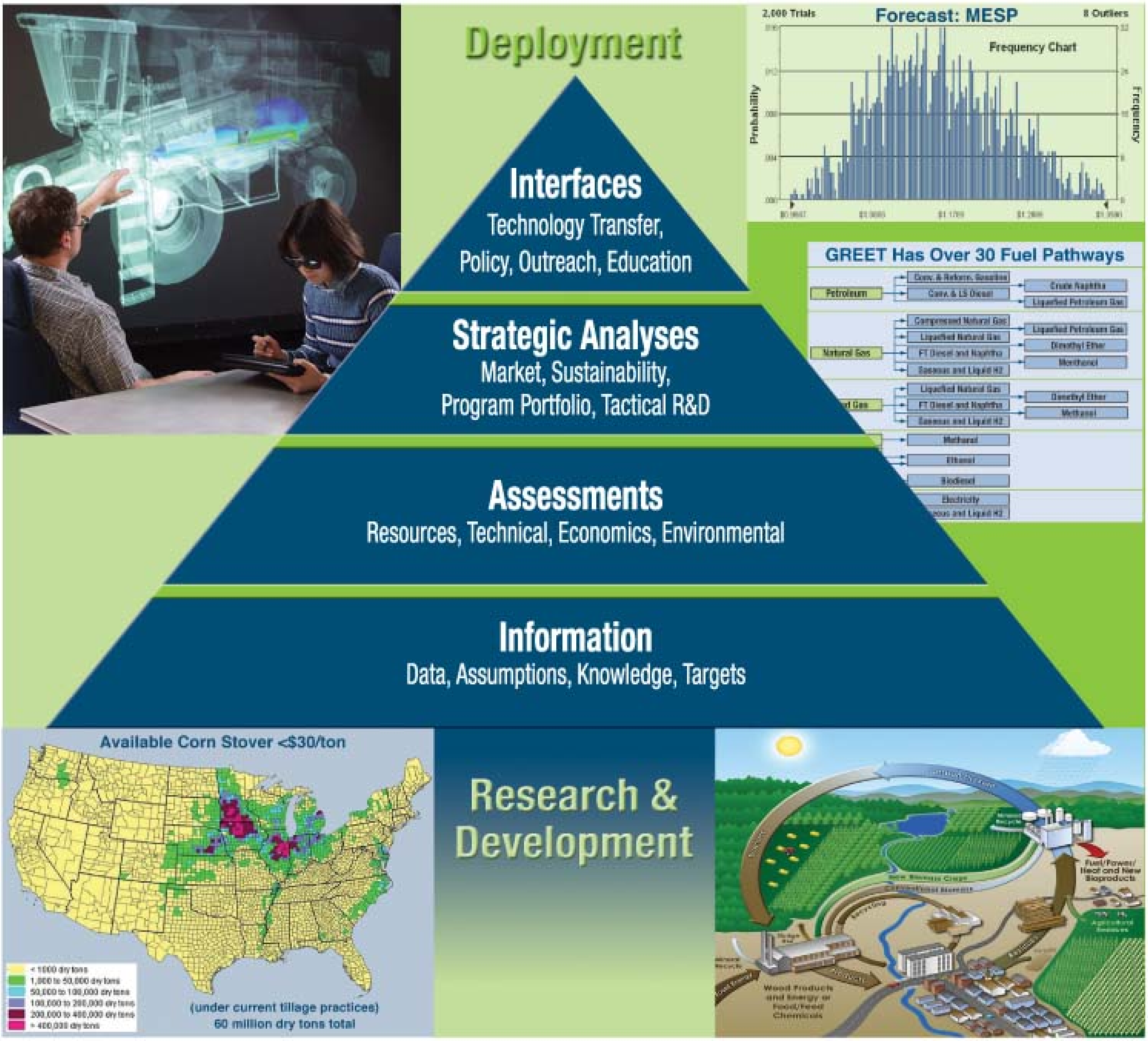
Office of the Biomass Program

Multi-Year Analysis Plan
FY04-FY08



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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: 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 developing 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 analysis plan (MYAP) is a companion to the multi-year technical plan, and documents the Biomass Program's planned engineering and analysis activities for the next 5 years to achieve the OBP's goals. This plan is the first analysis plan written for an EERE office. It defines analysis performed not only in the OBP, but also in EERE, it lays out the multi-year analysis effort needed in each of the program areas to achieve DOE's goals, and discusses the integration necessary to ensure a complete biomass utilization analysis.

Analysis plays three main roles in the program:

1. It shows progress toward the goals of DOE/EERE/OBP via benefits analysis.
2. It provides direction and guidance for program planning functions.
3. It provides engineering knowledge for biorefinery development.

Analysis that demonstrates progress toward goals is the first priority. It provides information for benefits analysis and budget formulation. Analysis that provides information for program planning and research and development (R&D) management is the second priority.

There are different types and levels of analysis. The Stage Gate methodology used by the program should determine both the type and rigor of analysis efforts. The types of analysis needed are:

- Resource evaluation tools to develop supply curves
- Mass/energy balance and costing tools to ensure feasible process designs for harvesting and processing
- Life cycle assessment tools to ensure sustainability of the entire cycle
- Market evaluation tools to assess biomass impact via products

The purpose of the MYAP is to provide an integrated picture of analysis in and for the Biomass Program. While the mulit-year technical plan (MYTP) contains analysis components, they are split among the R&D areas. Plans for the analysis work in each program area were taken from the MYTP and detail was added as needed by the key personnel doing the analysis. A benefit to creating a companion MYAP is that it begins to show where the plan is integrated across program areas and where gaps exist. This is valuable as the National Bioenergy Center begins to work for the biomass program in a much more integrated fashion. Another benefit is that a MYAP allows us to match analysis projects to specific goals, targets and roles. This provides program management with the opportunity to tune the analysis, reduce redundancy and ensure that all the analysis is working toward a goal, be it to support EERE benefits analysis for the Biomass Program, direct the R&D projects, or enabling biorefinery stakeholders.

Most of the engineering and analysis is done to support R&D projects and to direct and establish quantifiable targets. It was difficult to extract the analysis efforts from the R&D projects and show them clearly here; in most cases, it is safe to assume that every project has an aspect of analyzing, providing targets, showing progress to them, and providing information to support stage gate reviews.

The development of the MYAP is an on-going process, and will likely follow the MYTP review/revision process as it did its conception. It may become a component of the MTYP at some point to help address the difficulty of reporting analysis outside the context of R&D projects with which it is so tightly linked.

Timing the analysis products to be most useful to both the R&D projects and the program office is another area that will be improved with an analysis plan. Knowing, for example, that some analysis showing the progress of the program is needed for the budget process in the spring, recurring milestones have been added to the plan to provide updates of the state of technology in each area. A yearly analysis roundtable meeting, which has taken place informally since FY01, and regular web meetings ensure the analysis is coordinated and makes the most of integrating the results.

1 Role of Analysis in EERE

Figure 1 shows the hierarchy of the Program's goals, including goals for each section of the portfolio.

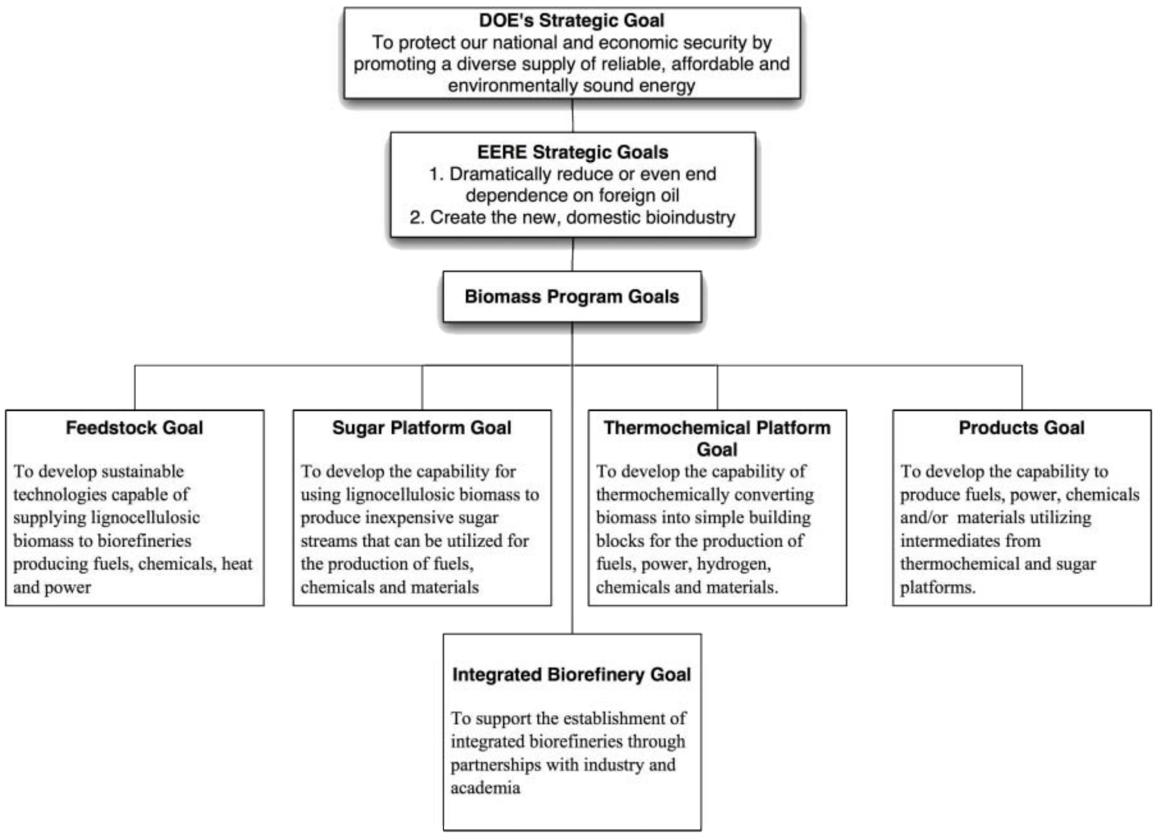

Figure 1: Biomass Program Goals

The U.S. Department of Energy's (DOE's) office of Energy Efficiency and Renewable Energy (EERE) has strategic goals of reducing foreign oil imports and creating a domestic bioindustry. To achieve those goals, EERE needs OBP to meet feedstock, sugar, thermochemical, and products goals; however, these goals are too qualitative to manage a research portfolio.

Analysis allows OBP to set targets that quantify the goals by using system models to predict the cost reductions from R&D advancements. OBP's targets include the following cost goals:

1. Reduce biomass harvesting and storage cost so that the delivered cost of wheat straw and corn stover will be reduced from $53 per dry ton in 2003 to $38 per dry ton biomass by 2015.
2. Reduce the estimated cost for production of a cleaned and reformed biomass-derived synthesis gas produced from a mature gasification plant, from $6.48 per million Btu ($6.14 per GJ) in 2003 to $5.28 per million Btu ($5.01 per GJ) by 2010. Both the current and target syngas cost assume $30 per dry ton wood feedstock cost.
3. Reduce the estimated cost for production of a mixed, dilute sugar stream suitable for fermentation to ethanol, from 15 cents per pound in 2003 to 10 cents per pound by 2010.

These targets are synonymous with output targets in EERE's program planning logic diagram, which EERE has followed for the last several years. The logic diagram for program planning provides guidance to link research expenditures to end outcomes (quantitative measurements of EERE's strategic goals) and is shown in Figure 2 and Table 1. It does not identify all the steps from inputs to outcomes; instead, it shows the key steps and reflects the measurement points required under the Government Performance and Results Act (GPRA). This information was originally presented in EERE's "Performance Planning Guidance (GPRA Data Call)" document[1].

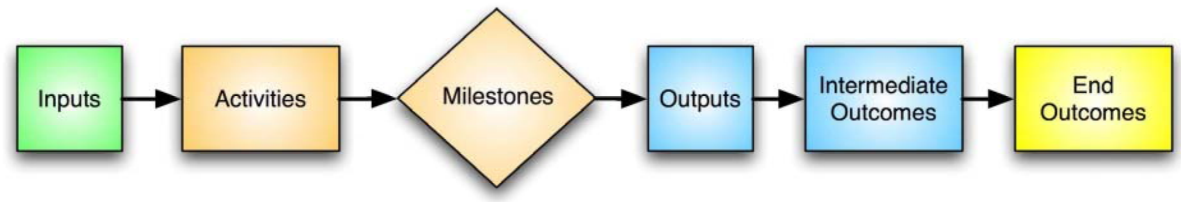

Figure 2: Logic Model used in EERE Program Planning Guidance

Table 1: Performance Information Fitted to the EERE Planning Model

Inputs	Milestones	Outputs	Intermediate Outcomes	End Outcomes
EERE expenditures (millions $) Other gov't expenditures (millions $) Private sector expenditures (millions $)	**Internal Milestones** Research advances (tbd) Initial prototypes (#) Refined prototypes (#) **External milestones** Commercial prototype (#)	**For each technology:** Year technology introduced into market Technology performance (tbd) Technology cost (tbd)	Market penetration (units or %) Net consumer investment (millions $)	**Security** Primary energy displaced (trillion Btu) Petroleum displaced (million barrels) Natural gas displaced (billion cubic feet) Electricity displaced (billion kWh) Coal displaced (million short tons) Other energy displaced (trillion Btu) Peak load reduction (megawatts) **Environment** Emission reductions (MMT carbon, NO_x, SO_x, PM, VOCs, CO) **Economy** Energy cost savings (millions $) Non-energy cost savings (millions $) Net economic benefit (millions $)

Inputs consist of money and resources put into research and are quantifiable in terms of money spent. Activities are the actual work and are not shown in Table 1 because they are not easily quantified. Milestones are the measured results from research either as research advances (e.g., yield improvements) or as prototype development or other commercialization targets.

Analysis translates information from research advance milestones to outputs, to intermediate outcomes, then to final outcomes and has historically been viewed prospectively (i.e., if one improvement is achieved the affect on others is analyzed). For example, if a milestone were a product yield, one of the corresponding outputs would be minimum product selling price, from which the market penetration could be calculated as an intermediate outcome, and finally the

[1] Performance Planning Guidance (GPRA Data Call) FY 2004-2008 Budget Cycle. Produced by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. Draft version. April 1, 2002. – According to PBA staff, the April 1, 2002 draft version is the most updated (i.e., the draft was not finalized and no later version was written).

amount of petroleum displaced could be calculated as a final outcome. The single measured data item is processed through models to estimate outcomes of national importance. Likewise, desired national outcomes can be used as starting points to calculate the necessary market changes, the minimum product selling prices (MPSPs) to affect those changes, and the research targets necessary to achieve the necessary MPSPs.

2 Role of Analysis in the Biomass Program

Analysis gives the Biomass Program context and justification for decisions at all levels by providing quantitative metrics. From the macroscopic benefits analysis that shows yearly progress toward DOE and EERE goals to the microscopic technical analysis that directs R&D projects on a daily basis, analysis quantifies goals, targets, and results and provides alternative directions. Analysis plays three main roles in the program:

1. It shows progress toward the goals of DOE/EERE/OBP via benefits analysis.
2. It provides direction and guidance for program planning functions.
3. It provides engineering knowledge for biorefinery development.

Analysis that contributes information in one or more of these areas is necessary for the program's success.

2.1 Shows Progress to the Goals of DOE/EERE/OBP via Benefits Analysis

Under DOE's outcome based management system, research projects are selected by their potential to improve society. The benefits or end outcomes of research need to be quantified so that different projects can be compared and the comparisons used in portfolio management and justification. Intermediate outcomes are the individual market effects of EERE research projects and are necessary to calculate end outcomes. To communicate the necessary outcome measurements, a framework was developed by EERE that shows the benefits of research. The work proposed by this plan follows that evaluation framework.

The framework focuses on the benefits (also referred to as end outcomes or outcomes) already achieved through the program's work as well as potential benefits of the work on the expected future scenario and a couple of potential future scenarios. Benefits are broken into the following four categories: economic, environmental, security, and knowledge.

The framework was originally developed during a National Academy of Sciences (NAS) review and published in the report titled "Energy Research at DOE: Was it Worth it? Energy Efficiency and Fossil Energy Research 1978 to 2000.[2]" A modified version of the framework was included in the GPRA data call (Performance Planning Guidance). The most recent version is shown in Table 2 with prioritized evaluation areas; columns represent timeframes for the analysis and rows represent criteria categories.

Table 2: Evaluation Framework with Prioritized Evaluation Areas
(H is high priority; M, medium priority; and L, low priority)

	Realized Retrospective	Expected Prospective	Option
Economic	L	H	M
Environmental	L	H	M
Security	L	H	M
Knowledge	L		

EERE's office of Planning, Budget and Analysis (PBA) is currently in the process of determining which end outcomes will be used for selection and reporting. Different technologies address

[2] National Research Council. "Energy Research at DOE Was it Worth it? Energy Efficiency and Fossil Research 1978 to 2000." National Academy Press, Washington, DC. (2001).

different issues, providing desired improvements as end outcomes. For example, some technologies improve power grid security by increasing the distribution of electricity production, while OBP projects can reduce the amount of imported oil used for transportation. Because differing technologies have differing needs, OBP needs to play a role in determining the outcomes reported.

PBA sees its role as comparing data (primarily outputs) from all EERE programs on the same basis and estimating end outcomes based on that data. Therefore, OBP is responsible for activities, milestones, and output estimates up to the bioindustry analysis and PBA is responsible for modeling necessary for final outcomes with bioindustry analysis and benefit modeling. The two groups overlap in the bioindustry (intermediate outcomes) analysis.

Intermediate outcomes are individual market effects of EERE research projects. For transportation fuels and commodity chemicals, they are market size and should be linked to price – the calculated output. End outcomes are then calculated using the market sizes.

