U.S.-supported IEA Bioenergy Tasks (federal organization providing support)

IEA Task 30:	Short Rotation Crops for Bioenergy Systems (USDA-FS)
IEA Task 31:	Conventional Forestry Systems for Sustainable Production of Bioenergy (USDA-FS)
IEA Task 32:	Biomass Combustion and Co-Firing (DOE-OBP)
IEA Task 33:	Thermal Gasification of Biomass (Brigham Young University)
IEA Task 34:	Pyrolysis of Biomass (DOE-HFCIT)
IEA Task 35:	Technoeconomic Assessments for Bioenergy Applications (DOE-OBP)
IEA Task 38:	Greenhouse Gas Balances of Biomass and Bioenergy Systems (DOE-OBP)
IEA Task 39:	Liquid Biofuels (DOE-OBP)

There is also a biomass-related activity under the Energy End-Use Technologies area, implementing agreement on Pulp and Paper: Annex XV - Gasification Technologies for Black Liquor and Biomass. This activity started with EERE's OIT and has major U.S. involvement, managed through ORNL.

3.2 Program Management Approach

The work breakdown structure (Figure 37) translates the core activities of Program Management into a working organization of focused efforts and projects in three distinct areas:

- Program Management and Integration, which includes Program-wide activities such as planning, budgeting, execution tracking, evaluation, and technical integration
- Analysis, which includes analysis that cuts across the technical elements of the program and provides information to EERE/PBFA
- Outreach, Education, and Partnerships, which are crosscutting support activities. Partnership activities included here are broad, with the goal of increasing collaboration with regional, state, and local governments and encouraging the participation of small businesses in biomass-related research through the federal programs.

3.3 Program Management and Integration

The Program will employ the four phases of the EERE management system:

- Planning
- Budget formulation
- Budget execution
- Analysis and evaluation

The strategic plans of DOE and EERE are the foundation of the planning hierarchy for the Biomass Program. Figure 4 illustrates the timing of OBP management planning and evaluation activities throughout the year and grouped into two general categories:

- Program and portfolio management
- Project management

These activities are scheduled to coincide with Congressional budget schedules, fiscal year start-end, and internal DOE planning and project implementation factors.

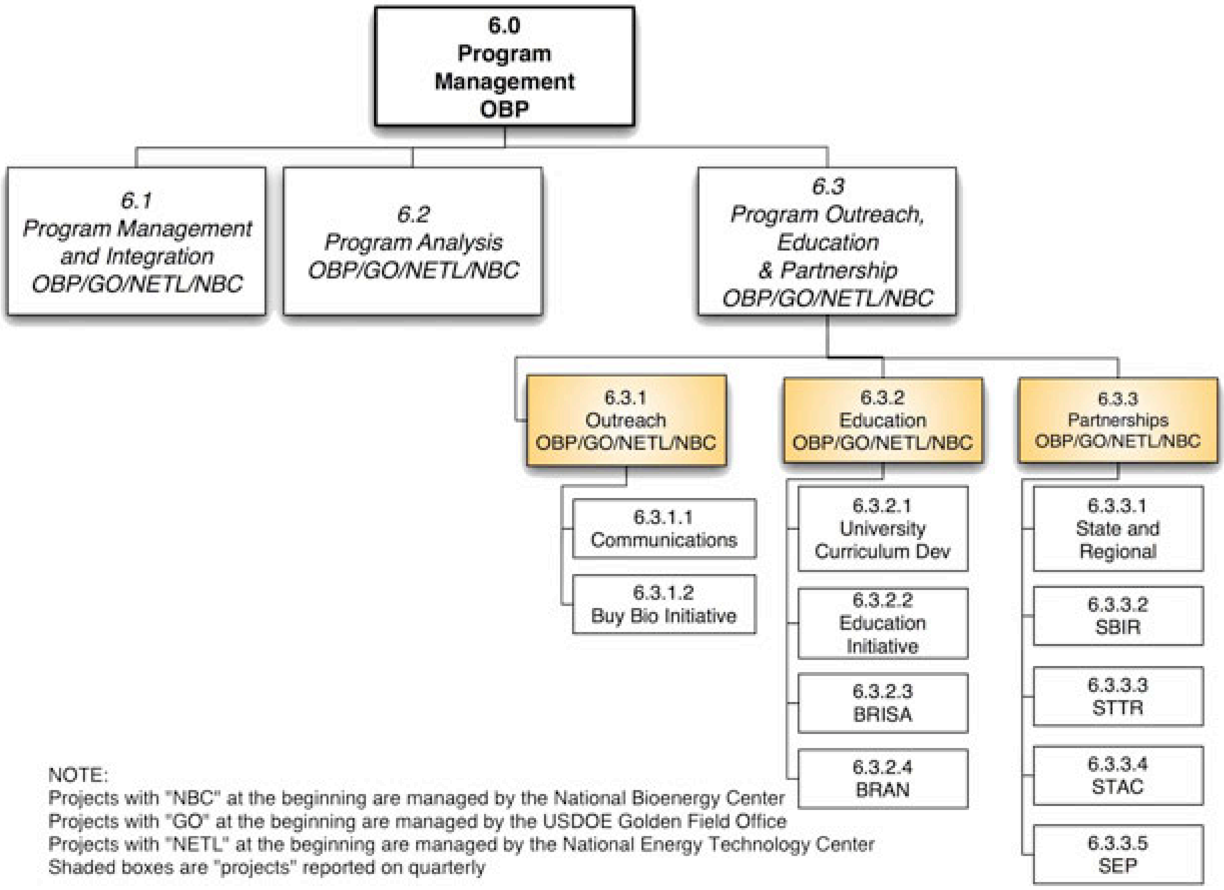


Figure 37: Work Breakdown Structure for Program Management

3.3.1 Program Planning

There are five OBP planning documents, included in Figure 4 and described below, that guide and help integrate the work of OBP: the MYPP, the MYTP, the MYAP, the annual operating plan (AOP), and the annual communications plan.

- The MYPP describes OBP goals and strategies at a high level consistent with the DOE and EERE Strategic Plans.
- The MYTP is the link between the high-level goals in the MYPP and the detailed plans for each project defined as part of the stage gate management process. By bringing together all of the separate plans that comprise the work of the program, the MYTP facilitates the identification of the linkages and interdependencies among the various projects being funded. The timing and duration of the activities included in the plan are resource driven. This is an important feature of the plan that permits OBP to understand the relationship between the time required to meet the milestones and resources available to support them.