Often the intermediate outcomes are transparent or reported with the end outcomes because they are calculated in the National Energy Modeling System (NEMS) or Market Allocation model (MARKAL). NEMS and MARKAL are based exclusively on least-cost calculations with minimal modeled regions; therefore, they miss other market drivers including "greenness" and regional issues. Due to those shortcomings, NEMS and MARKAL underestimate the market sizes of emerging and minority technologies. To overcome this issue, the market sizes for renewable technologies are estimated exogenously to NEMS and MARKAL and the results are hard coded into the macroeconomic models (e.g., using EERE's "GreenPower" market models for electricity generation and RYM and ELSAS for E10 blending into the liquid fuel market).

OBP needs to choose which products will be used to estimate the program's benefits. These products need to have a potentially high impact on the nations energy future. For example, within EERE the Vehicle Technologies and the Hydrogen and Fuel Cells Infrastructure Technology programs use transportation fueled by hydrogen, and the Solar Energy Technology and the Wind and Hydropower Technologies programs use power. Historically, the Biofuels program used cellulosic ethanol, the Biopower program used power, and the Office of Industrial Technologies used energy reductions (natural gas, coal, and others) by bioproducts.

OBP will then need to determine whether or not the currently used specialized biofuels market models provide adequate demand curves for the high-energy impact products chosen. The demand curves will be time specific; in other words, one demand curve will be used for 2010, another for 2015, and a third for 2020. PBA needs to be consulted during development of these curves to provide input.

Figure 3 shows an example of a hypothetical supply and demand curve for biomass-based ethanol at an unspecified time point – starch based ethanol is not included in this hypothetical curve. The solid line is the supply curve and shows how the supply might change as the market price changes. It is the sum of the feedstock supply curve (converted to gallons of ethanol with a given process yield) and conversion costs. The dashed line is the demand curve and shows how demand decreases with the market price. The intersection between the demand curve and the supply curve for a specific product at a specific time point will indicate the market size. In this case, the market size is approximately 6.5 MM gal and the market price is approximately $1.40/gal.

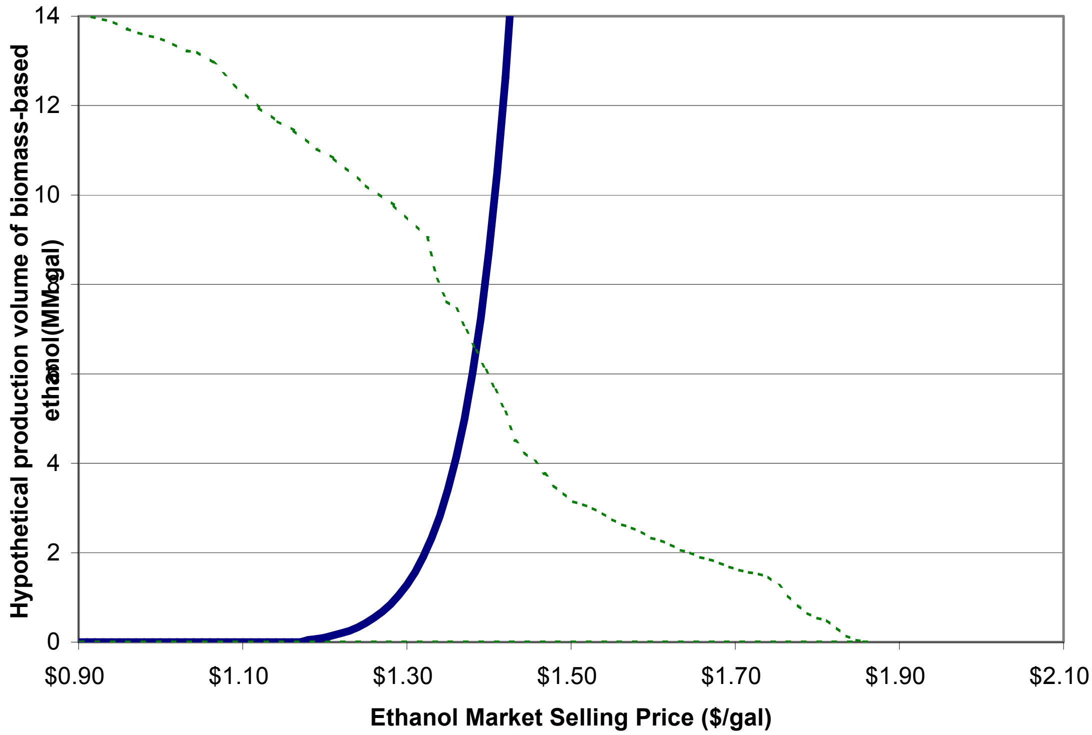

Figure 3: Hypothetical Supply and Demand Curves for Biomass-Based Ethanol

A set of tools to link demand and supply curves will need to be developed so that market sizes (intermediate outcomes) for each of the primary products can be estimated.

Value-added products will not be used directly in environmental and economic outcome estimations. Instead they will alter supply curves so that more of the high-impact model product can be produced with the value-added product than without it. To determine the value-added product's effect on the high-impact product's supply curve, a process like the following is necessary:

1. The value-added product is determined (or steps 2-3 can be estimated for a class or hypothetical value-added product).
2. The value-added product's affect on conversion costs of the high-impact product is estimated.
3. The volume of the high-impact product that the cost reduction is valid for is determined.
4. The supply curve for the high-impact product is adjusted.

The new supply curve will be matched to the demand curve and a larger volume of the high-impact product will be produced at the given time points. The larger volume will then be used to calculate final outcomes.

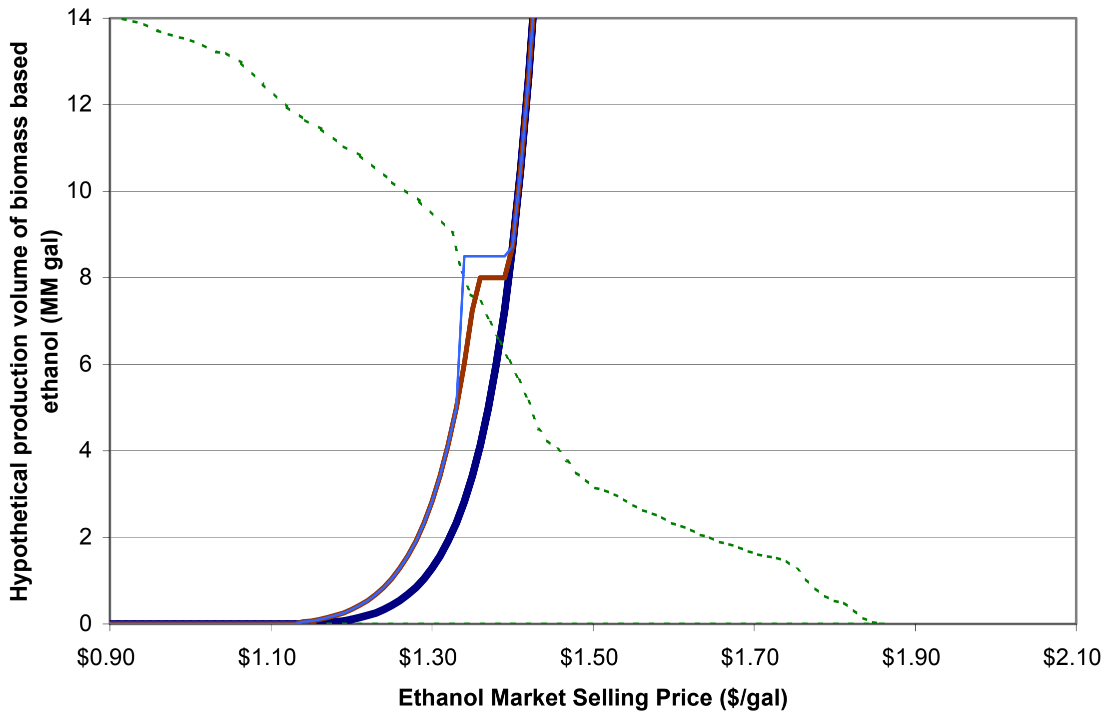

Figure 4: Hypothetical Supply and Demand Curves for Biomass-Based Ethanol with Value Added Products

A hypothetical example of the effects of value-added products is shown in Figure 4. As in Figure 3, the dashed and heavy solid lines are hypothetical demand and supply curves for the high-impact model product (biomass-based ethanol). In this figure, a hypothetical value-added product that can reduce the price of 8 million gallons of ethanol by $0.05/gal is shown by the left-shifted (lighter) supply curve. Likewise, the far left (lightest) supply curve shows another value-added product that can reduce the price of 500,000 gal of ethanol by an additional cent or so per gallon. In this case, the ethanol market size went from approximately 6.5 MM gal without the value added products to approximately 8 MM gal and the ethanol market price went from approximately $1.40/gal without the value added products to approximately $1.35 with the value-added products.

Bioindustry modules could potentially be put into NEMS and MARKAL to integrate value-added products into the calculation process; however, the size and complexity of those models make them difficult to converge with too many unconstrained variables. Adding bioindustry modules would open them up to additional variables and increase the difficulty of conversion while not necessarily improving the credibility of the results.

For intermediate outcome analysis, OBP could develop new market models with input and consultation from PBA. As stated above, large national economic models are incapable of estimating the small market variations that take place when a new technology is entering the market. In the past, small market variations have been determined exogenously and hard-coded into NEMS[3] and MARKAL[4]. That way they get included in outcome analysis. OBP understands the niche and entry markets better than PBA so it needs to determine whether the currently used curves provide the best estimate of demands. At some point, the markets are large enough to be properly captured in NEMS and MARKEL; that is where PBA should use the models to take over the market estimations and insert those tools into NEMS and MARKAL.

2.2 Provides Direction and Guidance for Program Planning Functions

Analysis provides direction and guidance to OBP for program planning by helping select and show progress on R&D projects. Engineering and analysis are used in all stages of the stage gate management process to determine the technical feasibility and competitive advantage of projects. Figure 5 shows the relationship between the program areas (and the area precursors before the creation of OBP). Each area has an analysis component, and a crosscutting analysis task links the core R&D platforms to each other in biorefinery design, new technology assessments and methods development.

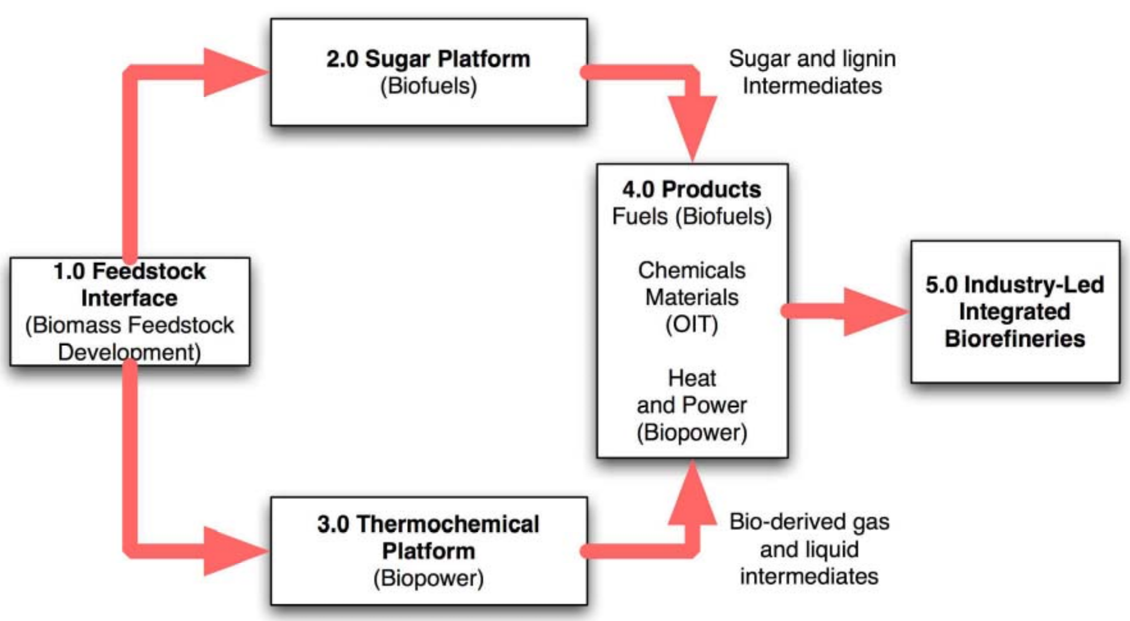

Figure 5: Workflow schematic for the Biomass Program

2.2.1 Helps Select R&D Projects

Engineering and analysis help determine a project's technical feasibility and competitive advantage – two of the six stage-gate criteria. The level of rigor necessary depends on the stage of project development. As the projects move along the development pathway, the technical and economic assessments become more robust and accurate as data are collected and utilized. A new idea first requires a "back of the envelope" estimate to determine that the return is greater than the expense in an ideal situation. For new (stage 1 or A) projects, the idea is translated into a process design that can be reviewed. Simply developing a process design often identifies showstoppers to be overcome before the idea can become commercially viable. In most cases, a new process

[3] Energy Information Administration, *The National Energy Modeling System: An Overview*, DOE/EIA-0581 (Washington, DC, May 1998).

[4] MARKet ALlocation system. International Resources Group. "Energy Planning and the Development of Carbon Mitigation Strategies: Using the MARKAL Family of Models" International Resources Group Report. February 2001.

design is a "best case" design, with optimistic yields; the rationale being that if the optimistic case is not economically viable, anything less cannot be economically viable either.

After developing the process design, the cost of the process option is estimated so that it can be compared to current technology (if it exists) and other research options. A more advanced project could require material and energy balance closures and capital cost quotes or even site-specific designs. For projects on the commercial track, the level of robustness appropriate for assessing each gate in the process has been defined in the stage gate manual[5] and can be found in Appendix B of this document.

Engineering analysis requires the proper techniques for the research project and platform. Those techniques could involve agronomic engineering practices for designing and estimating new harvesting equipment or they could involve chemical engineering material and energy balance development and process economic estimations for new conversion and purification technology.

2.2.2 Assessment of R&D Progress

Research barriers are the technology areas that require improvement to make the process commercially viable and where research funds should be focused. Process engineering and analysis helps identify the barriers and the targets to overcome them – the parameter values that make the process viable. These targets are the research program "off-ramps"; the point at which a certain barrier has been overcome and further research is not warranted.

To determine research barriers and targets for a model product, that product's output goal must be selected and a process model that results in that output goal must be developed. Determining the output goals for each platform's model product(s) is important in this area because the ultimate results are the outcomes and benefits discussed above and the outcomes and benefits are most affected by the model products.

The output goals need to be selected using intermediate outcome analysis. That process requires that one model market size for various fuel prices to develop demand curves and then look for the market-tipping output on the demand curve. A market-tipping output is the fuel price where the renewable fuel enters the market in a significant way and should be the programmatic target For example, if the target market size is 12 MM gal/yr and the demand curve in Figure 6 (above) were used, the output goal would be $1.12/gal.

Once the target output for the product has been selected, a conceptual process design to produce the product complete with capital and operating costs needs to be developed. The design should be based on equipment that is either available now or can be developed, and on process parameters from actual data or reasonable targets achievable with research. It also needs to interface with goals from other program areas (e.g., feedstock costs and physical conditions need to match the feedstock platform targets). A process model should be developed that includes mass balances, and energy balances once the research enters stage 3 or stage B in the stage gate program. The process model allows one to conduct sensitivity analysis on the process unit operations to understand which areas have the most cost sensitivity and where the barriers are. Yield and process parameters (e.g., temperatures and catalyst addition rates) will be used as research targets and so need to be estimated in conjunction with project management staff that are involved in multi-year planning for that project area.

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[5] NREL. "Stage Gate Management in the Biomass Program." April 2003.

Once the barriers and associated targets are identified, technical and economic feasibility assessments track the status of research, or the difference between the experimental data and the targets, using experimental data cases (also referred to as "State of Technology" cases) and target cases. Experimental data cases help to understand the status of technology development by linking experimentally measured data to target outputs that are reported by the program. Developing experimental data cases also improves the connection between experimental work and process models by verifying that experiments measure the necessary data for process design and by matching the terms used in process models to those used by people running experiments. They also assist in certifying that process designs and models use the most updated process understanding. Experimental data cases need to be developed and then updated as new information becomes available. These cases should use data from experiments that are as integrated as possible (e.g., product production should use actual platform intermediates, like prehydrolyzed biomass and syngas produced from biomass, instead of model intermediates, like pure sugars or bottled syngas).

Together, experimental data and target cases quantify the economic effects of improvements in barrier areas. For example, Figure 6 shows experimental data cases (labeled "FY00", "FY01", and "2002 Experimental Data"), a target case (labeled "Mature Technology (2020)"), and the economic effects of overcoming barriers for ethanol via bioconversion.