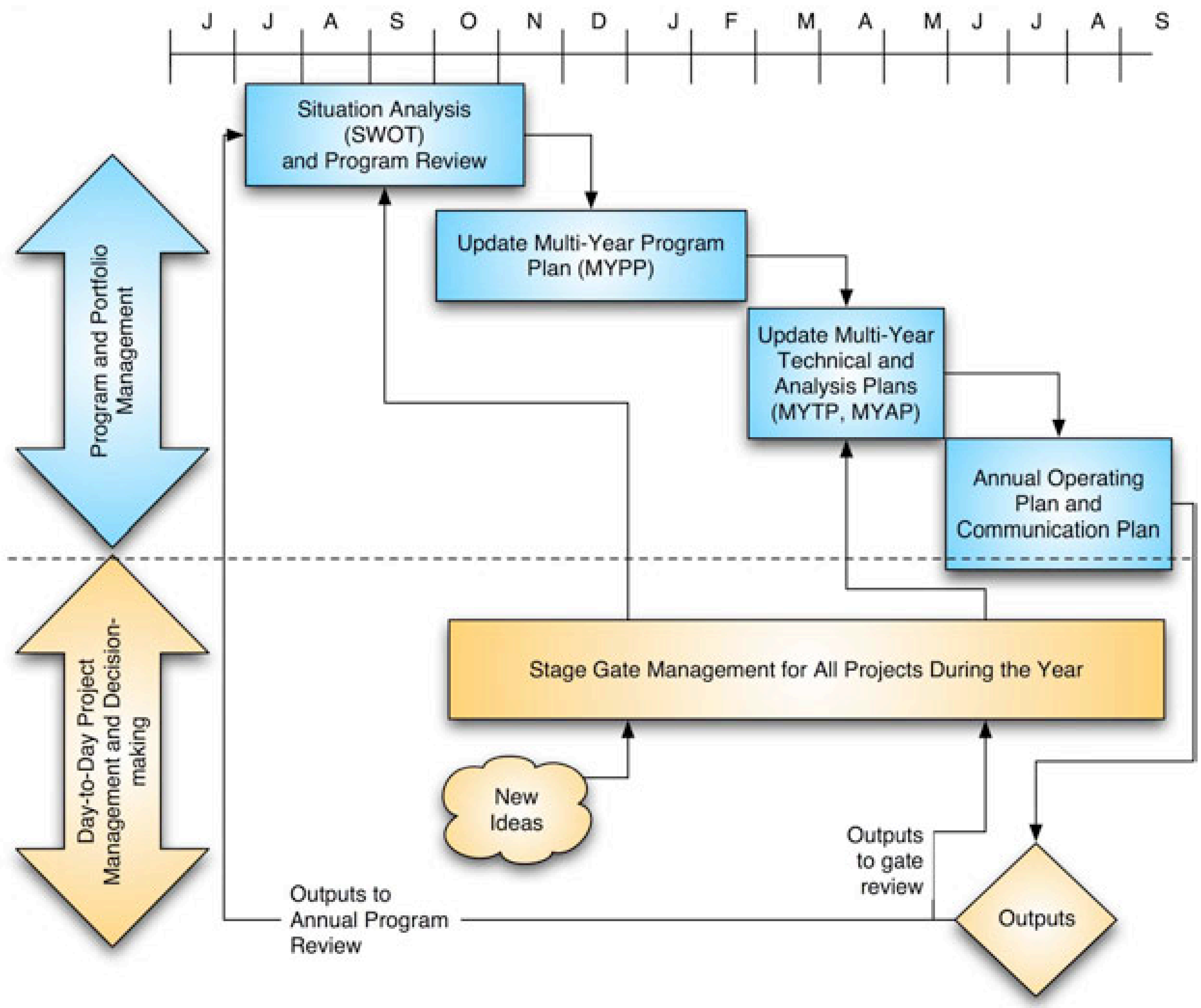


Figure 4: OBP Annual Planning, Control, and, Evaluation Schedule

- The MYAP shows the analysis activities needed to assess progress towards achieving OBP's goals. It will define tasks and resources for analysis efforts in feedstock development and infrastructure, technical and economic feasibility, environmental assessment, and the development of biorefineries and a bioindustry. Aimed at directing OBP-funded analysis, this plan will include work by national laboratories, contractors, and Financial Assistance Awardees (FAA). The goals of the MYAP are to ensure that biomass utilization analysis efforts are credible, transparent, integrated, and useful.
- The AOP is essentially a 1-year slice of the MYTP and MYAP. OBP has chosen to prepare a single all-inclusive AOP based on a compilation of the individual annual plans for specific technical projects and program support areas such as analysis. Each project plan includes objectives, a statement of work, milestones, and schedule and cost projections along with specific performers of the research or support. These plans are the basis for evaluating performance during the year and identifying needed modifications during project execution. The milestones in the AOP identify tangible, measurable results against which actual achievement can be compared. Having a single AOP enhances overall Program integration and communication.

- The OBP communications plan is updated annually. It describes the important OBP stakeholder audiences, identifies the specific activities planned for the upcoming fiscal year as they relate to those audiences, and provides up-to-date contact information for stakeholder groups and organizations.
- Stage gate management is a process employed at the project level to plan the project and evaluate progress relative to the plan as the project moves along the technology development pathway. The decision-making criteria employed are consistent with the OMB Applied R&D Investment Criteria, as described in the EERE Strategic Plan. Stage gate management is described in more detail in Section 3.3.1.4.

Control of planning documents is an integral part of the program management process. RD&D plans make assumptions that sometimes are market based and other times are based on technology status. These assumptions change with time as the technologies and market forces change. It is imperative to keep excellent documentation of the plans and the assumptions within the plans and to track changes to the assumptions over time to keep the Program focused. Program and technology development schedules emerge from the composite of plans described above, but only if they are well integrated and consistent. This is another factor that requires proper control of planning documents. This responsibility will reside within the program integration function (Section 3.3.2).

3.3.2 Program Budgeting

The budget falls under the jurisdiction of two separate Congressional appropriations subcommittees:

1. Energy and Water Development for Biomass and Biorefinery Systems R&D
    a. Advanced Biomass Technology R&D
        i. Thermochemical Conversion R&D
        ii. Bioconversion R&D
    b. Systems Integration and Production
        i. Feedstock Infrastructure
        ii. Bioconversion Production Integration
        iii. Thermochemical Production Integration
        iv. Crosscutting Biomass R&D

2. Interior and Related Agencies for Biomass and Biorefinery Systems R&D
    a. Advanced Biomass Technology R&D
        i. Thermochemical Conversion R&D
        ii. Bioconversion R&D
        iii. Systems Integration and Production
        iv. Technical Program Management Support

Activities under the Energy and Water Development funding have traditionally focused on developing advanced technologies for producing fuels and power using biomass feedstocks, more specifically the work of the former Biomass Feedstock Development, Biofuels, and Biopower

Programs. Activities under the Interior and Related Agencies funding have traditionally focused on developing advanced technologies for more energy efficient industrial processes and high-value industrial products, more specifically:

- Products Development (formerly the Agriculture Industries of the Future)
- Industrial Gasification (formerly the industrial gasification part of the Combustion Crosscutting Program and the gasification projects from the Forest Products Industry of the Future Program)

As a result of the EERE reorganization, the Program can better focus on research pathways for converting biomass into an optimized slate of useful outputs in an industrial biorefinery. As described in this plan, resources appropriated by Energy and Water Development and Interior and Related Agencies are planned, executed, and evaluated as one Program.