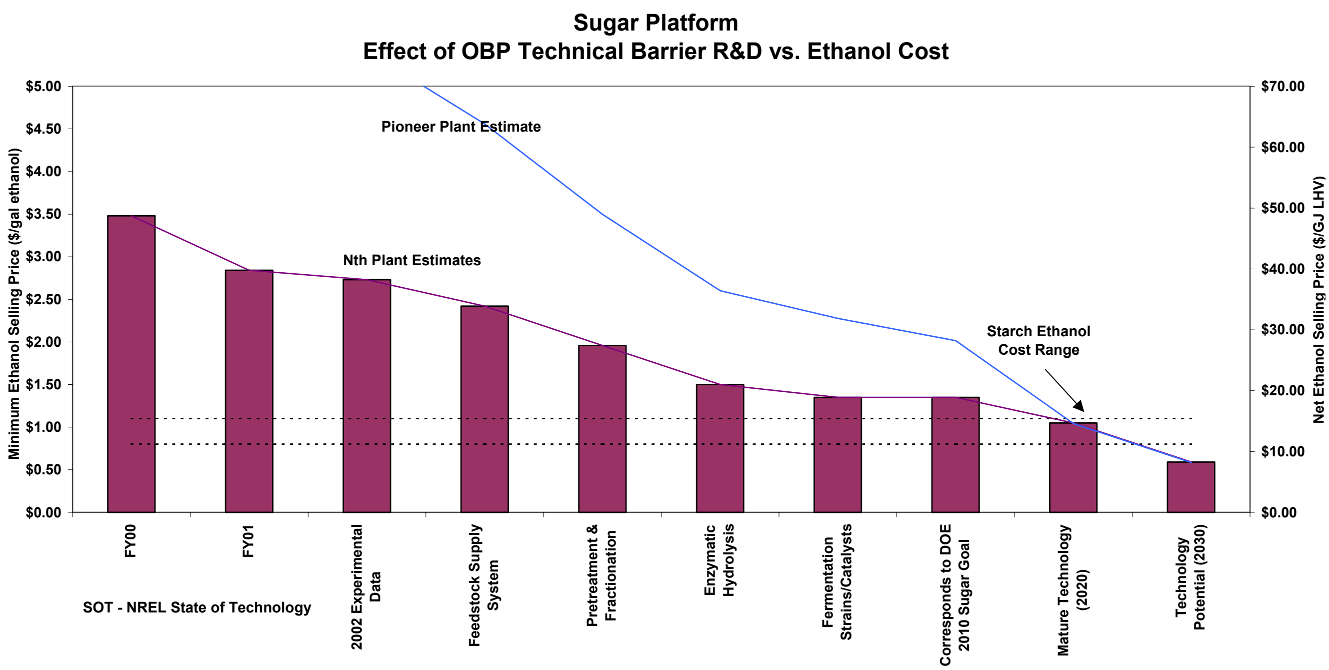

Figure 6: Barrier vs. Cost Curve for Ethanol from Fermentation

Because the State of Technology case is based on actual experimental data and the DOE 2010 goal is a target output, the difference in minimum ethanol selling price between the two can be broken into four technology barriers:

1. Feedstock Supply System,
2. Pretreatment and Fractionation,
3. Enzymatic Hydrolysis, and
4. Fermentation Strains/Catalysts.

The MYTP outlines the research plans for overcoming these barriers. “Barrier vs. cost curves” are proving useful in describing the barriers and targets for each program area, and are derived from the experimental and target cases.

Each area of the program is at a slightly different place in their development of these curves:

- Biomass Supply: The feedstock interface analysis team is leading the effort to analyze current and future supply-cost data for a variety of feedstocks.
- Biomass Infrastructure: The feedstock interface analysis team has developed a first-cut state of technology case for corn stover and wheat straw collection and from that supply system barriers and targets.
- Sugar Platform: The Biofuels program developed an experimental data case for ethanol in FY00 and it has been updated regularly.
- Thermochemical Platform: Experimental data cases will be developed for thermochemical processes in FY04, which will enable a more robust quantification of the barrier targets in the thermochemical platform.
- Products: The current plan is to quantify the barriers and targets for technologies that could enable the “Top Ten” study products, resulting in a single unit operation barrier vs. cost curve rather than a whole process curve. These unit operation barriers can then be integrated into a process curve. The “fermentation strains/catalysts” bar on Figure 6 is an example.

2.3 Provides Engineering Knowledge for Biorefinery Development

Figure 7 shows the biorefinery concept that represents a generic integration of all aspects of biomass conversion technology.

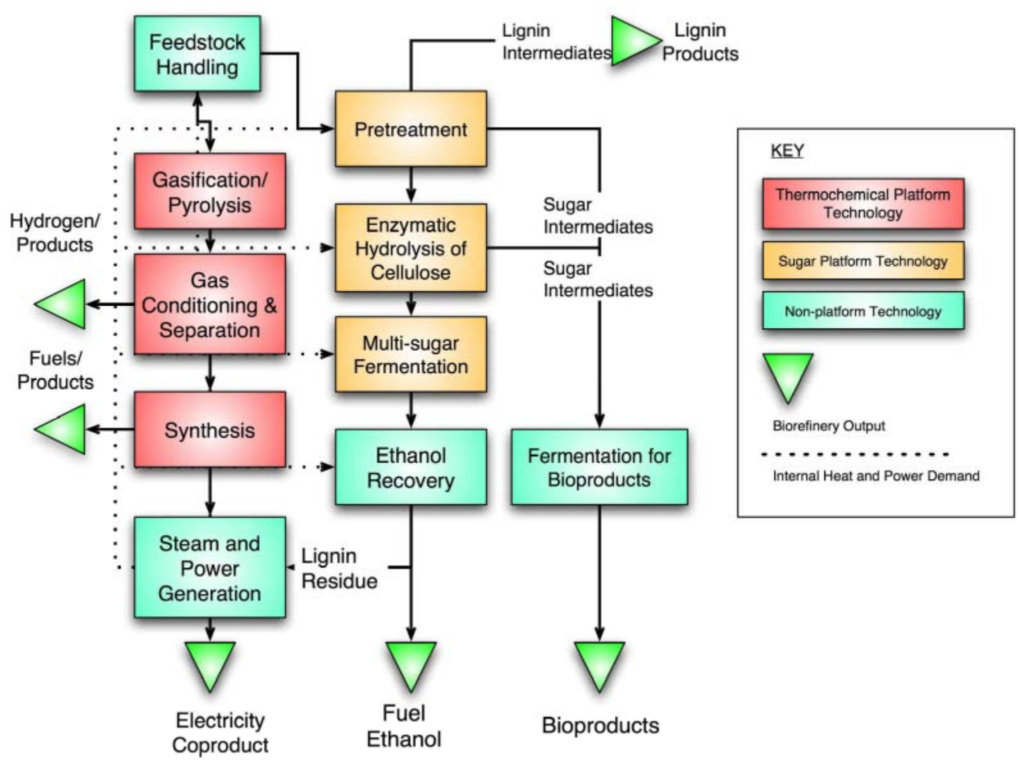

Figure 7: Schematic of an Integrated Biorefinery

Engineering knowledge is necessary to construct and operate a successful commercial bioindustry and to develop the feedstock infrastructure to support it. Engineering and analysis that provides information to parties interested in commercializing biomass is necessary to enable widespread investigation of biomass processing, and can play a role in reducing the financial risk associated with pioneer plants through better understanding of the process.

Some examples of engineering knowledge include improved material and energy balance information, kinetic models, and improved thermodynamic properties. Improved material and energy balance information involves developing better balances around unit operations like feedstock harvesters, conversion reactors and product separation equipment. Developing these balances provides information about how well or poorly measurements are made and improves confidence when using the measurements within process designs. Sometimes components that were considered to have minor impact are found to be important so their effect on the process is captured.

Kinetic models can be necessary to help procure financing for a commercial facility. Dr. Charles Wyman has stated that development of kinetic models and proof that the models are valid on several scales shows financiers that those unit operations are understood and increases confidence in the expected yields. That increased confidence is necessary for financing a capital-intensive facility like a biorefinery[6].

Improved thermodynamic properties are necessary to help design integrated processes. Unlike the crude oil industry, parameters for physical property models do not exist for many biomass components. Without good physical property estimates, unexpected separations could lead to inhibitor build-up in a recycle stream or another similar problem. Those issues may not appear in small-scale experiments or short integrated runs but could cause a commercial facility to fail.

Some tasks to develop engineering knowledge are identified in research areas and are kept separate from the analysis work (e.g., optimization of metallurgy in pretreatment, gas cleanup or black liquor equipment). Those projects are not included here because they are separated out in the work breakdown structure; however, results from those projects will be used to improve process designs.

In 1981, DOE contracted the Rand Corporation[7] to seek a better understanding of the reasons for inaccurate capital and operating cost estimates for first (pioneer) plants. The inaccurate estimates were made during the early stages of process development. The Rand Corporation broke down the problems that face pioneer plants into two categories: cost growth and plant performance. They found that cost was underestimated due to many factors: new technology, impurities within the process, complexity of the process, and inclusiveness of the process design and estimation. Rand Corporation showed that improved understanding of designs and design issues (engineering knowledge) improved estimates and reduced down time during initial operations.

The biorefinery can also benefit from lessons learned during the evolution of modern-day petroleum refineries, and knowledge gained in specific integrated biorefinery projects can be applied to other similar projects.

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[6] Wyman, Charles, E. “Research Directions to Support the Emergence of a New Biocommodity Industry.” Presentation at the 4th Annual Green Chemistry and Engineering Conference. Washington, DC. June 27-29, 2000.

[7] Rand Corporation. “Understanding Cost Growth and Plant Performance Shortfalls in Pioneer Process Plants.” 1981.

Uncertainty analysis is another way to better understand and reduce the risks associated with biomass commercialization. For example, knowing that the carbohydrate or carbon content of a feedstock varies can allow the processor to blend feedstocks or plan for a different product slate. This type of analysis uses stochastic modeling, which introduces random values within defined probability functions to predict the uncertainty of modeled systems. Monte Carlo is the best-known method; although others exist. Software packages exist that make the evaluations fairly straightforward depending on the complexity of the system. Uncertainty (also termed risk) analysis is most often used in the R&D sector for evaluating projects risk vs. return, although there are some examples of systems analysis.

The best method of disseminating engineering knowledge we have found to date is the publication of design reports. The results can be referenced in documents such as the program's multi-year technical plan[8] and can be used by the biomass community as a reference process design. The Biofuels Program published design reports for wood (1999)[9] and corn stover (2002)[10]. These reports established the credibility and transparency of the program's work and enabled integration across biomass research areas both in the program and in the biomass community at large.

Design reports should include the following elements (with the sources for all costs fully documented):

- A process description including yields and other process parameters and showing what has been achieved experimentally and what are targets in the process design
- Process flow diagrams with all equipment required (PFDs typically exclude instrumentation and control equipment)
- Stream ladders reporting stream conditions and flow rate from the process model
- Equipment and installation costs
- Total capital investment factors
- Variable and fixed operating costs
- Sensitivity analyses showing the effects of altering key process parameters such as yields

[8] NREL. "Office of the Biomass Program Multi-Year Technical Plan (draft)." November 2003.
[9] Wooley et al. "Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis Current and Futuristic Scenarios." 1999.
[10] Aden et al. "Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis For Corn Stover." 2002.

3 The Analysis Plan

Figure 8, taken from the MYTP, illustrates where analysis lies in the overall OBP structure. Platform level analysis integrates closely with the R&D projects, and the crosscutting effort under program analysis ties all of the platform analysis together in biorefinery design. The other component of program analysis is the PBA-led efforts at DOE. A new analysis task in the multi-year technical plan, Integrated Biorefinery Analysis, was proposed but not funded in FY04. The integration opportunities are greater now than ever with program wide planning established. The different laboratories that are performing analysis have increased communication opportunities thanks to the creation of the NBC and the integrated vision of the OBP.

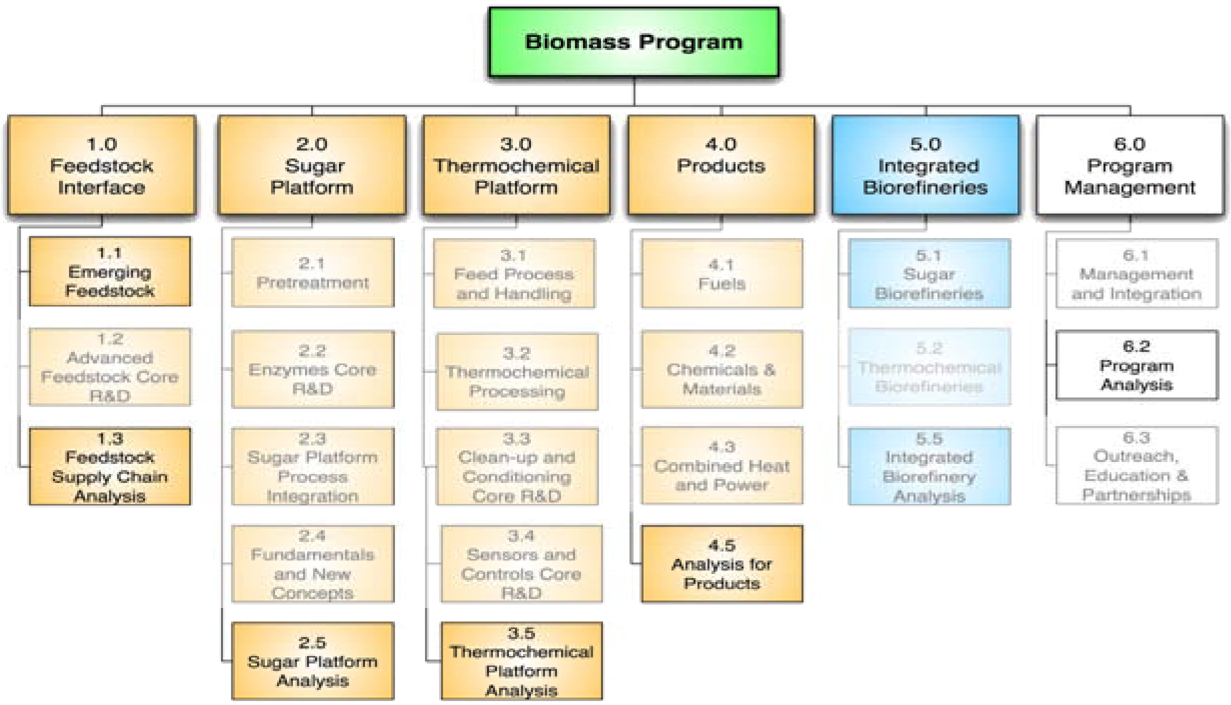

Figure 8. Work Breakdown Structure for OBP

The Gantt charts in Figures 9 through 14 show the schedules for major projects managed by the analysis teams in the NBC. In an effort to show an "analysis snapshot" the Gantt charts, milestones and resources for all the areas are shown together. Analysis in support of specific R&D projects and their milestones is discussed in this section; however, for the R&D project timing, refer to the MYTP Gantt charts. Ongoing analysis, such as updates to the state of technology and barrier cost curves, are annual events. The feedstock interface analysis plan is divided into supply forecasting and supply system logistics. The sugar platform core R&D analysis support efforts are modest; however, there is a significant amount of analysis work being performed by NREL engineers in the Bioenergy CRADAs (Broin, Dupont and Abengoa) in the Integrated Biorefineries area. The thermochemical analysis plan was well defined for 2004; based on the results of key projects in 2004, we'll be able to better define the plan for 2005-2008. Products analysis will become better defined as the products core R&D plan is developed.

Development of demand curves, necessary to estimate intermediate outcomes, is missing in the project descriptions. Historically, that work has been part of program analysis (see Section 6.6) but it is better suited as new projects within the two platforms – sugar and thermochemical.

Researchers in those areas have contacts and information that can help them solicit subcontracted assistance to develop those demand curves. The work will need to be well integrated with program analysis because the demand curve information or the specific intermediate outcomes will need to be included in the benefits analysis models.

ID	WBS	Task Name
1	**1.1.1.1/1.3**	**Biomass Feedstock Interface Analysis**
2	**1.3.1**	**Supply Forecast and Analysis**
3	1.3.1.1	Corn stover and wheat straw supply schedules
4	1.3.1.2	Billion ton vision paper
5	1.3.1.3	Forest residue and urban wood waste supply schedules
6	1.3.1.4	Perennial energy crop and agricultural crop residue supply forecasts
7	1.3.1.5	Agricultural residues supply forecasts with advanced technology assumptions
8	1.3.1.6	Transport cost functions
9	1.3.1.7	Supply forecast review
10	**1.1.1.1/1.3.2**	**Supply System Logistics**
11	.1	Develop feedstock assembly model
12	.2	Verify and publish feedstock assembly model
13	.3	Optimize feestock assembly model using multiple agricultrual residues
14	.4	Optimize feestock assembly system for a forest biorefinery system
15	.5	Optimize feestock preprocessing systems using fractional milling concepts
16	.6	Integrate feedstock assembly model with chemical process models (Aspen)

Figure 9. Feedstock Interface Analysis Activities (INEEL, ORNL)

ID	WBS	Task Name	
29	**2.5**	**NBC Sugar Platform Analysis**	
30	2.5.1	Publish corn stover LCA results	5/31/04
31	2.5.2	Update State of Technology case annually for budget preparation	
32	2.5.3	Rigorous Optimized Sugar Model	11/30/05
33	2.5.4	Sugar Platform Future Studies	

Figure 10. Sugar Platform Analysis Activities (NREL)

ID	WBS	Task Name	
34	**3.5**	**Thermochemical Platform Analysis**	
35	**3.5.1**	**Biomass feed systems**	
36	3.5.1.1	State of the Technology case completed	
37	3.5.1.2	Update State of Technology case annually for budget preparation	
38	3.5.1.3	Complete state of the art review of Biomass Feeder Systems	
39	3.5.2	Feedstock Program Coordination	
40	**3.5.3**	**NREL Analysis**	
41	**3.5.3.1**	**Gas Cleanup**	
42	3.5.3.1.1	Detailed Equipment Costs	
43	3.5.3.1.2	Incorporate into ASPEN & cost models	
44	3.5.3.1.3	Updates	
45	**3.5.3.2**	**Oxygen and fuel synthesis as a function of O2 purity**	
46	3.5.3.2.1	ASU Detailed Equipment Costs	
47	3.5.3.2.2	Incorporate into ASPEN and cost models	
48	3.5.3.2.3	Other/emerging technologies	
49	**3.5.3.3**	**Fuel Synthesis**	
50	3.5.3.3.1	Mixed alcohols	
51	3.5.3.3.2	Other fuels/future studies	
52	**3.5.3.4**	**Pyrolysis**	
53	3.5.3.4.1	State of the art	
54	3.5.3.4.2	ASPEN Modeling	
55	3.5.3.4.3	Complete ASPEN Model	3/31/04
56	3.5.3.4.4	Report on preliminary economic analysis of upgrading possibilities (NREL)	9/30/05
57	**3.5.3.5**	**Biomass to hydrogen design report**	
58	3.5.3.5.1	Biomass to hydrogen design and modeling completed	9/30/04
59	3.5.3.5.2	Biomass to hydrogen design report draft completed	12/31/04
60	3.5.3.5.3	Thermochemical Platform Future Studies	
61	3.5.3.5.4	Biorefinery residues characterization	

Figure 11. Thermochemical Platform Analysis Activities (NREL)

ID	WBS	Task Name	
62	**4.4**	**Analysis for Products Core R&D**	
63	**4.4.1**	**NBC Technical and Market Studies**	
64	4.4.1.1	High level analysis of impact of biobased products	4/30/04
65	4.4.1.2	Market analysis with Top 10 study	6/30/04
66	4.4.1.3	Prepare an interim report on an expanded pyrolysis oil upgrading concept to include new chemical products (PNNL)	6/30/05
67	4.4.1.4	Refine and validate models for products analysis	9/30/05
68	4.4.1.5	Integrate products analysis into biorefinery model	9/29/06

Figure 12. Products Analysis Activities (NREL, PNNL)

ID	WBS	Task Name	
71	**6.2.1**	**HQ/Field Managed Analysis**	
72	**6.2.1.1**	**Renewable Fuels Standard and Other Policy Analyses**	
73	6.2.1.1.1	Analysis of ethanol demand under updated scenarios	4/30/04
74	6.2.1.1.2	Analyze the first set of request for waiver from the RFS submitted by States with limited biomass resources or other constraints	9/30/05
75	5.2.1.1.3	Analyze additional State waiver requests of other issues as needed	9/29/06
76	6.2.1.1.4	Analyze additional State waiver requests of other issues as needed	9/28/07
77	6.2.1.1.5	Analyze additional State waiver requests of other issues as needed	9/30/08
78	6.2.1.1.6	Analyze proposed amendments to RFS (assumed enacted in a prior year)	9/30/09
79	**6.2.1.2**	**Biomass Market Studies**	
80	6.2.1.2.1	Udpated state ethanol incentive list	12/31/03
81	6.2.1.2.2	Draft paper on tax and market characteristics of fuel ethanol	9/30/04
82	6.2.1.2.3	Portfolio analysis - illustrative results	9/30/04
83	6.2.1.2.4	Complete analysis of the interaction of first generation sugar-based biorefineries with local electricity markets and regional gasoline/diesel markets. This will use OBP's assumed biorefinery characteristics	9/30/05
84	6.2.1.1.5	Begin assessment of international biofuels potential in view of the global transportation demand and its impact on fuels prices	9/29/06
85	6.2.1.1.6	Assess the interaction of biorefineries with regional chemical markets, using bio-based products Analysis II completed by OBP in 2006	9/28/07
86	6.2.1.2.7	Evaluate gas-to-liquids interaction with bio-based and other transportation fuels. Benchmark with USDA and other market studies	9/30/08
87	6.2.1.2.8	Evaluate hydrogen/biofuels market interactions using new thermochemical data and biomass supply data from the program and results from ANL's pathway analysis	9/30/09
88	6.2.1.2.8	Revisit E85 prospects using new feedstock supply data, fuel cost data, demand data and ethanol industry capacity	9/30/10
89	**6.2.1.3**	**Biomass Market Models**	
90	6.2.1.3.1	Biomass market model enhanced and used to support NEMS and MARKAL analyses	7/30/04
91	6.2.1.3.2	Complete documentation of ELSASBioref and EBSA (biomass benefits models)	2/28/05
92	6.2.1.3.3	Add data for carbon policy scenario	7/29/05
93	6.2.1.3.4	Integrated Biomass Market Model - version 1 documentation	9/30/05
94	6.2.1.3.5	Add POLYSYS agricultural impacts for scenarios of 0.5, 0.75 and 1 billion dry tons of biomass/year to Integrated Biomass Model	9/29/06
95	6.2.1.3.6	Add relevant information from the Role of Biomass study	9/29/06
96	6.2.1.3.7	Update Integrated Biomass Model based on OBP's biorefinery analysis and USDA resource analysis completted in FY06. Add thermochemical performance and cost data provided by the program	9/28/07
97	6.2.1.3.8	Conduct RYM enhancement of petroleum refining modules. Add economic effects from input-output model as resonse function to Integrated Biomass Model	9/30/08
98	6.2.1.3.9	Update 2001 study of fuels distribution infrastructure and costs for scenarios of 0.5, 0.75 and 1 billion dry tons of biomass/year	9/30/08
99	6.2.1.3.10	Incorporate new thermochemical data from OBP and new fuels distribution costs into Integrated Biomass Model. Add risk considerations. Update regional supply/demand and fuels distribution flows of IBM	9/30/09
100	6.2.1.3.11	Update POLYSYS and other biomass models	9/30/09
101	6.2.1.3.12	Update IBM with new energy crop and harvesting/storage cost data from USDA and OBP	9/30/10
102	**6.2.1.4**	**Biomass Benefits Analysis**	
103	6.2.1.4.1	Ethanol potential/market paper	4/30/04
104	6.2.1.4.2	NEMS and MARKAL results for FY06 budget	9/30/04
105	6.2.1.4.3	Retrospective analytic tool prototype	9/30/04
106	6.2.1.4.4	Estimate employment and other economic effects of biorefineries	9/30/05
107	6.2.1.4.5	Produce carbon policy scenario results	9/30/05
108	6.2.1.4.6	Work with Biomass Systems Integrator to update cost and market information in biomass baseline	9/29/06
109	6.2.1.4.7	Conduct new GPRA analysis for reference case and additional policy cases	9/29/06
110	6.2.1.4.8	Conduct new GPRA analysis for reference case using new OBP energy crops information	9/28/07
111	6.2.1.4.9	Conduct new GPRA analysis for reference case using new OBP residue information	9/30/08
112	6.2.1.4.10	Conduct new GPRA analysis for reference case and additional policy cases using revised refinery blending results and biorefinery assumptions	9/30/09
113	6.2.1.4.11	Update cost and market information in biomass baseline and incorporate results of the advanced biorefinery analysis completed by OBP in 5/2008	9/30/09
114	6.2.1.4.12	Conduct new GPRA analysis for reference case and additional policy cases	9/30/10
115	**6.2.1.5**	**Analysis: Biomass and Hydrogen Pathways**	
116	6.2.1.5.1	Draft mobility chain results for Role of Biomass study	5/31/04
117	6.2.1.5.2	Analyze 3 biomass pathways to support the Role of Biomass study	9/30/05
118	6.2.1.5.3	Analyze 2-3 hydrogen pathways specified in the Role of Biomass study and other EERE activities	9/30/05
119	6.2.1.5.4	Analyze additional fuels/vehicle pathways as requested	9/29/06
120	6.2.1.5.5	Update prior pathway analyses to reflect new data from Fossil Energy Office and EERE programs	9/28/07
121	6.2.1.5.6	Analyze bio-based product pathways for top OBP chemical	9/28/07
122	6.2.1.5.7	Conduct joint analysis with industry and/or USDA similar to the 2001 GM/ANL/Exxon/Mobil/BP/Shell study	9/30/08
123	6.2.1.5.8	Complete joint analysis with industry and/or USDA	9/30/09
124	6.2.1.5.9	Update hydrogen pathway analysis	
125	**6.2.1.6**	**Life Cycle Analysis Model (GREET)**	
126	6.2.1.6.1	Update of GREET biomass and hydrogen data	8/31/04
127	6.2.1.6.2	Incorporate new data provided by Role of Biomass study team	9/30/05
128	6.2.1.6.3	Incorporate energy for farm machinery production (for ethanol analysis)	9/30/05
129	6.2.1.6.4	Incorporate corn stover and ORNL/Andress's soil carbon analysis	9/29/06
130	6.2.1.6.5	Publish article on revised corn ethanol and cellulosic ethanol analysis	9/29/06
131	6.2.1.6.6	Add new technology data from Fossil Energy Office and EERE programs	9/28/07
132	6.2.1.6.7	Add new bio-based product data as OBP makes these available	9/30/08
133	6.2.1.6.8	Update thermochemical technology data as OBP makes these available	9/30/09
134	6.2.1.6.9	Add new bio-based product data as OBP makes these available	9/30/10
135	**6.2.1.7**	**Economic Impacts from Biomass Demand Under Future Growth Scenarios**	
136	6.2.1.7.1	Biomass demand scenarios analytic summary paper	3/30/05
137	6.2.1.7.2	Coordinate with OBP analysts in updating selected supply curves for biomass. Circulate Bioenergy and bio-based products draft report for review	5/31/05
138	6.2.1.7.3	Analysis of impacts draft report	9/30/05

Figure 13. HQ/Field Managed Analysis Activities (PBA)

ID	WBS	Task Name
138	**6.2.2**	**National Laboratory Crosscutting Analysis**
139	**6.2.2.1**	**Biorefinery process design and optimization**
140	**6.2.2.1.1**	**Emerging biorefinery process designs**
141	6.2.2.1.1.1	Perform stage 1 relative product analysis
142	6.2.2.1.1.2	Report on 4-5 promising advanced biorefinery designs
143	6.2.2.1.1.3	Develop mass/energy balances
144	6.2.2.1.1.4	Develop more rigorous mass/energy balances and costs for most promising designs
145	6.2.2.1.1.5	Biorefinery design and costing
146	**6.2.2.1.2**	**LP model for emerging biorefineries**
147	6.2.2.1.2.1	Validate sugar production modules
148	6.2.2.1.2.2	Add and validate syngas production modules
149	6.2.2.1.2.3	Add and validate pyrolysis production modules
150	6.2.2.1.2.4	Report on LP model results
151	**6.2.2.1.3**	**Advanced biorefinery process designs**
152	6.2.2.1.3.1	Perform stage 1 relative product analysis
153	6.2.2.1.3.2	Select process designs and products
154	6.2.2.1.3.3	Develop mass/energy balances
155	6.2.2.1.3.4	Estimate capital and operating costs
156	6.2.2.1.3.5	Report on 1-2 promising pathways
157	**6.2.2.1.4**	**LP model for advanced biorefineries**
158	6.2.2.1.4.1	Alter existing production modules
159	6.2.2.1.4.2	Add and validate new production modules
160	6.2.2.1.4.3	Report on LP model results
161	**6.2.2.2**	**Technology assessment**
162	**6.2.2.2.1**	**Assessment of emerging technologies**
163	**6.2.2.2.1.1**	**Process Set "A"**
164	6.2.2.2.1.1.1	Stage 1 analysis - most promising scenarios
165	6.2.2.2.1.1.2	Sensitivities on successful scenarios
166	6.2.2.2.1.1.3	Report to OBP to enable R&D portfolio decisions
167	**6.2.2.2.1.2**	**Process Set "B"**
168	6.2.2.2.1.2.1	Stage 1 analysis - most promising scenarios
169	6.2.2.2.1.2.2	Sensitivities on successful scenarios
170	6.2.2.2.1.2.3	Report to OBP to enable R&D portfolio decisions
171	**6.2.2.2.2**	**Assessment of advanced technologies**
172	**6.2.2.2.2.1**	**Process Set "AA"**
173	6.2.2.2.2.2.1	Stage 1 analysis - most promising scenarios
174	6.2.2.2.2.2.2	Sensitivities on successful scenarios
175	6.2.2.2.2.2.3	Report to OBP to enable R&D portfolio decisions
176	**6.2.2.2.2.2**	**Process Set "BB"**
177	6.2.2.2.2.2.1	Stage 1 analysis - most promising scenarios
178	6.2.2.2.2.2.2	Sensitivities on successful scenarios
179	6.2.2.2.2.2.3	Report to OBP to enable R&D portfolio decisions
180	**6.2.2.3**	**Analysis infrastructure development**
181	**6.2.2.3.1**	**Coordination**
182	6.2.2.3.1.1	MYAP draft completed
183	6.2.2.3.1.2	Annual analysts' roundtable meeting
184	6.2.2.3.1.3	Methods standardization
185	6.2.2.3.1.4	Web accessible tools, methods, data and documents
186	**6.2.2.3.2**	**Develop methods/tools**
187	6.2.2.3.2.1	Risk analysis in scientific processes - develop method
188	6.2.2.3.2.2	Develop pioneer plant cost estimation methodology
189	**6.2.2.3.2.3**	**Develop options analysis methods/tools with PBA**
190	6.2.2.3.2.3.1	Method "A"
191	6.2.2.3.2.2	Method "B"
192	**6.2.2.3.3**	**Communication with DOE and stakeholders**
193	**6.2.2.3.3.1**	**OBP and EERE analysis communication**
194	6.2.2.3.3.1.1	Improved understanding of EERE analysis
195	6.2.2.3.3.1.2	Identify point of contact for each level or report
196	6.2.2.3.3.1.3	Plan for strategic analysis that defines the vision and path to get there
197	6.2.2.3.3.1.4	Develop analysis website for information transfer
198	6.2.2.3.3.1.5	FAQ website participation

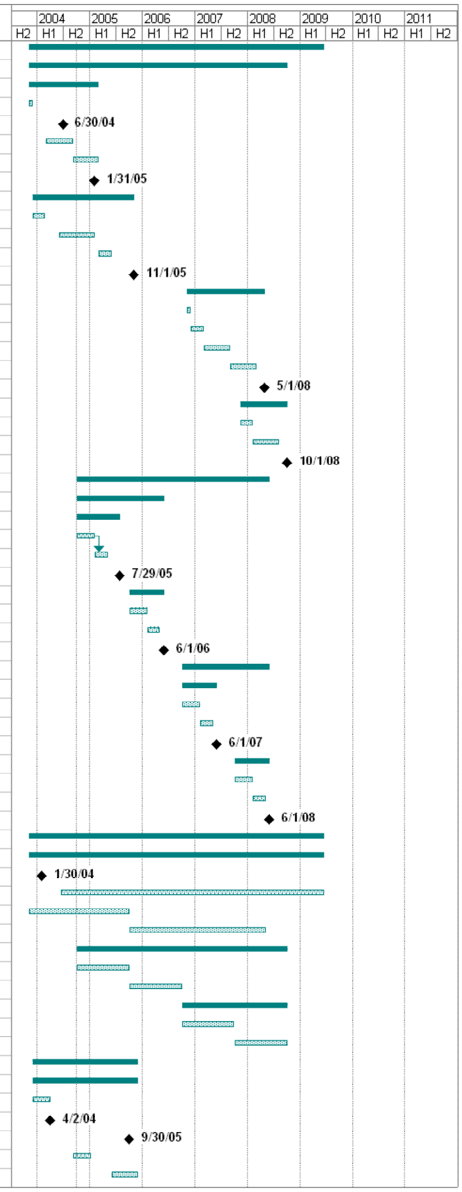

Figure 14. National Laboratory Crosscutting Analysis Activities (NREL)

Table 3: Analysis Milestones (lead lab noted for project milestone responsibility)			
Technical Barrier Area	**Project**	**Specific Technical Barriers Addressed**	**Milestones**
1.3 Feedstock Supply Chain Analysis	1.3.1 Supply Forecasts and Analysis (ORNL)	• Lack of credible data on price, location, quantity, and quality of biomass	9/2004 Corn stover and wheat straw supply schedules – document FY2003 analysis of current sustainable corn stover and wheat straw supplies. 9/2004 Billion ton vision paper – develop and document a vision for achieving an annual biomass supply of 1 billion dry tons. 9/2005 Forest residue and urban wood waste supply schedules – re-evaluate forest residue and urban wood waste supply schedule forecasts based on assumptions developed for the billion ton vision paper. Post information on resource website. 9/2006 Perennial energy crop and agricultural crop residue supply forecasts. Update energy crop and agricultural residue supply forecasts using the POLYSYS model. Post information on resource website. 9/2007 Agricultural residues supply forecasts with advanced technology assumptions – estimate agricultural residue supply forecasts using advanced technology assumptions (e.g., single-pass harvester). Post information on resource website. 9/2008 Transport cost functions – develop regionally-specific transportation cost functions with variable facility demand to support crop and forest residue supply schedules. Post information on resource website. 9/2009 Supply forecast review – conduct review and update, as needed, of all major feedstock supply forecasts. Post information on resource website.

	1.1.1.1 & 1.3.2 Supply System Logistics (INEEL, ORNL)	• Feedstock supply is a significant cost 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.	8/2004 Develop feedstock assembly model – define optimal (least cost) baseline collection systems for straw and stover. 8/2005 Verify and publish feedstock assembly model – optimize agricultural residue supply system incorporating novel packaging, storage, and transport options (single feedstock). 8/2006 Optimize feedstock assembly model using multiple agricultural residues – integrate physical and system dynamics models through virtual engineering tools 8/2007 Optimize feedstock assembly model for a forest biorefinery system – integrate forest biorefinery models through virtual engineering tools. 8/2008 Optimize feedstock preprocessing systems using fractional milling concepts – develop a low cost, high value, densified, and flowable feedstock for a biorefinery. 8/2009 Integrate feedstock assembly model with chemical process models (ASPEN) – integrate models through virtual engineering tools.
2.5 Sugar Platform Analysis	2.5 Sugar Platform Analysis (NREL)	• Biomass recalcitrance • Cost of biomass conversion to sugars	5/2004 Publish Corn Stover LCA results 11/2005 Rigorous, optimized sugar model.
3.5 Thermochemical Platform Analysis	3.5 Thermochemical Platform Analysis (NREL)	• Provide direction and focus to R&D by evaluating the technical, economic and environmental aspects of biomass Syngas production and conversion. • Feasibility projects will address cost barrier issues associated with small-scale integrated Biorefineries.	3/2004 Pyrolysis process design and model. 9/2004 Biomass Syngas to hydrogen production design and model. 12/2004 Biomass Syngas to hydrogen production design report. 8/2005 Effect of oxygen purity on direct-fired gasifier. 9/2005 Report on preliminary economic analysis of upgrading possibilities.