3.3.3 Program Execution

Each project in the five program areas is discreetly identified and targeted to overcome specific barriers. Projects are carried out by industry contractors, national laboratories, and universities. Milestones have been established for every project to focus efforts on the performance targets. Within each area and project, activities are prioritized by assessing the current status against out-year targets. Because all related targets must be met simultaneously for a given technology development effort to be declared successful, trade-offs between related targets will occur, and they cannot be evaluated separately. Based on the composite results from projects in a research area, the R&D may be refocused and redirected. The Integrated Biorefinery portion of the Program portfolio is ultimately where technology development efforts are integrated and validated in projects led by industry partners.

Milestone reports will be prepared to document completion of planned tasks. Results in these reports must provide project leaders, technology managers, and program integration staff the information needed to track the status of research efforts and measure progress toward Program goals. Distribution of milestone reports will be determined on a case-by-case basis depending on the nature and sensitivity of the information included in a particular report. All Program participants will strive to make information available to the widest audience.

Effective and timely internal communications are essential for an efficient organization. OBP has implemented a weekly highlights email process and two intranets, one for DOE only and one for DOE and the NBC, to aid communication and collaboration among the Program and project management participants. The intranets contain up-to-date Program information, including planning and management documents, presentations, a calendar, weekly highlights, and more.

OBP also supports the I-Manage and ePME efforts in DOE and the EERE plans to implement an interim corporate management system in FY04. OBP will provide all necessary management information to the system and may adapt or evolve management processes as necessary to accomplish this.

3.3.4 Program Analysis and Evaluation

Evaluation is conducted at the Program level and the project level. Program reviews are carried out every 2 years according to EERE peer review guidelines. Members of the Biomass R&D Technical Advisory Committee are included as reviewers. This MYTP is currently undergoing such a peer review. In addition, OBP has implemented quarterly and annual progress reports at the project and Program area levels. These reports provide information critical to successful program integration.

- Quarterly and annual progress reports are prepared for each technical project and support area outlining technical status, problems areas, achievements, and cost issues. Site reviews may be conducted as needed to assess obstacles and view the work in progress. This information is critical for the monitoring and controlling activities of project management.
- Project team leaders are responsible for preparing quarterly and annual summary reports that roll up the collective status of each program area. This information is critical to conducting an overall program progress review at the end of each fiscal year.

At the project level, stage gate management is the main process to analyze and evaluate progress in depth. It is a process for making disciplined, informed decisions about RD&D investments and helps ensure program dollars are used effectively and efficiently. As practiced by the Biomass Program, stage gate management includes two paths, or tracks, that a project can take depending on the planned outcomes (Figure 5). The commercial track is for projects in which the outcome is a commercial process or product. The research track is for more basic and applied research. 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. Interim stage reviews are held at least on an annual basis for projects that are expected to be in a single stage for multiple years. A Stage Gate Management Guide has been prepared for the Biomass Program to inform and educate participants about the process and enable consistent and rigorous application throughout the Program. Information regarding project progress prepared for project gate reviews and interim stage reviews is needed to perform the program integration function.

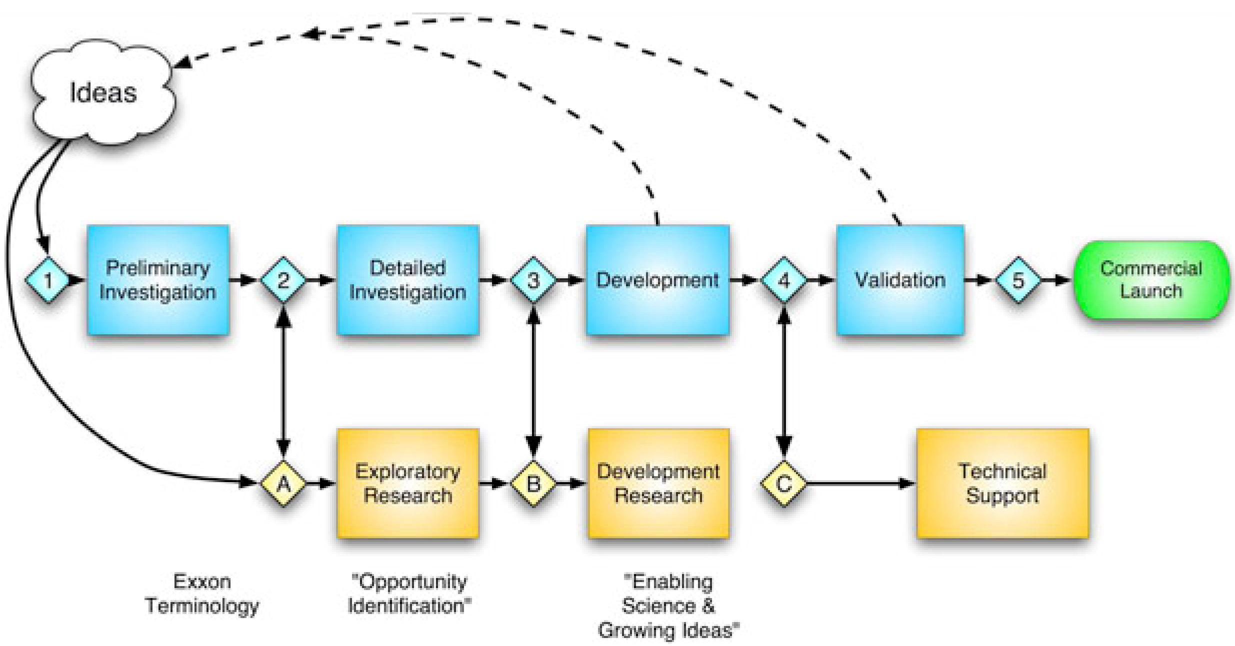


Figure 5: Stage Gate Management Flow Chart

3.3.5 Program Technical Integration

OBP will implement a program integration function that provides and maintains a solid foundation for the results-driven program approach described above. The goal of this effort is to manage the complex interactions between interrelated technical and programmatic elements of the Program so that objectives can be met in the most cost-effective manner through ongoing evaluation of performance, cost, schedule, and risk. Because industry and the energy, chemicals, and products markets they serve are ultimately the customers for OBP technologies, the program must manage its efforts in the context of a dynamic system in which requirements are established by the ever-changing marketplace.

The interdependencies of Program activities in Feedstock Interface R&D, Sugar Platform, Thermochemical Platform, Products, and Integrated Biorefineries must be understood and the interfaces managed to integrate and align efforts in the Program areas and in individual projects. The core function of program integration is to establish, validate, and maintain the integrated technical and programmatic baseline. To accomplish this, the program integrator must do the following: 1) establish and implement management tools that enable gathering, developing, and analyzing of data and information across and between each of the levels; 2) conduct analyses, planning, and evaluation; and 3) interpret the results in products that identify issues and opportunities and provide well analyzed options and recommendations. These products will provide a strong and credible basis for program management decisions.

The program integration function will be carried out by a group that can provide systems engineering, analysis, and integration support to OBP. The program integration group directly supports the OBP program manager and works in collaboration with OBP, GO, NETL, and NBC staff. This group will assist OBP in strategic program planning, selecting program and policy options, formulating and justifying budgets, and tracking Program and project progress.