4.4 Analysis for Products	1.4.1 Technical and Market Studies (PNNL, NREL)	• Prioritizing technical barriers that can be overcome with R&D • Establishing technical targets and quantifiable metrics for Products Platform R&D	4/2004 High level analysis of impact of biobased products. 6/2004 Market analysis with Top Ten Study. 6/2005 Prepare an interim report on an expanded pyrolysis oil upgrading concept to include new chemical products as an E or D level milestone (PNNL). 9/2005 Refine and validate models for products analysis. 9/2006 Integrate products analysis into biorefinery model.
6.2 Program Analysis	6.2.1 HQ/Field Managed Analysis (PBA)		
	Renewable Fuels Standard and Other Policy Analyses		9/2004 Analysis of ethanol demand under updated scenarios. 9/2005 Analyze the first set of request for waiver from the Renewable Fuels Standard submitted by States with limited biomass resources or other constraints. 9/2006 Analyze additional State waiver requests or other issues as needed. 9/2007 Analyze additional State waiver requests or other issues as needed. 9/2008 Analyze additional State waiver requests or other issues as needed. 9/2009 Analyze proposed amendments to Renewable Fuels Standard (assumed to be enacted in a prior year).

	Biomass Market Studies		12/2003 Updated state ethanol incentive list. 9/2004 Draft paper on tax and market characteristics of fuel ethanol. 9/2004 Portfolio analysis – illustrative results. 9/2005 Complete analysis of the interaction of first generation sugar-based biorefineries with local electricity markets and regional gasoline/diesel markets. This will use OBP's assumed biorefinery characteristics. 9/2006 Begin an assessment of international biofuels potential in view of the global transportation demand and its impact on fuels prices. 9/2007 Assess the interaction of biorefineries with regional chemical markets, using bio-based products Analysis II completed by OBP in 2006. 9/2008 Evaluate gas-to-liquids interaction with bio-based and other transportation fuels. Benchmark with USDA and other market studies. 9/2009 Evaluate hydrogen/biofuels market interactions using new thermochemical data and biomass supply data from the program and results from ANL's pathway analysis. 9/2010 Revisit E85 prospects using new feedstock supply data, fuel cost data, demand data and ethanol industry capacity.

	Biomass Market Models		7/2004 Biomass market model enhanced and used to support NEMS and MARKAL analyses. 2/2005 Complete documentation of ELSASBioref and EBSA (biomass benefits models). 7/2005 Add data for carbon policy scenario. 9/2005 Integrated Biomass Model - version 1 documentation (this is ELSASBioref in a speeded-up version with GREET benefit factors and capability for adding future thermochemical biomass technology data). 9/2006 Add POLYSYS agricultural impacts for scenarios of 0.5, 0.75 and 1 billion dry tons of biomass/year to Integrated Biomass Model. 9/2006 Add relevant information from the Role of Biomass study. 9/2007 Update Integrated Biomass Model based on OBP's biorefinery analysis and USDA resource analysis completed in FY06. Add thermochemical performance and cost data provided by the program. 9/2008 Conduct RYM enhancement of petroleum refining modules. Add economic effects from input-output model as response function to Integrated Biomass Model. Update 2001 study of fuels distribution infrastructure and costs for scenarios of 0.5, 0.75 and 1billion dry tons of biomass/year. 9/2009 Incorporate new thermochemical data from OBP and new fuels distribution costs into Integrated Biomass Model. Add risk considerations. 9/2009 Update regional supply/demand and fuels distribution flows of Integrated Biomass Model. 9/2009 Update POLYSYS and other biomass models. 9/2010 Update Integrated Biomass Model with new energy crop and harvesting/storage cost data from USDA and OBP.

	Biomass Benefits Analysis		4/2004 Ethanol potential/market paper. 9/2004 NEMS and MARKAL results for FY06 budget. 9/2004 Retrospective analytic tool prototype. 9/2005 Estimate employment and other economic effects of biorefineries. 9/2005 Produce carbon policy scenario results. 9/2006 Work with Biomass Systems Integrator to update cost and market information in biomass baseline. 9/2006 Conduct new GPRA analysis for reference case and carbon policy cases. 9/2007 Conduct new GPRA analysis for reference case using new OBP energy crops information. 9/2008 Conduct new GPRA analysis for reference case using new OBP residue information. 9/2009 Conduct new GPRA analysis for reference case and additional policy cases using revised refinery blending results and biorefinery assumptions. 9/2009 Update cost and market information in biomass baseline and incorporate results of the advanced biorefinery analysis completed by OBP in 5/2008. 9/2010 Conduct new GPRA analysis for reference case and additional policy cases.

	Analysis: Biomass and Hydrogen Pathways		5/2004 Draft mobility chain results for Role of Biomass study. 9/2005 Analyze 3 biomass pathways to support the Role of Biomass study. 9/2005 Analyze 2-3 hydrogen pathways specified in the Role of Biomass study and other EERE activities. 9/2006 Analyze additional fuels/vehicle pathways as requested. 9/2007 Update prior pathway analyses to reflect new data from Fossil Energy Office and EERE programs. 9/2007 Analyze bio-based product pathways for top OBP chemical. 9/2008 Conduct joint analysis with industry and/or USDA similar to the 2001 GM/ANL/Exxon Mobil/BP/Shell study. 9/2009 Complete joint analysis with industry and/or USDA. 9/2010 Update hydrogen pathway analysis.
	Life Cycle Analysis Model (GREET)		8/2004 Update of GREET biomass and hydrogen data. 9/2005 Incorporate new data provided by Role of Biomass study team. 9/2005 Incorporate energy for farm machinery production (for ethanol analysis). 9/2006 Incorporate corn stover and ORNL/Andress's soil carbon analysis. 9/2006 Publish article on revised corn ethanol and cellulosic ethanol analysis. 9/2007 Add new technology data from Fossil Energy Office and EERE programs. 9/2008 Add new bio-based product data as OBP makes these available. 9/2009 Update thermochemical technology data as OBP makes these available. 9/2010 Add new bio-based product data as OBP makes these available.
	Economic Impacts From Biomass Demand Under Future Growth Scenarios (University of TN)		3/2005 Biomass demand scenarios analytic summary paper 5/2005 Coordinate with OBP analysts in updating selected supply curves for biomass. Circulate Bioenergy and bio-based products draft report for review. 9/2005 Analysis of impacts draft report.

	6.2.2 National Laboratory Crosscutting Analysis (NREL)	• Reduces pioneer plant risk • Provides Biorefinery proof of concept • Addresses process integration challenges • Ensures feasible advanced technologies enter the R&D program	1/2004 Complete MYAP. 6/2004 4 to 5 biorefinery designs – stage 1 analysis. 1/2005 Biorefinery design and costing. 6/2005 Complete analysis of the role of biomass in America's Energy Future (RBAEF). 7/2005 Emerging technologies update. 9/2005 Plan for strategic analysis that defines the vision and path to get there. 6/2006 Comprehensive emerging Biorefinery analysis. 9/2007 Advanced technologies status report. 5/2008 Comprehensive advanced Biorefinery analysis.

Resource Allocation Plan
Table 4 and Figure 15 summarize the resource plan for analysis across the OBP. About half of the analysis in the program analysis area (6.2) is PBA analysis whose aim is to integrate the program's outcomes with the outcomes from the other EERE programs and technologies that compete with EERRE technologies. The remainder is crosscutting analysis, which includes subcontract funds for analysis support. This funding allows the analysis teams to get extra help on short notice to handle unplanned requests. Using contract funds in this way has proven to be very successful and efficient in the OBP analysis effort. The crosscutting analysis effort is undergoing a change in FY05 to incorporate more strategic analysis to help in program planning.

Table 4: Analysis Resource Plan by Year (000)

Year	1.0 Feedstock Interface	2.0 Sugar Platform	3.0 Thermo-chemical Platform	4.0 Products	6.2.2 National Lab Crosscutting	6.2.1 HQ Program Analysis (PBA)	Total
2004	$602	$150	$507	$300	$400	$750	$2,709
2005 (request)	$945	$300	$728	$497	$1,600	$660	$4,230
2006	$1,090	$500	$1,100	$450	$1,100	$660	$4,900
2007	$1,000	$300	$1,100	$450	$1,100	$720	$4,670
2008	$925	$300	$1,100	$450	$1,100	$720	$4,595
Total	$4,562	$1,550	$4,535	$2,147	$4,800	$3,510	$21,104

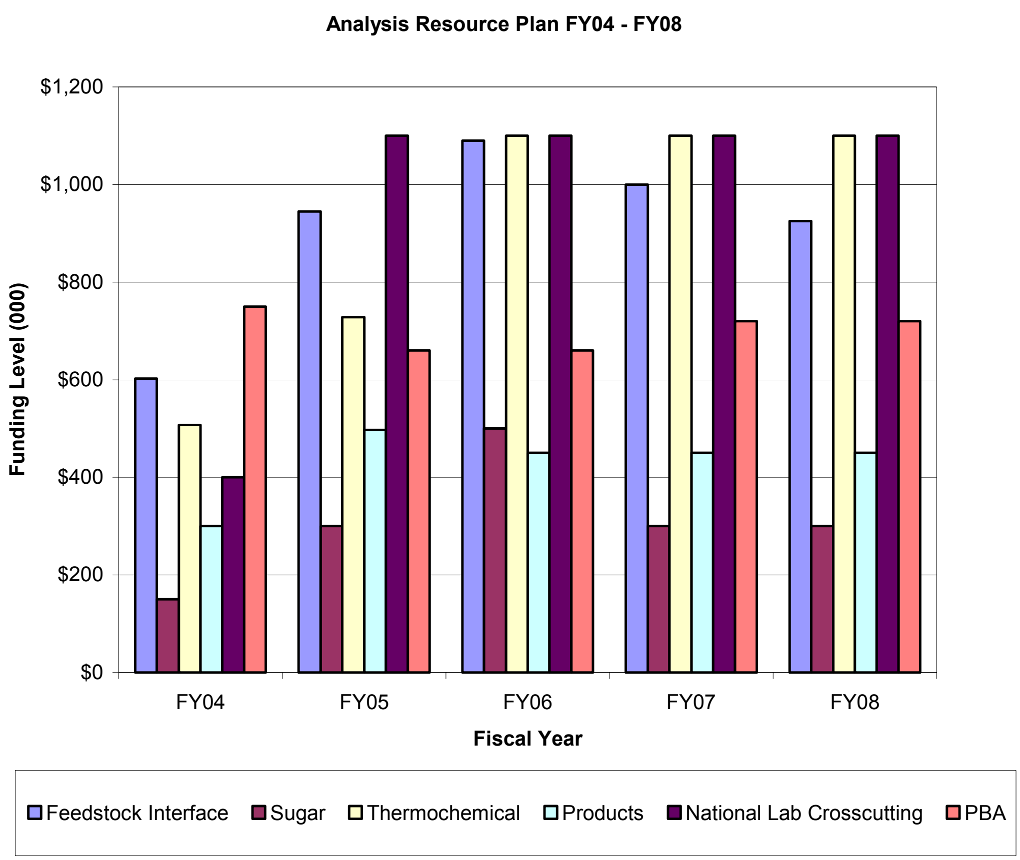

Figure 15: Analysis Resource Plan, Totals for FY04-FY08

3.1 Biomass Feedstock Interface Analysis (INEEL, ORNL)

The overall goal of the biomass feedstocks interface R&D is to develop sustainable technologies capable of supplying lignocellulosic biomass to biorefineries producing fuels, chemicals, heat and power. The specific area objectives are listed in Table 5, along with corresponding analysis objectives. The analysis for feedstock interface R&D provides information to the benefits analysis effort, program direction and engineering knowledge for biorefinery development.

Table 5: Feedstock Interface Objectives

Area Objectives:

- 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.

Analysis Objectives:

- Develop feedstock supply forecasts, models and analyses necessary to optimize feedstock supply chains to biorefineries and reduce supply risks.
- Develop process designs for harvest and collection technologies to meet feedstock supply goal.
- Show progress toward the feedstock price target, including the market and investment influenced grower payment, and the technology influenced supply system costs.
- Develop investment strategies for grower feedstock supply logistics in order to maintain supply and cost stability.
- Develop credible supply curves for a variety of feedstocks.

3.1.1 Analysis Status

Supply Forecast and Analysis

ORNL has developed a set of integrated modeling tools (ORIBAS, POLYSYS, BIOCOST) and databases (ORRECL) for estimating current sustainable feedstock supplies and forecasting supplies from new resources such as energy crops. These modeling tools encompass economic, geographic and environmental constraints in assessing the availability of biomass wastes, agricultural residues, forest residues, and energy crops. Biomass resource estimates are sensitive to environmental and soil conservation issues, to the scale of the processing facility, and to the economics of farming as an enterprise. 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. This approach was used to estimate potential agricultural residue supplies from all important corn and wheat soils in the United States. 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.

Different development and policy scenarios are assessed through a comparison of three investment strategies made using information from current modeling tools. These investment strategies include fixed commodity pricing, shared equity investments and a combination of the two. The current fixed price of biomass as a commodity is set at $10/ton. However, this price is known to be a conservative average representing only a small portion of the available market, and being unable to account for supply variability and market perturbations. On the other hand, the risk of a shared equity investment may deter potential grower investments and limit the location of certain biorefineries. A comparison of these investment strategies will evaluate the potential benefits in terms of supply and cost stability to an integrated biorefinery infrastructure for various regional factors.

Supply System Logistics

The INEEL, in partnership with equipment manufacturers, has made considerable progress and advancements in the feedstock infrastructure area over the past couple of years. Specifically as part of the ongoing highly successful OBP sponsored Selective Harvest and Multi-Component projects, considerable work and progress has occurred to determine which components of the agricultural residue biomass should be left in the field to address soil health and sustainability concerns and which parts should be harvested as biorefinery feedstocks. Also as part of these projects, numerical and computational models on mechanical fractionation and air stream biomass separation have been developed and integrated into a format that can be analyzed using virtual reality allowing virtual engineering models to be developed. These models are available to perform virtual engineering analysis of various biomass selective harvest techniques and 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 required for 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 feedstocks needs could be largely meet with existing harvest and collection technology and methods. However, more detailed analysis has shown this is not the case and new technology and methods are needed to meet the feedstock needs of the biorefinery. Unfortunately, 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 is an innovative method for overcoming this dilemma.

The INEEL, in partnership with growers and academia, 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 that have been developed and conceptually evaluated show considerable promise for meeting the feedstock availability and price targets. Additionally, the INEEL has evaluated several long-term storage technologies for both wet and dry storage options that are low cost with minimal degradation and losses.

ORNL research focuses on developing and applying 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. The model output consists of costs and energy and utilization rate of current or future available 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, USDA, and NBC researchers. ORNL and INEEL scientists will work closely together to generate the experimental and operational data needed to validate and use the model. The supply chain model will be designed to directly interface with process models being developed by NREL and others.

Technical Barriers
Figure 16 shows the cost impacts of addressing the barriers of single-pass harvesting and selective harvesting.

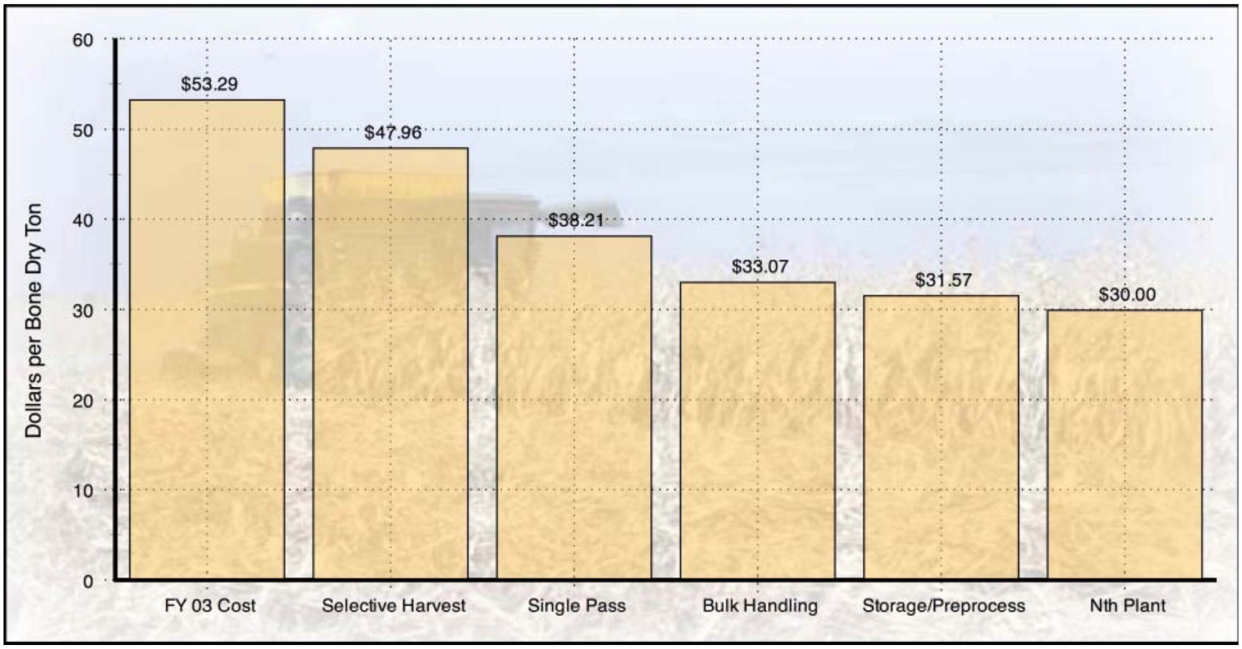

Figure 16: Translating Feedstock Interface Barrier Reductions to Cost Impacts

Analysis Plan
The Feedstock Supply-Chain Analysis Area will focus on developing analytical tools for optimizing overall logistics of the infrastructure system as well as on tools for estimating the supply and costs of grower payments and the amount and price of agricultural residues and energy crops.