Key business integration functions include the following:

- Integrated field budget development, tracking, metrics, and cost performance
- Procurement planning

Key technical integration functions include responsibility and accountability for the following:

- Technical planning, which includes developing and maintaining the overall technical plans to achieve program goals (MYPP, MYTP, and AOP).
- Technical information, which includes tracking milestones, preparing quarterly program summary reports, and creating and maintaining data management systems.
- Technical analysis and evaluation, which includes creation and maintenance of the integrated baseline that includes both a technical baseline and a program baseline. The technical baseline describes the performance requirements that must be met to achieve the goals of the Program. Analysis efforts throughout the Program will contribute to the technical baseline. The program baseline contains information on the projected costs associated with each work element and the schedule interdependencies.
- Capability development and integration, which includes identifying capability gaps and strategies for developing unique capabilities to achieve Program objectives.

3.4 Analysis

The Biomass Program uses engineering and analysis to support decision making, show progress toward goals, and direct research activities. Integrated analysis activities provide crosscutting, quantified information to the Biomass Program to manage its research portfolio and develop analysis methods and tools to benefit all analysis efforts. Platform-level analysis activities provide direction, focus, and support to the development and introduction of feedstock production, processing, and use technologies. The majority of process engineering and analysis is performed as part of the research platforms; refer to the specific platform analysis projects for details.

Integrated analysis provides direction and focus to the overall research program by evaluating the technical, economic, environmental, and market aspects of biomass utilization via integrated pathways. This analysis also provides quantifiable measures of success towards OBP's goals and is part of the MYAP for OBP and its EERE analysis activities. Integrated analysis has three objectives: 1) to combine the results of platform analysis into biorefinery process designs, 2) to assess emerging technologies that are not currently part of a research platform but have potential to improve biomass utilization, and 3) to develop advanced methods, tools, and partnerships to improve analysis value and efficiency. This evolving analysis infrastructure also supports platform analysis and industry-led projects.

Figure 6 shows the components of integrated analysis. Analysis philosophy represents the highest-level assumptions and rules that an analysis will follow. The level of rigor is determined by the project stage and data available. The analysis team ensures that all the methods and parameters used in the different analysis methods are well documented, transparent, credible, and updated regularly to reflect the dynamic nature of a robust RD&D program.

Figure 7 shows the types of analyses that are used in the program, supported by the analysis infrastructure of methods, tools, and analysts. Used in combination, these analyses provide a sound understanding of the program technologies. Each of these methodologies provides information and recommendations to the Program. In general, each type of analysis builds on results from other areas in the analysis pyramid to quantify the benefits, drawbacks, and risks of different biomass utilization scenarios. Results from each type of analysis method, used at the appropriate level of rigor, are used in the stage gate reviews of individual projects as described previously. Each element of the analysis pyramid is described below.

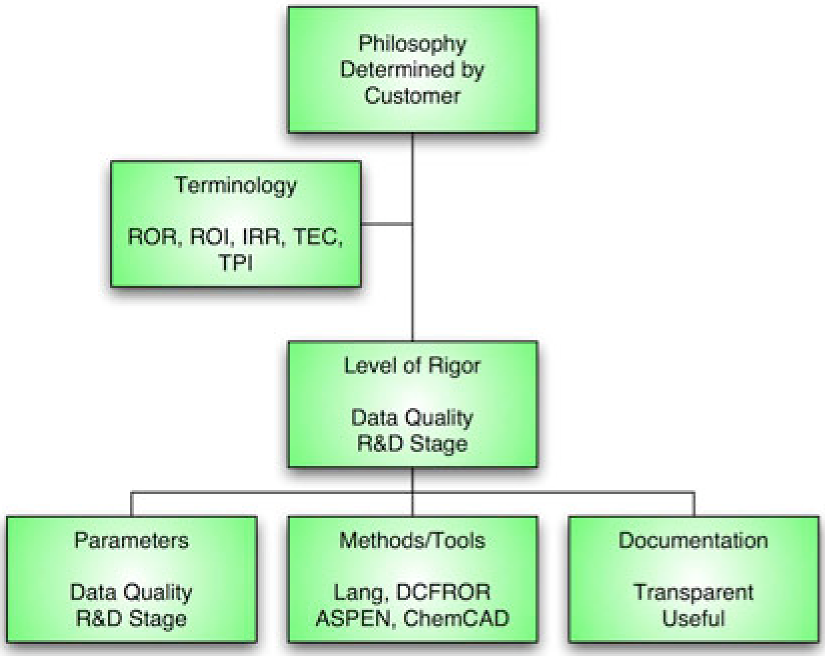


Figure 6: The Components of Integrated Analysis

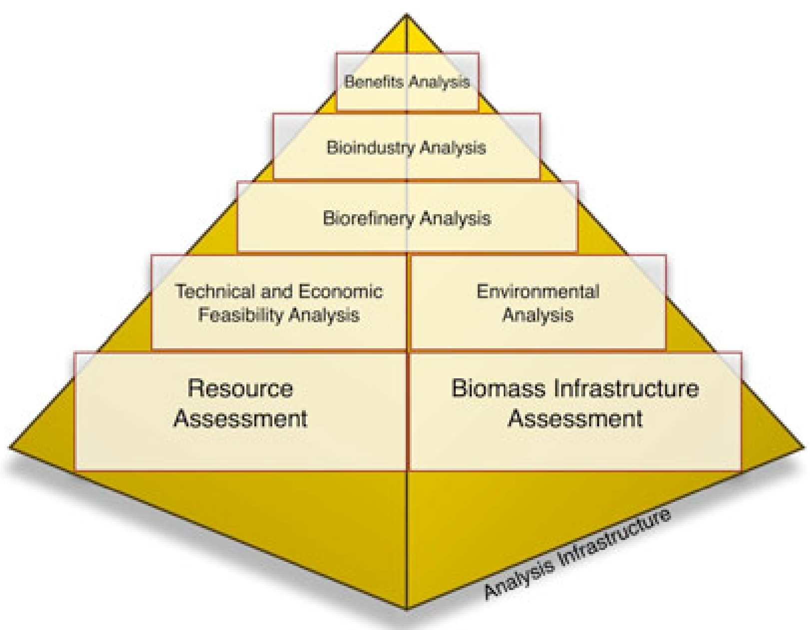


Figure 7: The Analysis Pyramid

3.4.1 Analysis Infrastructure

Analysis infrastructure includes the resources (methods, tools, and analysts) to perform analysis for the Program. Maintaining these capabilities at the cutting edge is essential to ensure that the analysis provides the most efficient and complete answers to the technology developers and the Program. Analysis methods for biomass processes are as new as the processes themselves. Although some methods and tools from other industries (especially the process industries such as petroleum refining and petrochemical processing) can be used with modification, others, such as biomass physical property estimation methods, must be developed.