A professor from Clarkson University who specializes in groundwater contamination will take a sabbatical and work at NREL to help understand the environmental implications of biomass production from a life cycle perspective. There will also be a significant amount of contact with ORNL. This work will include a literature review to identify the range of contaminants for a given feedstock, collecting data to determine what level of contaminant modeling could be done as well as assessing where data gaps exist, and a preliminary evaluation of the magnitude of the impacts in order to set priorities for further investigation.

3.2 Sugar Platform Analysis (NREL)

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 to produce fuels, other chemicals, and materials. The specific area objectives are listed in Table 6, along with corresponding analysis objectives. The analysis for the sugar platform R&D provides information to benefits analysis, direction to the program and engineering knowledge for biorefinery development.

Table 6: Sugar Platform Objectives

Area Objective:

- Reduce the estimated cost for production of a mixed, dilute sugar stream suitable for fermentation to ethanol, from 15 cents per pound in 2003 to 10 cents per pound by 2010.

Analysis Objectives:

- Provide conversion process design and costs for biomass to sugar and to a model product.
- Justify and guide research within in the sugar platform. Show progress to the R&D targets.
- Provide design and cost information for sugar production to the biomass community.

Analysis Status

Analysis of several biomass to ethanol processes has taken place. The products of those analyses have included two design reports that show refined process designs, capital cost and operating cost estimates, and overall economic analyses. The following process areas were modeled: inside facility feedstock handling; pretreatment and conditioning; saccharification and fermentation; distillation and product dehydration; wastewater treatment; lignin combustion for steam and power; and utilities. The process designs are modeled in the ASPEN Plus material and energy balance system that required development of thermodynamic parameter estimates for biomass-specific components. The process design and equipment costing work involved Delta-T Corporation, Reaction Engineering Inc., Merrick, and the Harris Group to validate the design and assist in estimating capital costs.

NREL has extended the analysis reported in the design reports to include the capability of Monte Carlo risk assessment, feedstock composition variability and its effect on cost, and the alternative pretreatment chemistries represented by the Biomass Refining Consortium for Applied Fundamentals and Innovation (CAFI). A life cycle assessment of corn stover production, conversion, and ethanol use as a fuel has been completed. That assessment highlighted the importance of soil sustainability and carbon sequestration in soil. NREL also developed a cost metric to determine the status of work in the enzyme subcontracts with Genencor and Novozymes. "State of Technology" cases were developed to report the cost effects of using experimental data instead of targets as the model's input parameters.

Technical Barriers

OBP uses technoeconomic analysis to judge the relative cost impacts of addressing technical barriers for a given technology. Figure 17 is an example of such an analysis done in 2003 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 depends upon the assumed cost of feedstock delivered to the plant. $53 per ton of corn stover has been used here.
- Feedstock Interface: Reduce cost of corn stover and wheat straw from $53 to $30 per dry ton.
- Pretreatment: Increase yields of hemicellulosic sugars from demonstrated level of 60%-70% to 80%

- Pretreatment: Decrease pretreatment systems capital cost by 24% by increasing solids concentration in the reactor from 19% to 30%. This lowers capital cost for pretreatment equipment from $35.8 million (in the "FY 03 Cost") to $27.4 million.
- Enzymatic Hydrolysis: Reduce the cost of enzyme from $0.64 to $0.10 per gallon of ethanol
- Strains: Achieve high yields of ethanol from glucose (>95%) and xylose (>85%).

As indicated in Figure 17, 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.

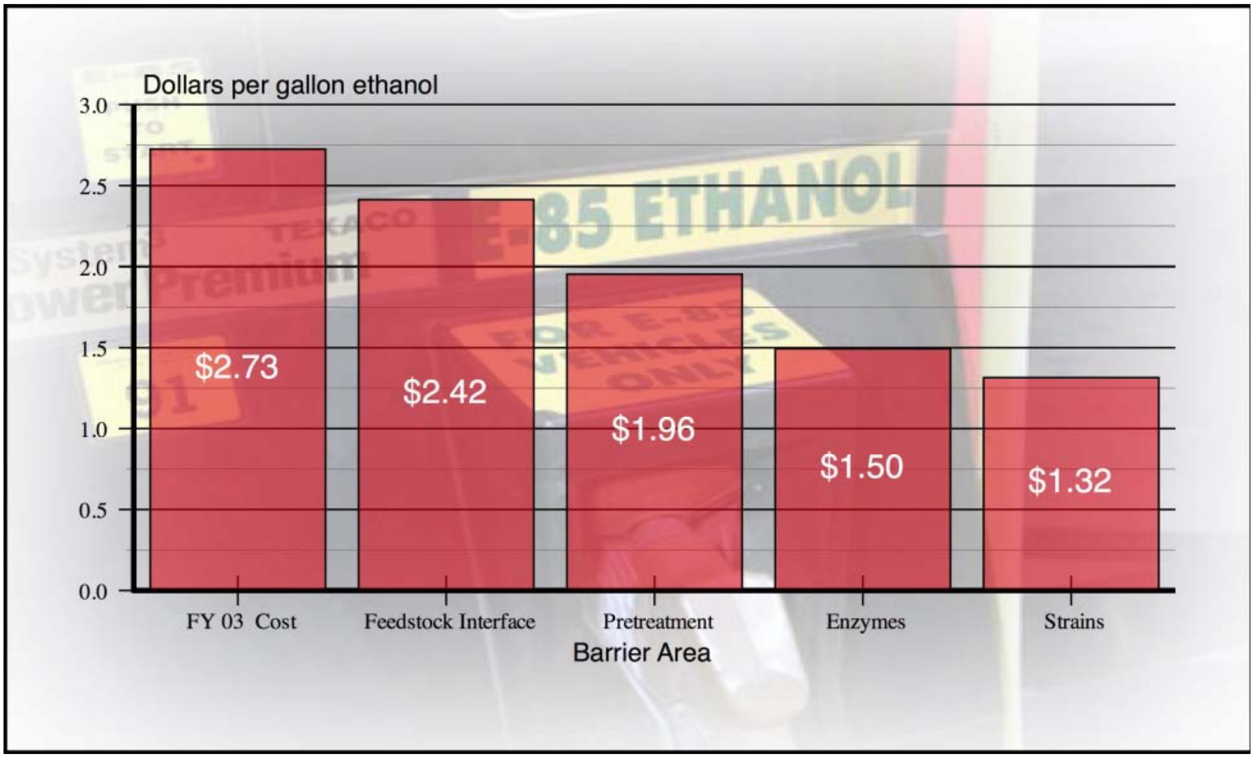

Figure 17: Translating Sugar Platform Barrier Reductions to Cost Impacts for Ethanol

Analysis Plan

The Sugar Platform Analysis project captures the process engineering and life cycle analysis needed to direct research by translating all of the proposed and actual outputs from research into quantifiable costs and benefits for the technology. Analysis is performed under this task to support the on-going 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. Much of the analysis work 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 will still be used as a base case process to evaluate the economic impacts of technology developments. However, increasingly greater emphasis will be given to producing additional products from the sugar streams in addition to ethanol.

Specific planned activities include:

- Continue to support the Novozymes and Genencor subcontracts to determine impacts of the developments

- Analyze the effect on MESP from the variability of a second large sampling of corn stover using techniques developed in FY03.
- Update the "State of Technology" case to properly reflect technologies demonstrated in the lab and pilot plant. It is anticipated that this case will be updated annually.
- Clearly outline incremental developments that are required to get to $1.07 per gallon MESP target case. Particular focus will be given to determining the economic benefit of performing saccharification at high solid and high temperature cellulases.
- Analyze the Clean Fractionation ideas as a way to process portions of intermediate streams to produce high value chemicals.
- Analyze the hot wash experiments for the material balance and the potential impact on the MESP of the biomass to ethanol process.
- Perform exploratory evaluations on the benefit of futuristic strategies for harvesting, biomass storage, and pre treatment of storage piles.
- Develop future directions for kinetic modeling in pretreatment. One possibility will be to combine CFD (Computational Fluid Dynamics) with accepted biomass depolymerization pathways.

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 that are facing critical technology choices prior to entering the commercial demonstration phase for their specific emerging sugar biorefinery projects.

3.3 Thermochemical Platform Analysis (NREL)

The technical goal of the Thermochemical Platform is to develop the capability of thermochemically converting biomass into simple building blocks for the production of fuels, other chemicals, and materials. The specific area objectives are listed in Table 7, along with corresponding analysis objectives. The analysis for the thermochemical platform R&D provides information to the benefits analysis effort, direction to the program, and engineering knowledge for biorefinery development.

Table 7: Thermochemical Platform Goal and Objectives

Area Milestones and Objectives:

- By 2005 validate a process for continuous biomass gasification, tar cracking and syngas reforming.
- By 2007 validate a condensing, gas cleanup system.
- By 2009 validate a catalytic system for cleaning tar.
- Reduce the estimated cost for production of a cleaned and reformed biomass-derived synthesis gas produced from a mature gasification plant, from $6.48 per million Btu ($6.14 per GJ) in 2003 to $5.28 per million Btu ($5.01 per GJ) by 2010.

Analysis Objectives:

- Provide conversion designs and costs for thermochemical conversion of biomass to intermediates and model products.
- Justify and guide research within the thermochemical platform. Show progress to the intermediates and model products price target.
- Provide design and cost information for thermochemical processes to the biomass community.

Analysis Status

Analysis performed under this task supports the on-going research in the thermochemical platform. That analysis has included developing technical characterizations of power production from direct combustion of biomass as well as from several gasification options. A life cycle assessment has also been developed that compares the environmental effects of power production from biomass to power production from non-renewable resources. Engineers have developed preliminary process models on hydrogen production and have performed initial screening and preliminary analysis of products from syngas.

Technical Barriers

Technoeconomic analysis can be used to establish the relative impacts of the technical barriers. Figure 18 shows the potential impact of overcoming these barriers on the cost of syngas via the Thermochemical pathway.

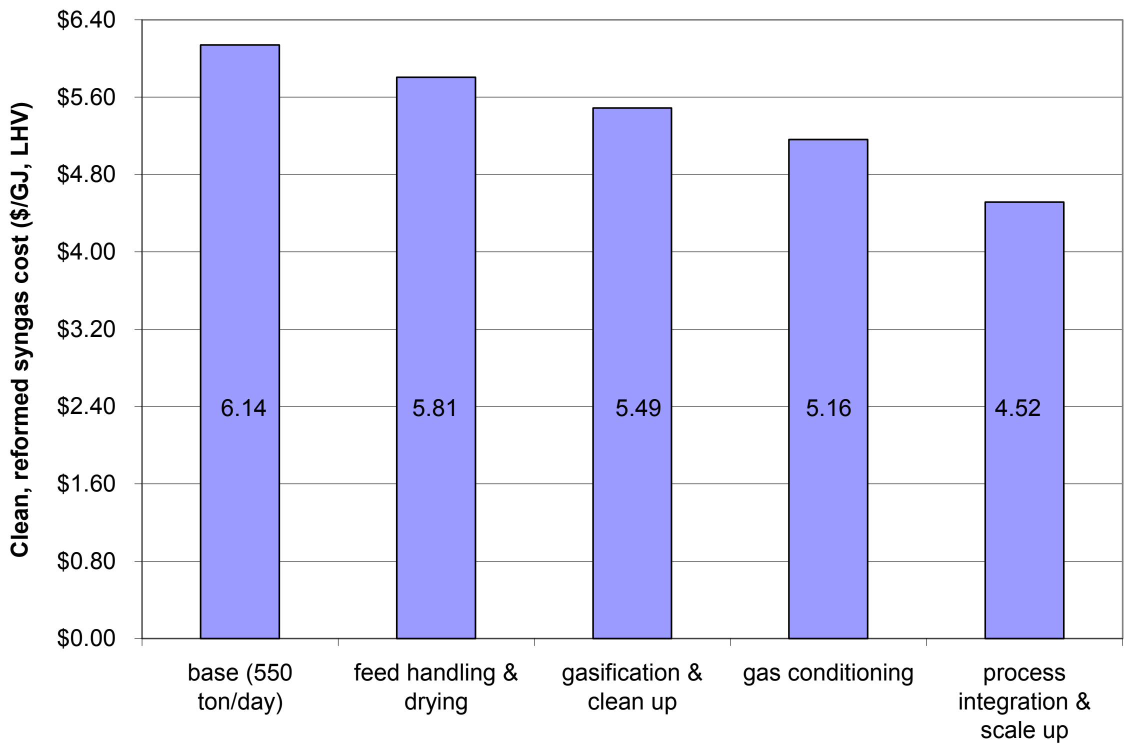

Figure 18: Translating Thermochemical Platform Barrier Reductions to Cost Impacts for Syngas Intermediate

Analysis Plan

OBP will conduct analysis activities on the Thermochemical Platform to provide information to decision makers. We will perform technoeconomic analyses 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 assessment 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 determine the relative advantages of each. This work will build upon extensive past efforts by the national laboratories and universities in building various analysis tools.

Pyrolysis is one of the thermochemical conversion options that could play a role in biorefineries. Initial work will summarize the state of the technology followed by pyrolysis model development. Additional work will include analysis of upgrading methods for crude pyrolysis oil.

Specific planned activities include:

- Biomass feed systems. Work will be done to determine the state of the art. This will involve gathering data on the various types of equipment including past experience, advantages, and disadvantages for each.
- Gas cleanup. Work in the gas clean up area will focus on obtaining better costs for the various pieces of equipment for several scales and different operating conditions. This information will be used in the syngas models and costing spreadsheets to help focus on the most economical combinations for clean syngas production from both direct and indirect gasification.
- Oxygen and fuel synthesis as a function of oxygen purity. Reduced oxygen purity may improve the economics of direct gasifier systems. Producing lower purity oxygen will reduce the cost of oxygen generation; however, more nitrogen in the syngas will affect the downstream equipment sizes and possibly conversion efficiencies. The trade offs of oxygen purity with capital cost will be examined.
- Fuel synthesis. Producing a fuel product is another potential opportunity for biomass syngas. Examine the advantages and disadvantages of various fuel synthesis processes integrated with biomass gasification. Initial work will look at the potential of mixed alcohols. Future work is anticipated to examine Fischer-Tropsch liquids and methanol.
- A design report of the same rigor used for those in the sugar platform will be developed for the chosen model product (hydrogen). The model product is a somewhat arbitrary choice, but having a product is essential to showing the benefits and challenges of an integrated system.

3.4 Products (NREL, PNNL)

The technical goal of Products is to develop the capability for using lignocellulosic biomass to produce inexpensive sugar streams that can be used to produce fuels, other chemicals, and materials. The specific area objectives are listed in Table 8, along with corresponding analysis objectives. The analysis for products R&D provides information for benefits analysis, direction of the program and engineering knowledge for biorefinery development.

Table 8: Products Objectives

Area Objectives:

- Fuels: Identify opportunities for reducing the cost of ethanol production by \$0.10 to \$0.18 per gallon by improving fermentation organisms and utilization of 5 carbon sugars.
- Chemicals and Materials: Identify opportunities for reducing the cost of producing products from biomass to a level where the final product is in the range of \$0.25 to \$0.50 per pound.

Analysis Objectives:

- Help select research projects within the products research area.
- Identify major cost barriers associated with products.
- Define a number (3-5) specific process for producing products based on the “Top Ten” analysis.
- Develop a set of simple models that can be used to direct research in the products area.
- Quantify the effects of high-value products on model product’s supply curves.

Analysis Status

Activities included in the Products R&D portfolio include a very broad array of technologies. In part, this is because prior to creation of OBP, three different EERE Programs conducted work in “products”. As described in the MYPP, the Products R&D work has a significant near-term focus on the sugars and thermochemical platforms. However, it also includes work on oil-based products, bio-oil products, and potential platform co-products. Analysis is needed to support all of these platforms and their respective potential co-products and markets. An outcome of FY03 work included the identification of the “top ten” opportunities for producing value-added chemicals from biomass that would support an integrated biorefinery, and the associated technologies that would offer the greatest impact in producing these intermediates. Follow-on to that work includes developing solicitation topics and core R&D efforts.

Technical Barriers
Several technical barriers have been identified in the products MYTP. The major barriers include improvements in fermentation, catalysis and separations. Specific barriers within each of the major barrier areas have also been identified. In fermentation development, the need for more robust organisms, high productivity and higher selectivity have been identified as critical technology barriers. In catalysis, more robust, long-lived catalysts that afford high selectivity and conversion have been identified as critical barriers. Separations include the need to develop low cost recovery and purification for both intermediate building blocks and final products.

Analysis Plan
Although each project in the products platform will include its own analysis and planning work, a crosscutting project is necessary. 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 will allow OBP to help EERE meet its goals of reducing dependence on foreign oil and helping to create the new, domestic bioindustry. These products are intended to provide an additional economic driver for the biorefinery.

One of the major elements in the analysis for products is to develop a set of simple models that can identify major cost barriers and therefore help facilitate the direction of research for the products area. A series of preliminary models have already been developed in an excel spreadsheet format with the basis being more robust tools such as ASPEN or ChemCad. The objective is to refine and validate these models. The refinements will include ensuring capital costs and operating costs are accurate with current industrial processes and that these models are valid over a broad range of inputs. These models will be user friendly and broadly available. A series of models has been developed for aerobic fermentation, anaerobic fermentation, oxidation catalysis, hydrogenation catalysis and separations such as distillation and crystallization. Ultimately the information developed in these models will be used in the broader biorefinery models.

Based on the results of the Top Ten analysis a series of relatively detailed process flow diagrams will be developed for 3-5 specific processes. This will include, for example, developing a process for the conversion of glucose to succinic acid and the subsequent conversion of succinic acid to 1,4-BDO. A number of case studies will be developed based on current technology status and future scenarios assuming specific technical hurdles can be overcome. These will be integrated into the biorefinery model.

Market studies are necessary to understand how higher-value products contribute to overcoming barriers and achieving OBP program goals. Objectives include creating or defining metrics for Products R&D, completing the Top Ten analysis and scope of oils R&D within OBP, examining other processing opportunities of biomass resources to provide raw materials for potential biorefinery operations, conducting market based analyses for bioproduct opportunities, working with other technical analysis teams within the OBP program to address integration of biobased products within biorefinery scenarios, and examining opportunities for other biomass components such as lignin, polysaccharides, and bio-oil type products as sources of biobased products.

Although the goal is not to pick the best targets for DOE to pursue, some products must be chosen for environmental and economic outcome estimation. As described in Section 4, value-added products will not be used directly in environmental and economic outcome estimations. Instead they will alter supply curves so that more of the high-impact model product can be produced with the value-added product than without it.

The Upgrading Pyrolysis Oils study at PNNL will continue to have an analysis task in FY05 as part of the IEA Bioenergy Pyrolysis Task (to be completed over the next 3 years). The Chemcad based flowsheet model and Excel based economics spreadsheet developed this year for the hydrogenation of the bio-oil to fuels and chemicals will be expanded to incorporate new chemical products into the product slate with the fuels.

3.5 Program Analysis

The overall goal of analysis in the program management area is to provide crosscutting analysis for program management and support and information for EERE analysis. The analysis in program management provides information to benefits analysis, direction for the program and engineering knowledge for biorefinery development.

Two work areas were determined to be necessary for program analysis but are not planned because the specific needs of PBA are not known at this time – 1) option analysis and 2) end outcome selection. PBA is currently determining how to estimate and report end outcomes of option analysis. Most likely, OBP will be able to use most of the same outputs for option analysis as are used for expected prospective analysis; however, additional benefit model runs will be necessary. Therefore, OBP needs budget money for those additional runs in FY05 and beyond. After FY05, PBA may also develop additional modeling needs for options analysis that are currently undefined. Due to the lack of definition of the work in this area, a project could not be well defined and was not included in the project descriptions.

End outcome selection is currently being led by PBA. As stated in section 4.1.1, the Biomass Program needs to play a role in selecting the economic, environmental, and security criteria so that its unique benefits are included in the ultimate criteria. This role is best filled by OBP management at the DOE headquarters building and should not be considered a separate project; however, it is an essential responsibility.

3.5.1 HQ/Field Managed Analysis (Andress & Associates (DAA), ANL, Jerry Hadder, ORNL, TMS, University of CA, University of TN)

No MYTP write-up was available for the HQ/Field Managed Analysis project, so the submission for the FY05 Annual Operating Plan was used. In general, projects in this area should provide input and support to EERE analysis - input to the NEMS and MARKAL models in the form of market data, and runs on both models for PBA budget and benefits reporting.

3.5.1.1 Renewable Fuels Standard (RFS) and other Biomass Policy Studies (ORNL, Hadder, DAA, TMS)

Analysis Plan
Conduct analysis in coordination with other DOE organizations in support of RFS implementation such as analysis of state waiver requests. If alternative biomass policies are contemplated by Congress or the Administration, conduct appropriate studies as needed. Studies may use refinery models and biomass market models or other tools.

3.5.1.2/3.5.1.3 Biomass Data and Models, Analyses, and Studies (ORNL, DAA, TMS, University of TN, Hadder)

Analysis Plan
Conduct analysis of market characteristics for biofuels and other bio-based products, transition pathways to a hydrogen/alternative fuels economy, and other studies as requested by DOE. Provide analytical input

to, and participate in OBP analytic planning efforts. Conduct analysis pertaining to biomass incentive policies or other biomass issues as requested. Provide assistance to NEMS and MARKAL modeling of biomass markets. Update refinery modeling work as needed by the benefits analysis task and RFS analysis task. Collaborate with USDA analysts and others on a growing biorefinery industry's effects on the agricultural sector and biomass prices.

Document enhancements made to biomass market models. Update biofuels facts document and provide relevant information to contractors working on the Biomass Data Book and Transportation Energy Data Book. Add new or updated biomass data to EERE website and other media.

Continue to provide environmental and tax incentive information to external and internal requesters and to countries that plan to deploy biofuels. Support exchange of information by authoring memoranda and white papers; responding to inquiries; and attending meetings and workshops as requested.

3.5.1.4 Biomass Benefits Analysis (ORNL, TMS, University of TN)

Analysis Plan
Keep abreast of information coming out of biomass multi-year technical plans (MYTPs) and updated targets in future budget request revisions. Review and support GPRA modeling assumptions and methodology. Run and/or review results of ELSASBioref, the Integrated Biomass Market Model, POLYSYS and other models to develop benefits for MARKAL and NEMS in support of budget requests. Develop GPRA documentation for EERE Benefits website.

3.5.1.5/3.5.1.6 GREET Environmental Modeling and Participation in "Role of Biomass in America's Energy Future" Study (Analysis: Biomass and Hydrogen Pathways) (ANL, University of CA, DAA)

GREET Analysis Plan
ANL will update prior life cycle analysis of corn and cellulosic ethanol and work with other LCA experts to resolve or clarify the basis for major differences in benefits associated with ethanol with a major focus on corn ethanol in FY05.

ANL will update biomass-based fuels pathways and evaluate additional fuels/vehicles pathways, including biomass-to-hydrogen ones as the need arises. ANL will also summarize its findings for use by DOE and stakeholders when requested.

RBAEF Project Analysis Objective
Determine the feasibility of biomass becoming a major energy source in the United States and estimate a timeframe for that societal change.

RBAEF Project Analysis Status
RBAEF project will be completed in FY05.

RBAEF Analysis Plan
The study involves Dartmouth University (funded by the Biomass Program), ANL (funded by PBA), and NRDC (funded by the Energy Foundation and the National Commission on Energy Policy). Dartmouth University focuses on technology and resource assessment. NRDC focuses on sustainability assessment and policy implications. The Dartmouth subteam includes Princeton University and ANL.

The study is investigating the feasibility for bioenergy to play a major role as an energy source for the United States and develop a plan to accelerate use of biomass-derived products including fuels and power. The feasibility investigation includes potential technologies for biomass production, power generation, and fuel refining and determining which have the greatest potential for development. The efficiency, environmental characteristics, and economics of these technologies will be addressed. The potential for co-producing multiple products from biomass will be included to propose the most economic, efficient and environmentally attractive combinations.

The second part of the study is investigating how bioenergy use can be accelerated and in what timeframe associated benefits could be realized. It will define the research and development, demonstration and deployment steps that will be needed to enable this vision, estimate a schedule for technology development and deployment, and determine what policies are needed to minimize undesired impacts and speed the transition to a biomass based economy.

ANL participates in the “Role of Biomass in America’s Energy Future” study led by Dartmouth College. ANL is responsible for conducting a “mobility chain” analysis of various fuels produced from biomass via the sugar and syngas platform and for characterizing vehicle technologies using these fuels. ANL will also contribute to the report of the study. For fuel production pathways not in the current GREET version (such as hydrogen, Fischer-Tropsch diesel, and methanol), new data concerning energy and mass balance will continue to be obtained from other organizations such as industry, National Laboratories and universities to construct simulation options in GREET. The results of the mobility chain analysis will be then used by the project team to determine the magnitude of energy and environmental effects of introducing biomass-based fuels.

3.5.1.7 Economic Impacts From Biomass Demand Under Future Growth Scenarios (University of TN)

Analysis Objective
Estimate growth scenarios for biofuels, biopower and bio-based products and impacts of increased demand on biomass prices and other parameters.

Analysis Status
The POLYSYS modeling framework is capable of considering a wide variety of region-specific management practices. Crops currently considered in POLYSYS include corn, grain sorghum, oats, barley, wheat, soybeans, cotton, rice, alfalfa, and other hay crops. Land types include cropland acres in current crop production, idle, in pasture, and in the Conservation Reserve Program. Changes in agricultural land use, based on cropland allocation decisions made by individual farmers, are primarily driven by the expected productivity of the land, the cost of crop production, the expected economic return on the crop, and domestic and world market conditions. POLYSYS has also been used to analyze bio-energy crop scenarios.

Technical Barriers
This work address the Ag-sector-wide paradigm shift barrier from the Feedstocks barrier discussion in the MYTP:

> *“Energy crops, per se, 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 in America, and it may involve dramatic changes in agriculture that may take some time bring about.”*

Analysis Plan
- Work with Biomass Program and PBA to identify reasonable scenarios for future growth.

- Estimate a national bioenergy and bioproducts demand for agricultural feedstock, the agricultural resources demanded, and the price and income impacts on the agricultural sector using the USDA model POLYSYS.
- Document results in annual status report and final report

3.5.2 National Laboratory Crosscutting Analysis (NREL)

Analysis Objectives

- To integrate the results of platform analysis into biorefinery process designs and an optimization program
- To assess emerging technologies that are not currently part of a research platform but have potential to improve biomass utilization.
- To develop advanced methods, tools, and partnerships, improving analysis value and efficiency. This evolving analysis infrastructure supports platform analysis and industry-led projects.

Analysis Status

Past crosscutting analysis projects have covered work in areas that do not easily fit into a single research project. The majority of process engineering and analysis is performed as part of the research platforms; refer to the specific platform analysis projects for details. The integrated engineering and analysis team performs crosscutting analysis that benefits multiple OBP projects and external collaborators, and provides direction and focus to the overall research program by evaluating the technical, economic, and environmental aspects of biomass utilization via integrated pathways. This analysis project also provides quantifiable measures of success towards OBP's goals and is a part of the multi-year analysis plan (MYAP) for OBP and its EERE analysis activities. With the creation of the NBC, this project will become even more crosscutting, including input from multiple labs performing core R&D in the program.

Analysis Plan

With the increasing emphasis on analysis driven goals in EERE, this project is undergoing a change in FY05 to address the higher level analysis required to help the biomass program respond to EERE. The project is being expanded starting in FY05 to address not only the need for crosscutting analysis across the biomass platforms, but of a strategic analysis aimed at building and communicating a long term vision of the biomass industry as source of energy and products via a consolidated and quantitative set of analyses. Within this long-term vision is:

1. A definitive snapshot of progress toward Program goals and remaining hurdles
2. The benefits of biomass technology as part of a sustainable energy future
3. Possible pathways toward the Program's long term vision from which Congressionally required milestones and goals can be built based on rational "best guesses" about the dynamics of technology development, investment and deployment

Biorefinery process design and optimization

With the integration of the former biopower and biofuels programs and the efforts in identifying candidate products from biomass, we now have the information 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). 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 4-5 emerging biorefinery process designs with integrated heat and power utilization will be developed, using the information from all platforms and the feedstock interface program. Mass and energy balances will be developed along with capital and operating cost estimates at a stage 2 level of analysis. Modules for syngas production and use 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 4 model products will be selected to complete the process design from the products platform Top 10 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, 1-2 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. A second round of biorefinery development is envisioned using advanced technologies in the FY07-08 timeframe.

Emerging technologies assessment
The biomass scientific community is continually developing technologies that could substantially improve the production of biomass intermediates. Initial assessment of emerging technologies that are not currently part of a research platform but have potential to improve biomass utilization is performed under this project to ensure biomass research stays at the cutting edge, reducing the time to commercialization and optimizing R&D dollars. A stage 1 level analysis will performed using available process and cost data and optimistic assumptions to create a best case scenario. If this scenario is feasible, then 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. Catalytic production of ethanol from syngas is an example of one such technology. This will be an ongoing task and the results feed both the research platforms and the biorefinery analysis discussed above.

Analysis infrastructure development
Analysis methods for biomass processes are as new as the processes themselves. While some methods and tools from other industries can be used with modification, others, like biomass physical property estimation methods, must be developed. Coordination, development of new methods, and communication are the three pieces to continuing 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 at NREL to combine the former biopower and biofuels analysis teams and align with the Hydrogen group are complete. The next step is to develop similar alignment between the national laboratories in the NBC, then the biomass community as a whole.

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 simple methods to track progress on all OBP projects including solicitations and earmarks, and continued pioneer plant analysis to understand first of a kind plant costs for stakeholders. Efforts to improve communication of analysis results to DOE and stakeholders include improved understanding of EERE analysis methods, tools, and inputs, participation in an FAQ site for OBP staff, and development of this multi-year analysis plan.

Finally, this task will continue to serve as a central clearinghouse for all analysis, and in addition will serve as a catalyst for strategic thinking in setting program direction—both with DOE and external stakeholders.

4 Types of Analysis used in the Biomass Program

Analysis is defined as "the examination of a complex, its elements and their relations"[11]. One can analyze substances, organisms, processes, or actions. The boundaries chosen determine the size of the system to be examined. You can analyze a microscopic system, looking at how substances adhere to a catalyst surface, or a macroscopic system, looking at how a new chemical might affect a global market. Either way, the purpose is to understand the system well enough to make decisions about it: Could it be improved and at what cost? What improvements are possible and at what benefit? The goal of analysis, then, is to provide enough information about a system to know when it is optimal, be it a chemical, enzyme, gasification process, or the entry of a new fuel into the transportation market.

Engineering is defined as "the application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems"[12]. It is necessary to understand what designs are possible, how much the process options might cost, and what improvements are necessary to reach economic targets. Engineering contains the tools to create, and then improve a process.

Analysis relies upon engineering feasibility studies, financial estimates, environmental assessments, and market impact evaluations to understand 1) processes and how new technology affects them, 2) markets and how products from the processes would change them, and 3) the environment and how the process and products will affect them.

There are many different types of analysis and all of the analyses described here build on each other and are supported by an infrastructure of tools and methods, some specific to a certain analysis, some that tie the results of several analyses together.

The types of analysis discussed in this plan are:

- Resource assessment (availability)
- Technical and economic feasibility
- Environmental impacts
- Markets (biomass supply, biorefinery and bioindustry infrastructure logistics)
- Societal benefits

Some analysis tools are models that describe the system under study; examples include mass and energy balance models for the process and market penetration models for a product. Other types of analysis (e.g. chemical or structural) that figure prominently in the execution of the OBP's portfolio are covered in the multi-year technical plan.

The OBP uses engineering and analysis to support decision-making, show progress to goals and direct research activities. Platform level analysis activities provide direction, focus, and support to the development and introduction of feedstock production, and processing and use technologies. The majority of process engineering and analysis is performed as part of the research platforms. Program level (integrated platform) analysis provides direction and focus to the overall research program by evaluating the technical, economic, environmental, and market aspects of biomass use via integrated pathways. Program analysis has three objectives: 1) to combine the results of platform analysis into biorefinery

[11] *Webster's Ninth New Collegiate Dictionary,* Merriam-Webster Inc. (1983).
[12] *The American Heritage® Dictionary of the English Language, Fourth Edition*. Houghton Mifflin Company (2000).

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.

Figure 19 shows the hierarchy of an analysis system. Analysis philosophy represents the highest-level assumptions and rules that an analysis system 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, useful, and updated regularly to reflect the dynamic nature of a robust R&D program.

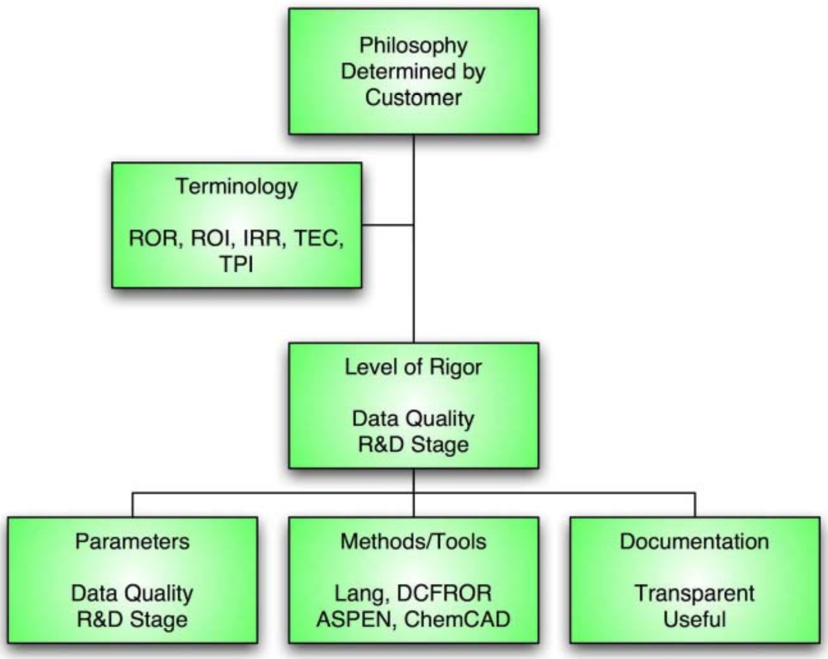

Figure 19: The Hierarchy of an Analysis System

Figure 20 shows how analysis aids the progression of R&D projects to deployment. Information (data) is used in a variety of assessments. These assessments feed broad strategic analyses, which culminate in technology transfer. Used in combination, different assessments provide a complete understanding of the OBP technologies. The different analysis types of the OBP program provide information and recommendations to the program to quantify the benefits, drawbacks, and risks of different biomass utilization scenarios. Results from each assessment, at the appropriate level of rigor, are used in the stage gate reviews of individual projects. Each type of OBP analysis is described below, along with the infrastructure required to develop them.