Coordination, development of new methods, and communication are the three pieces used to build the analysis infrastructure for biomass. Within the biomass scientific community, there is analysis at several levels with different methods. Developing partnerships in this community is key to ensuring the results are transparent, transferable, and comparable. Building an analysis infrastructure for biomass R&D improves the analysis value and efficiency, while eliminating redundancy and gaps. Efforts by the NBC to combine the former biopower and biofuels analysis capabilities and methodologies and align with the evolving HFCIT Program analysis group are complete. The next step is to develop similar alignment between the national laboratories in the NBC and the rest of the organizations performing R&D in support of OBP.

Multi-lab coordination plans include holding annual analysts roundtable meetings, standardizing methods, and developing Web-accessible tools, methods, data, and documents. Near- and mid-term new methods and tools development plans include training in the use of risk analysis for scientific processes, developing methods to track progress on all OBP projects, and continued pioneer plant analysis to understand first-of-a-kind risks in plant costs and performance for stakeholders. Efforts to improve communication of analysis results to DOE and stakeholders include improved understanding of EERE analysis methods, tools, and inputs; development of a MYAP; and creation of technology design reports that are crucial to specifying the technology baseline and technical targets on a program-wide basis.

3.4.2 Biomass Resource and Infrastructure Assessment

Resource assessment determines the quantity and location of biomass resources on state, county, and land type levels. Additionally, resource analysis quantifies the cost of the resources as a function of the amount available for utilization. An example of output from feedstock resource assessment is crop suitability by geographic region of the United States (Figure 8).

Biomass infrastructure assessment identifies the optimal methods for collection, transportation, and storage of biomass feedstocks, and much of this analysis takes place in the Feedstock Interface R&D Program area. Because a robust biomass infrastructure does not exist, it is crucial to evaluate the many options for getting biomass to the processing facility to determine which ones could be viable in different regions of the country. Developing a market basis for biomass is another part of the analysis because biomass can be valued in several different ways. Combining the results of the Feedstock Interface analysis with those of the conversion platforms (sugar and thermochemical) enables identification of synergies between the field and the processing facilities.

3.4.3 Technical and Economic Feasibility Analysis

Technical and economic feasibility analysis determines the potential economic viability of a process or technology and helps to identify which technologies have the greatest likelihood of economic success. The biomass scientific community is continually developing technologies that could substantially improve the production of biomass intermediates and products. Initial assessment of emerging technologies and new ideas that are not currently part of the Program portfolio but have potential to improve biomass utilization is performed to ensure biomass research stays at the cutting edge, reducing the time to commercialization and optimizing DOE investment. A stage 1 analysis is performed using available process and cost data and optimistic assumptions to create a best-case scenario. If the resulting scenario is feasible, sensitivity analyses are performed to determine the cost sensitivity to process parameters such as yield. With the analysis results, the Program can determine if the process should be added to the R&D portfolio.

Results from technology feasibility analysis provide input to decisions regarding portfolio development and technology validation plans. The economic competitiveness of a technology is assessed by evaluating its implementation costs for a given process compared with the costs of current technology. These analyses are useful in determining which projects have the highest potential for near-, mid-, and long-term success. Parameters studied include production volume benefits, economies of scale, process configuration, materials, and resource requirements. Tools used for technology feasibility analysis include process design and modeling (e.g., ASPEN Plus©), capital and operating cost determination, and cash flow analysis.

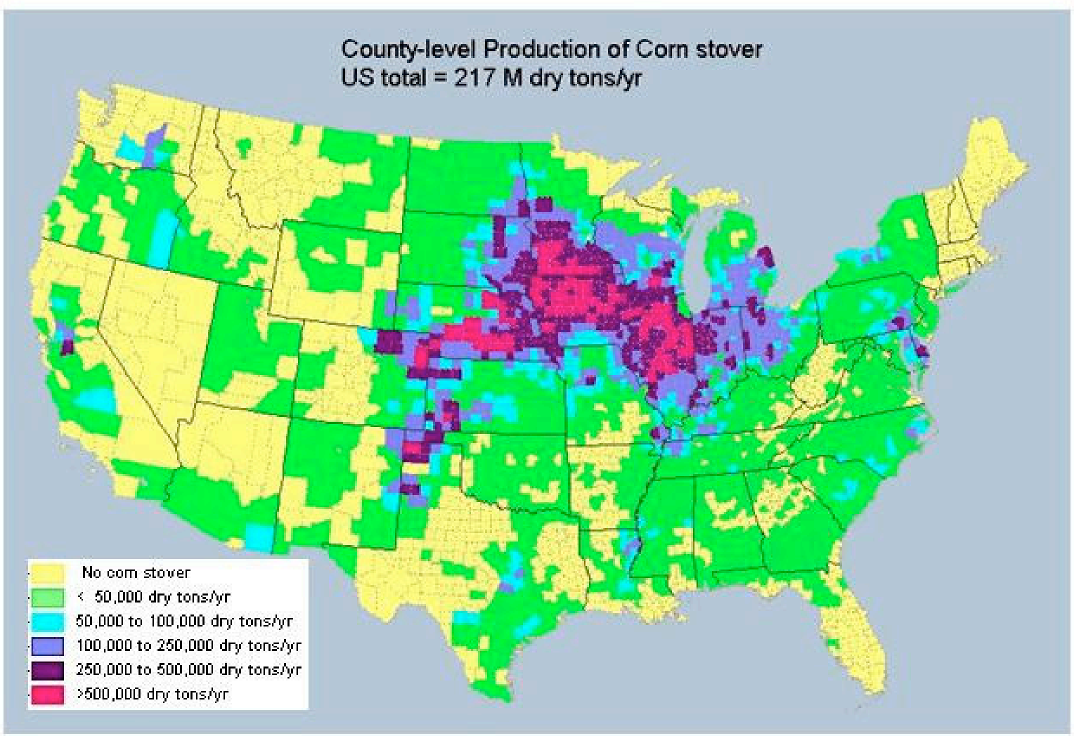


Figure 8: Corn Stover Production Map

3.4.4 Environmental Analysis

The Program uses environmental analysis to quantify the environmental impacts of biomass production and utilization technologies. Specifically, life cycle assessment is used to identify and evaluate the emissions, resource consumption, and energy use of all processes required to make the process of interest operate, including raw material extraction, transportation, processing, and final disposal of all products and by-products. Also known as cradle-to-grave or well-to-wheels analysis, the methodology is used to better understand the full impacts of existing and developing technologies, such that efforts can be focused on mitigating negative effects. Several detailed life cycle assessments have been carried out, documented, and peer reviewed on biomass to power and biomass to ethanol. Additional life cycle assessments will be carried out as needed to identify the important energy and environmental characteristics of new biomass-based processes.

3.4.5 Integrated Biorefinery Analysis

Integrated biorefinery analysis combines the technology assessments to determine the optimal mix of technologies to produce a slate of products. Using a linear program type model, technology developers can study the possible options before investing in development or deployment activities. This "single biorefinery" optimization feeds directly into a "whole bioindustry" optimization in the market penetration analysis. With the integration of the former biopower and biofuels programs and the efforts to identify candidate products from biomass, the information is now in one place to develop emerging and advanced biorefinery process designs for plants producing a combination of power, fuels, and chemicals. The Biomass Program is currently working with existing biorefineries (dry mills, wet mills, pulp and paper mills, and forest products facilities). A stage 1 analysis using products with relative values based on a primary product (e.g., ethanol) will be performed first to understand the sensitivity of market value and size on the product slate. Then, four to five emerging biorefinery process designs with integrated heat and power utilization will be developed, using the information from all platforms and the Feedstock Interface area. Mass and energy balances will be developed along with capital and operating cost estimates using a stage 2 analysis. Modules for syngas production and utilization will be added to BioRefine, a spreadsheet-based linear program that currently contains sugar production modules. When new production technology designs (such as pyrolysis oil production) are completed in the platform analysis projects, they will be added to the biorefinery process design work and to BioRefine. Up to four model products will be selected to complete the process design from the products platform Top Ten analysis. The purpose of this selection is not to pick winners but to find model products that will allow a complete analysis of the biorefinery process designs. From this process design, modeling, and product optimization work, one to two possible pathways to a competitive biorefinery will be identified, which can become the basis for designs in industry-led projects with the partner's selection of products. The models developed as part of this effort will be critical to evaluating options and opportunities relative to the Program technology baseline characterizations.

3.4.6 Bioindustry Analysis

Bioindustry analysis determines market penetration for biorefinery products from multiple biorefineries. Scenario analyses, in the context of market analysis, are used to answer several questions:

- What are the feasible options for developing a future in which biomass plays a role?
- Which technologies are most likely to be a part of the biobased future, and what are the interactions between these technologies and other, established technologies?
- What market penetration pathways are likely?

• What are the scenarios for biomass use in energy, transportation, and chemical markets?

3.4.7 Benefits Analysis

Benefits analysis helps the Program quantify and communicate the overarching outcomes from biomass research, development, and deployment—such as imported oil displacement, miles driven on domestic fuels, and greenhouse gas mitigation—using EERE-wide models such as NEMS and MARKAL. The scenarios that are developed and the costs and benefits that are quantified are used to develop a broad understanding of the most viable routes for achieving biomass utilization. Results are useful in crosscutting benefits analysis and are used in decision making across all renewable technologies in the EERE portfolio. Additionally, all the analysis capabilities described in the analysis pyramid will be synthesized into energy market analysis models to develop a broad capability for analyzing the development of possible biomass utilization pathways. This is especially important in the area of environmental analysis, in which renewable technologies are not well characterized. Also important in renewables benefits is a longer horizon analysis model. This work is performed by EERE/PBFA and provides the intermediate and end outcomes for the EERE logic model (Figure 9). Specific examples of the intermediate and end outcomes are shown in Figure 10.

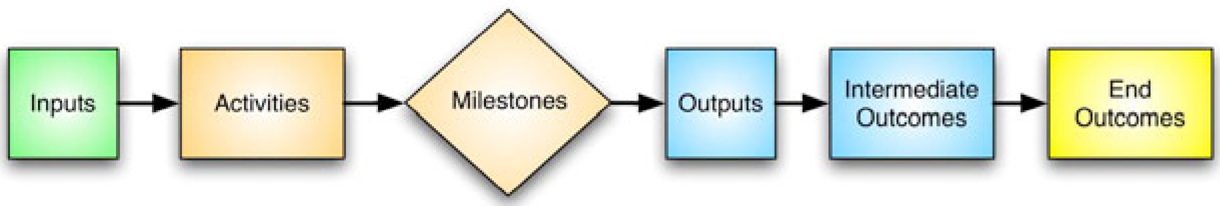


Figure 9: EERE Program Planning Logic Diagram

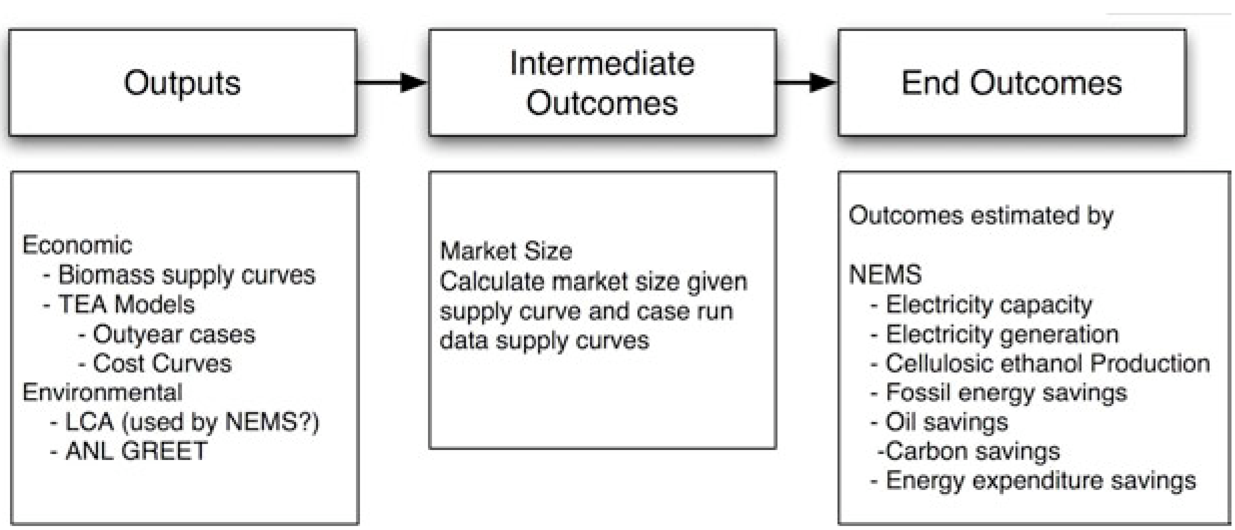


Figure 10: Sample Outputs from EERE Logic Model Steps

3.5 Outreach, Education, and Partnerships

This portion of the program management portfolio includes crosscutting activities in outreach, education, and partnership development. Partnership activities are broad, with the goal of increasing collaboration with regional, state, and local governments and organizations and encouraging the participation of small businesses in biomass-related research through federal programs such as the Small Business Innovative Research Program.

OBP has a rich tradition of building partnerships to conduct joint research; commercialize technologies and processes; educate consumers and governmental agencies on the use of biomass-based fuels, chemical, and products; and provide timely information and technology transfer assistance to potential users of biomass-based systems. These roles are expanding as interest grows in key audiences in biomass feedstocks, biomass conversion systems, and biobased products.

3.5.1 Outreach

The two major crosscutting outreach projects are Communications and the Buy-Bio Initiative.

3.5.1.1 Communications

To facilitate communication of Program results and other OBP activities, OBP annually develops a communications plan. This plan guides outreach efforts and ensures that communications are effective and consistent. People must become aware of new technology before they can use it. Education and outreach are especially important for biomass because biomass offers significant economic and societal benefits (e.g., energy security, ambient air quality, and reduced GHG emissions) that are not fully represented in its price. Increased use of biomass relies on recognition of the external benefits associated with bio-based options and legislation (financial incentives and compliance). Both of these critical drivers hinge on successful education and outreach. DOE/OBP identified a range of important audiences for communications efforts, each with its own needs for information, interests in biomass, and concerns. OBP identified 10 key audiences:

- Rural/farm community
- State, local, tribal, and regional organizations
- Business/financial community
- International community
- DOE senior management
- USDA and other federal entities
- Industry
- Technology developers/users
- Academia
- Consumers

OBP reaches out to these stakeholders by providing an array of communication products such as publications, a Web site, workshops, conferences, and educational material. All these products are designed to engage industry in developing biomass technologies and practices, stimulate manufacturer interest in applying those technologies and practices, and encourage consumers to purchase biobased products.

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 OBP.

OBP communicates technology development and other information to industry or customers through various outreach activities, including the Web (www.bioproducts-bioenergy.gov). OBP's Web site provides information on new technologies, solicitations, publications, and legislative activities. It links with key USDA sites and other government and private sector activities, provides information on DOE-sponsored biomass activities, and characterizes the contribution of biomass to the economy.

3.5.1.2 Buy-Bio Initiative

The Buy-Bio Initiative was created in 2002 by DOE and USDA to encourage federal procurement of biobased products, which includes ink, paint, construction materials, chemicals, lubricants, and plastics that are produced using domestic biomass feedstocks.

In the period FY04–FY07, the DOE Buy-Bio team and their counterparts at USDA will continue to work towards accelerating preferential purchases of biobased products in federal agencies through interagency work group coordination, performance monitoring, and recognition. One of Buy-Bio's key priorities is to train procurement personnel, government credit card holders, and personnel involved with affirmative procurement to plan for biobased product purchases.

Iowa State University, under a cooperative agreement with the USDA Office of Energy Policy and New Uses, is developing the infrastructure to establish a biobased product testing program and to make available information on test results and other information. The efforts include a Web site that will be open to manufacturers/vendors to post information about biobased products that qualify for preferred procurement under the statute. This information will be available to federal agencies as they seek to identify qualifying biobased products to meet their procurement needs.

3.5.2 Education

In the "Roadmap for Biomass Technologies in the United States," the Biomass R&D Advisory Committee highlighted the need to develop science-based education and outreach programs for K-12 as well as college and university levels. The first three projects described below are designed to help meet these needs. The fourth project, the Biomass Rapid Analysis Network, is a response to requests from industry and university partners to develop rapid biomass chemical analysis methods along with a training program to educate researchers on their use.

3.5.2.1 University Curriculum Development

Providing a well-educated, well-trained workforce is critical for the commercial development of biomass technologies. This need is recognized in the OBP MYPP and the Roadmap for Bioenergy and Biobased Products. The goal of this education initiative is to provide a well-educated, well-trained workforce for the emerging biotechnology industry and for expansion of the current biomass processing and biofuels industries.

OBP has worked with eight universities to provide students with knowledge and experience in biomass processing and conversion technology. This work involved engineers and scientists at the undergraduate and graduate levels. New courses have been developed, and the focus of many others has been broadened to include biomass-related content. One project resulted in creation of an entirely new graduate degree in "Biorenewable Resources and Technology." All these projects were selected through competitive solicitations and will last 3 years.

3.5.2.2 Education Initiative—Mobile Learning Lab

In FY03, DOE/OBP launched an innovative program to take biomass feedstocks, conversion technologies, and processes to schools and universities through a mobile learning lab. This program will also seek to learn from the outreach programs of other federal and state agencies and biomass stakeholders that are targeted toward high school and university audiences.

The initial years of this initiative will involve primarily background preparation and planning of the education initiatives in two focus areas: challenge competition and awards and trailer-based hands-on demonstrations. The purpose of this preparative work is to identify the best ongoing education activities in the federal government and different biomass stakeholder groups and in turn allow OBP to coordinate and leverage the best opportunities to build a sound program. OBP will set the stage for a Biomass to Energy "challenge" competition, modeled on the best aspects of the Solar Decathlon and JETS program for high school students. Several trailer-based demonstrations will be put together, in which viewers can clearly see the steps involved in converting biomass to commercial/household-stage biobased products, fuels, and energy. The objectives of these educational activities are to contribute to the best understanding of how biomass-derived products, fuels, and energy have a positive impact on everyday life and to have the flexibility to reach the populations/audiences most relevant to meeting OBP's goals.

3.5.2.3 Biomass Research Initiative for Student Advancement

The Biomass Research Initiative for Student Advancement (BRISA) Program is a DOE/OBP activity dedicated to providing Hispanic students and academic professionals research opportunities in the Biomass arena. BRISA was established to increase Hispanic student involvement and an eventual career path in the sciences and engineering. The program has been active since 1996 and has sponsored over 20 participants from the University of Puerto Rico and Colorado State University.

3.5.2.4 Biomass Rapid Analysis Network

The Biomass Rapid Analysis Network (BRAN) was created in response to the request of industrial partners for biomass analysis methods that provide accurate, inexpensive biomass analysis at a speed relevant for process control. BRAN is being developed as a network of industrial partners that join together to share the cost of calibration and validation of the many biomass analysis tools and methods needed by the emerging biomass conversion industry. OBP will cost-share the organization and start-up of BRAN.

The BRAN approach is to develop new tools and analytical methods that can be used to monitor the composition of biomass feedstocks and biomass-derived materials throughout the conversion process. A trained workforce is needed to conduct R&D, and standardized methodologies must be developed so that commercial analytical laboratories can expand from the few currently capable of performing these analyses. BRAN will provide training materials and conduct training classes on the needed techniques and the QA/QC protocol established by the operation of the network.

3.5.3 Partnerships

One of the key characteristics of OBP's management strategy is to develop cooperative partnerships to leverage its investment. Many specific research projects described in this MYTP are partnerships with industry, universities, and other organizations placed through competitive solicitations. The projects listed below also have the goal of creating partnerships but generally on a broader and more crosscutting basis. The emphasis is on state and regional partnerships and cooperative research and development with small businesses.

3.5.3.1 State and Regional Partnerships

DOE/OBP and its predecessor offices have a long tradition of supporting regional biomass programs as well as cooperative research, development, and demonstration biomass projects with individual states. OBP's state and regional partnership efforts are primarily carried out through cooperation with the National Biomass State and Regional Partnership. The Partnership consists of 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 will provide leadership in its region with regard to policies and technical issues in order to advance the use of biomass.

The goals of the state and regional partnership activities include the following:

- Facilitate closer communication and encourage greater coordination among federal, regional, and state biomass and bioenergy activities
- Create awareness and support for bioenergy and biobased products and associated DOE programs at the highest levels of state government
- Strengthen and maintain regional partnerships with other federal agencies, the states, and stakeholders to help develop biomass as a potential and significant contribution to the nation's energy portfolio
- Provide an effective communication conduit for states and DOE to identify and address biomass issues of mutual interest
- Conduct activities supportive of OBP and state goals that provide associated metrics acceptable to EERE

3.5.3.2 Small Business Innovative Research Program

Federal agencies with extramural R&D budgets over $100 million are required to administer Small Business Innovative Research (SBIR) Programs, using an annual set-aside of 2.5%. The SBIR Program was created by the Small Business Innovation Development Act of 1982 (P.L. 97-219), reauthorized until September 30, 2000 by the Small Business Research and Development Enhancement Act (P.L. 102-564), and reauthorized again until September 30, 2008 by the Small Business Reauthorization Act of 2000 (P.L. 106-554).

The DOE SBIR Program's budget for FY03 is expected to be about $94 million, based on a set-aside of 2.5%. These funds are used to support an annual competition for Phase I awards of up to $100,000 each for about 9 months to explore the feasibility of innovative concepts. Phase II is the principal R&D effort, and the awards are up to $750,000 over 2 years. DOE funds about 200 Phase I projects and about 90 Phase II projects per year. In Phase III, it is intended that non-federal capital be used by the small business to pursue commercial applications of the R&D. Also under Phase III, federal agencies may award non-SBIR-funded follow-on grants or contracts for products or processes that meet the needs of those agencies, or for further R&D.

DOE's annual solicitation contains topics in technical areas such as basic energy sciences, biological and environmental research, high energy and nuclear physics, fusion energy sciences, advanced scientific and computational research, energy efficiency and renewable energy, nuclear energy, fossil energy, environmental management, and nonproliferation and national security. Each year about 45 topics are allocated among the technical areas in proportion to their contributions to the budget. DOE plans to select for award those grant applications of the highest overall merit within their technical subject area.

To aid awardees in seeking follow-on funding for Phase III, DOE has sponsored a Commercialization Assistance Project for the past 10 years, which has provided individual assistance in developing business plans and in preparation of presentations to potential investment sponsors

3.5.3.3 Small Business Technology Transfer Program

The Small Business Technology Transfer (STTR) Program was created by Title II of the Small Business Research and Development Enhancement Act of 1992 (P.L. 102-564), reauthorized until the year 2001 by the Small Business Reauthorization Act of 1997 (P.L. 105-135), and reauthorized again until September 30, 2009, by the Small Business Technology Transfer Program Reauthorization Act of 2001 (P.L. 107-50). Federal agencies with extramural R&D budgets over $1 billion are required to administer STTR Programs using an annual set-aside of 0.15%. The set-aside will increase to 0.3 percent in FY04. The DOE STTR Program's budget for FY03 is expected to be about $5 million, used to support annual competitions among small businesses for Phase I and Phase II awards. Phase I explores the feasibility of innovative concepts with awards up to $100,000 each for about 9 months. Phase II is the principal research or R&D effort, and awards are up to $500,000 over a 2 years. This amount will increase to $750,000 in FY04. There is also a Phase III, in which non-federal capital can be used by the small business to pursue commercial applications of the R&D.

The STTR Program is similar to the SBIR Program in that both seek to increase the participation of small businesses in federal R&D and to increase private-sector commercialization of technology developed through federal R&D. The unique feature of the STTR Program is that, for Phase I and Phase II projects, at least 40% of the work must be performed by the small business, and at least 30% of the work must be performed by a non-profit research institution. Such institutions include federally funded R&D centers (e.g., DOE national laboratories), universities, non-profit hospitals, and other non-profits. DOE issues annual SBIR and STTR Program solicitations. They are combined in one document, but different rules apply to each program.

3.5.3.4 State Technologies Advancement Collaborative Program

DOE, the National Association of State Energy Officials, and the Association of State Energy Research and Technology Transfer Institutions signed an agreement on November 14, 2002 that allows states, territories, and the federal government to better collaborate on energy research, development, demonstration, and deployment projects. The agreement established a 5-year pilot State Technologies Advanced Collaborative (STAC) Program that allows the states and DOE to move energy research, development, demonstration, and deployment forward using an innovative project selection and funding process. In addition, a STAC Operation Agreement was developed by the STAC Executive Committee to aid them in implementing this pilot project.

The STAC Program will promote research and deployment in innovative ways to produce, transmit, and distribute energy and use it more efficiently. The pact will make it easier for collaborative members to share information on research and to prevent wasteful duplication of efforts. By jointly funding selected projects, the collaborative will be able to leverage funds and to simplify the path for promising technologies to enter the market.

3.5.3.5 State Energy Program

DOE's State Energy Program provides funding to states for the maintenance of State Energy Offices and undertaking energy efficiency and renewable energy programs. The SEP administers different types of grants that have different sources of funding including “Special Projects” funding from the EERE programs including OBP. Each year DOE carries out a competitive SEP Special Projects solicitation. States submit proposals in response to the solicitation that identify how specific technologies could be implemented in their region of the country. DOE then selects the projects that best meet national energy goals. Often, cost-sharing is a requirement. OBP FY2003 funding of SEP Special Projects was $600,000. Recent biomass-related Special Projects cover a broad spectrum including landfill gas and anaerobic digestion demonstrations, curriculum development, incentives for biobased products and fuels, green tag programs for electricity from forest biomass, and biomass power demonstrations.

3.5.3.6 Resource Allocation Plan

Table 2 provides a high level summary of the the proposed costs for management, crosscutting analysis, and outreach, education and partnership activities. DOE Program Management and Integration costs (WBS 6.1.1) are covered by EERE Program Direction funds and therefor are not included in the table.

Table 17: Resource Allocation Plan for Program Management Area

WBS	Title	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
6	Program Management	11500	10780	9400	9600	9600
6.1	Program Management and Integration	5300	4900	4900	5100	5100
6.1.1	DOE Program Management and Integration	*	*	*	*	*
6.1.1.1	OBP Support Contracts	300	300	300	300	300
6.1.1.2	GFO Support Contracts	200	200	200	200	200
6.1.1.3	NETL Support Contracts	200	200	200	200	200
6.1.2	NBC Program Management	3100	3200	3200	3300	3300
6.1.3	Program Integration	1500	1000	1000	1100	1100
6.2	Analysis	2250	2250	2250	2250	2250
6.2.1	PBFA Analysis (Tax)	750	750	750	750	750
6.2.2	OBP Crosscutting Analysis	1500	1500	1500	1500	1500
6.3	Outreach, Education, and Partnerships	3950	3630	2259	2250	2250
6.3.1	Outreach	1400	1400	1400	1400	1400
6.3.1.1	Communication	500	500	500	500	500
6.3.1.2	Buy-Bio Initiative	150	150	150	150	150
6.3.1.3	EERE Communication (Tax)	750	750	750	750	750
6.3.2	Education	800	480	100	100	100
6.3.2.1	University Curriculum Development	400	80	0		
6.3.2.2	Education Initiative – Mobile Learning Lab	0				
6.3.2.3	BRISA	100	100	100	100	100
6.3.2.4	Biomass Rapid Analysis Network (BRAN)	300	300	0		
6.3.3	Partnerships	1750	1750	1750	1750	1750
6.3.3.1	State and Regional Partnerships					
6.3.3.2	SBIR	250	250	250	250	250
6.3.3.3	STTR	**	**	**	**	**
6.3.34	STAC	750	750	750	750	750
6.3.3.5	SEP	750	750	750	750	750

*DOE Program Management and Integration is included under EERE Program Direction Funds

**STTR funding included in SBIR