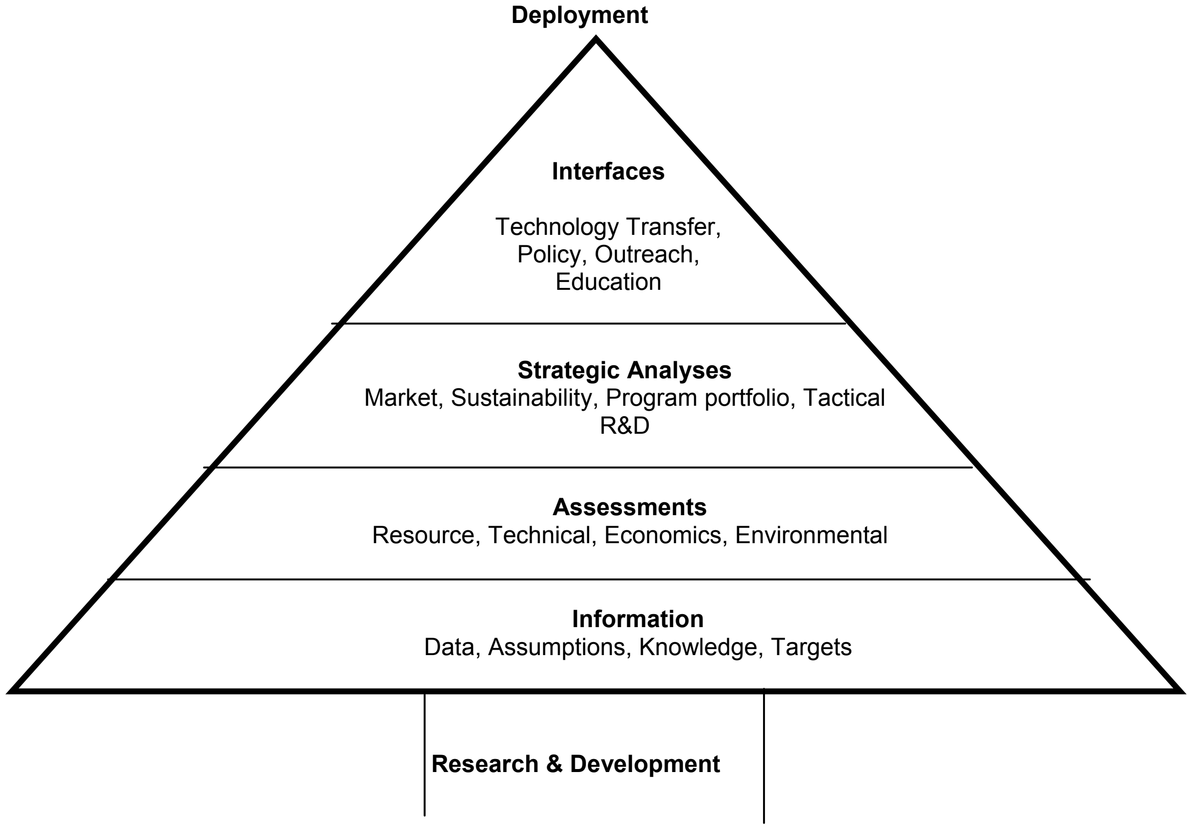

Figure 20: The Analysis Path from R&D to Deployment

In most cases, developing analysis products is an iterative process using outputs from several different assessments. One example, a technical assessment of a process design, is shown in Figure 21. From a chosen process design, parameters are identified and data collected or assumptions made. As the project progresses, more information is available and a progressively more robust assessment can be made. Optimization also occurs by recycling the results of the economic and environmental analyses steps back to alter the process design and mass and energy balances.

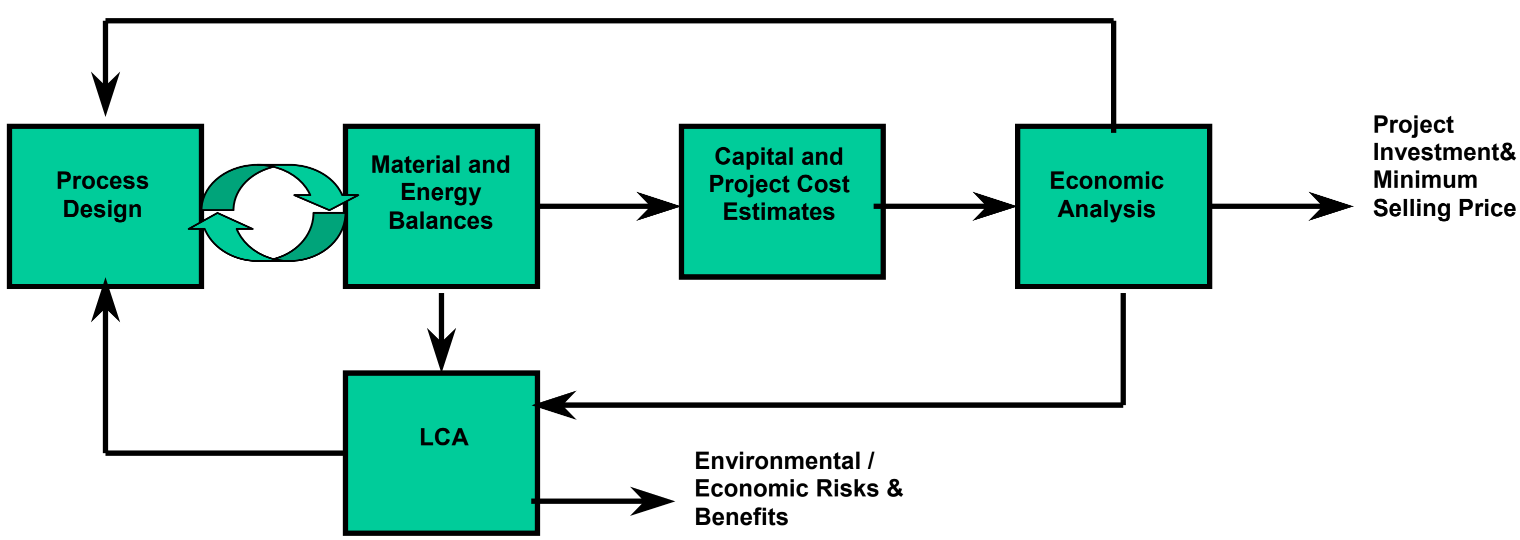

Figure 21: The Iterative Nature of Analysis

4.1 Analysis Infrastructure

Analysis infrastructure includes the resources (methods, tools, analysts) needed to perform the analysis for the Program. Maintaining these capabilities at the cutting edge is essential to ensure that the analysis provides the most efficient and most complete answers to the technology developers and the program. Appendix C lists the national labs' engineering and analysis capabilities, methods and tools. Analysis methods for biomass processes are as new as the processes themselves. While some methods and tools from other industries (especially the process industries which includes petroleum refining and petrochemical processing) can be used with modification, others, like biomass physical property estimation methods, must be developed. Coordination, development of new methods, and communication are the three pieces to continuing 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 emerging Hydrogen Program analysis group are complete. The next step is to develop similar alignment between the national laboratories in the NBC and 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 the following: improved understanding of EERE analysis methods, tools and inputs; improved communication between the analysis elements; and creation of technology design reports that specify technology baseline and technical targets on a program wide basis.

4.2 Biomass Resource 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 that is available for utilization. An example of output from feedstock resource assessment is crop suitability by geographic region of the United States, shown in Figure 22.

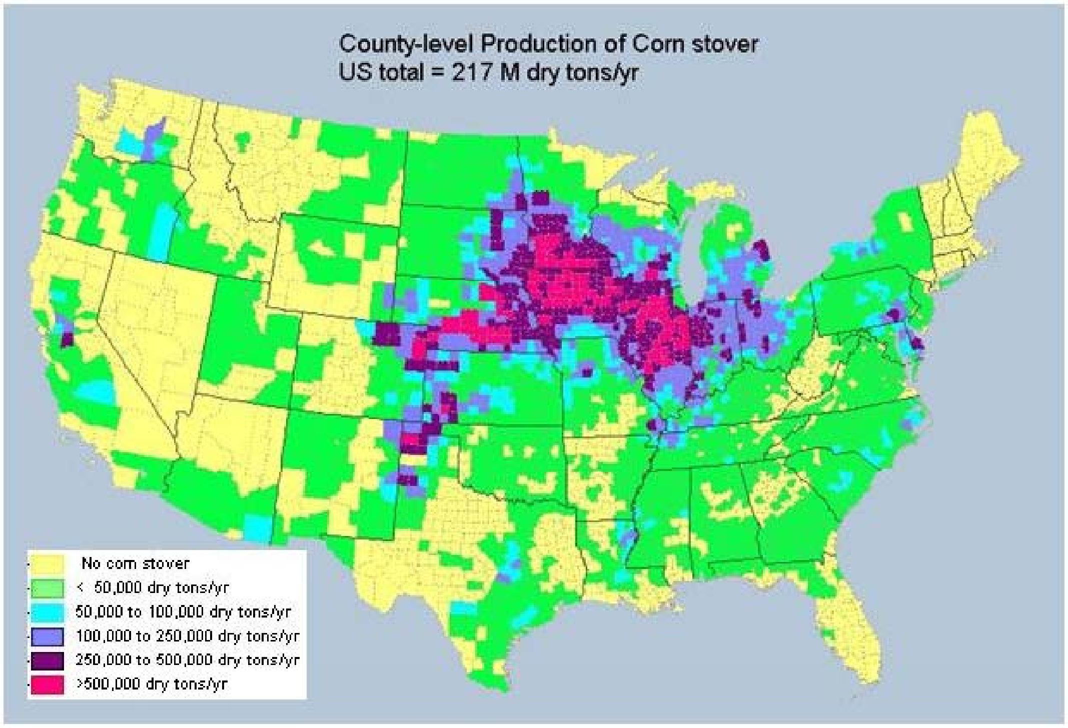

Figure 22: Corn Stover Production Map

4.3 Biomass Infrastructure Assessment

Biomass infrastructure assessment identifies the optimal methods for collecting, transporting, storing and processing of biomass feedstocks, and much of this analysis takes place in the Feedstock Interface R&D program area. Since a robust biomass infrastructure does not exist, it is crucial to evaluate the many options for getting the biomass to the processing facility to determine which one(s) make sense in which geographic areas. Developing a market basis for biomass is another part of the analysis, since biomass can be valued in several different ways. Combining the results of the Feedstock area analysis with those of the conversion platforms—sugar and thermochemical—allows synergies between the field and the processing facilities to be identified.

4.4 Technical and Economic Feasibility Analysis

Technical and economic feasibility analyses are performed to determine the potential economic viability of a process or technology, identify which technologies have the greatest likelihood of economic success, define which process parameters are the most critical to achieving the economic targets and ensuring the appropriate level of R&D funding is allocated to these areas.

The biomass scientific community is continually developing technologies and process improvements to make the slate of products more viable. An assessment of these emerging technologies and processes are an important component of these analyses to ensure the R&D is focused and directed toward reducing the time to commercialization.

Feasibility analysis is an iterative process conducted routinely during the R&D phase of work. Initially, a stage 1 level analysis is performed using published process and cost data to create a best-case scenario. This baseline study uses optimistic assumptions for feedstock cost, process efficiency, and yield. If the results of the baseline study appear feasible, then additional analyses are performed on the process parameters to determine the range of cost sensitivity. These analyses are used to assess the level of development of a process, whether the technology should remain in the portfolio, and if a major breakthrough is required or possible.

The economic competitiveness of a technology is assessed by evaluating its implementation costs for a given process compared to the costs incurred by current technology. These analyses are therefore useful in determining which projects have the highest potential for near-, mid-, and long-term success. During the development of the technology, the implementation cost is determined by varying the production volume, economy of scale, process configuration, materials, and resource requirements. The tools used for these analyses include process design and modeling, capital and operating cost determination, and cash flow analysis.

4.5 Environmental Analysis

Environmental analysis is used by the Program to quantify the environmental impacts of biomass 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.

4.6 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 bio-industry” optimization in the market penetration analysis. With the integration of the former biopower and biofuels programs and the efforts in identifying candidate products from biomass, we now have the information in one place to develop emerging and advanced biorefinery process designs for plants producing a combination of power, fuels and chemicals. The OBP is currently working with existing biorefineries (dry mills, wet mills, pulp and paper mills, 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 biorefinery process designs with integrated heat and power utilization will be created, using the information from all platforms and the feedstock interface program. Mass and energy balances will be developed along with capital and operating cost estimates at a stage 2 level of 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. A number of products will be selected to complete the process design from the “Top 10 Value Added Chemicals from Biomass” report. The purpose of this selection is to find model products that will allow a complete analysis of the biorefinery process designs. From this process design, modeling, and product optimization work, 1-2 possible pathways will be selected as the basis for designs of a biorefinery in industry-led projects with the partner's selection of products. The models developed as a part of this effort will be critical to evaluating options and opportunities relative to the program technology baseline characterizations.

4.7 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?

4.8 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 ability to analyze the development of possible biomass utilization. This is especially important in the area of environmental analysis, where renewable technologies are not well characterized. Also important in determining the benefits of renewables renewables is a longer horizon analysis model. This work is performed by PBA and provides the intermediate and end outcomes for the EERE logic model.

4.8.1 End Outcomes (Benefits)

Within the logic model framework (refer to Table 2), EERE follows three principles for benefits/outcomes evaluation: (1) benefits should be measured relative to what would have happened in the absence of the program; (2) benefits should be measured relative to the next best alternative technology instead of current technology; (3) the government impact should be reflected as an acceleration in commercial introduction of a technology and/or an alteration to the market penetration curve of a technology.

Timeframes

Three criteria timeframes are focused on for EERE analysis; retrospective, expected prospective, and option (or other potential prospective situations). The importance of retrospective analysis was shown by the National Academy of Sciences review. The review looked at whether or not the expenditure of tax dollars for DOE research brought a reasonable return to society and it led to an EERE desire to better quantify the benefits achieved by their programs. To that end, PBA is working with NREL's Energy Analysis Office to develop a retrospective analysis method and tool. The ultimate goal is a web tool that will be publicly available for this type of analysis. The method is being built with case studies for efficiency projects but not renewable energy projects so it may not be immediately applicable to biomass conversion technologies.

The retrospective analysis tool uses research and development budgets and timeframes and matches that information to market penetration data (both new market penetration and stock turnover are considered in the analysis). It then estimates market acceleration and increased benefits due to the existence of the program as compared to what would probably have happened if the program did not exist. The difference in benefits can be presented as a cost of DOE's research to show the benefits of DOE's work. Unfortunately, the tool does not automatically capture knowledge benefits although a single economic input can be entered for them. In other words, knowledge building (that could be in the form of patents that others build on) is not included in the current generation of the tool. The information gathering techniques and market curve fitting may also help with prospective analysis.

The results of retrospective analysis could assist with funding justification by showing how previous DOE research that now fits under the Biomass Program's heading has improved society. The information gathering techniques and market curve fitting may also help with prospective analysis by improving intermediate outcome calculations due to a better understanding of the markets and their drivers.

Expected prospective benefits have been reported for the Government Performance and Results Act (GPRA) during the last several budget cycles and are calculated by the EERE version of NEMS. The predicted economic, environmental, and security benefits that success in the programs will bring are compared to a baseline future that is reported in the Energy Information Administration's (EIA's) Annual Energy Outlook (AEO). The prospective benefits are used to justify the program's potential benefits to the country and to compare them with potential benefits of other programs. NEMS is intended to capture macroeconomic interaction that will affect the market size of any single factor. This includes feedback effects, upstream effects, and competition and synergies between technologies. To calculate the program's outcomes, feedstock cost curves and conversion costs are entered into NEMS for multiple future time-points. NEMS then estimates the macroeconomic status of the energy quadrant for each year through 2030. The difference between the baseline and the case with the program's inputs are the reported outcomes. MARKAL is an easier tool to use for these calculations but since NEMS is used by the EIA, it is easier to justify results from NEMS. MARKAL also provides better technology detail and estimates to 2050, but its market detail is not as rich as that in NEMS.

Other worldwide factors may affect the program's benefits, so an "Options" analysis has been deemed necessary. For example, greenhouse gas or carbon dioxide emissions may be taxed or restricted in the future. That would increase the outcomes of the Biomass Program's research because the world would likely become more dependent upon biofuels to replace petroleum fuels. PBA is investigating ways to capture the effects of those "Option" futures. The options analysis was originally envisioned as a couple of additional potential prospective scenarios. PBA is currently working with DOE's nuclear and fossil energy offices to define those scenarios. One of the defined cases will most likely involve constraints on greenhouse gas or carbon dioxide emissions and a second will involve increased fossil fuel prices. Like the expected prospective analysis, NEMS and/or MARKAL could be run to determine baselines for the defined cases and then estimate the program's benefits in these other potential scenarios. The analysis is not expected to require different feedstock or conversion cost information than the expected prospective case.

Other methods of options analysis are also being investigated. One involves calculating the technical potential of renewable technologies that would then provide "back-stop" prices for standard model technologies. In that case, a research product does not have to enter a market to add societal value; it provides value by keeping other prices low. A second "options" analysis under consideration involved measuring the reduction in price uncertainty. It is similar to the "back-stop" price calculation because the renewable technology provides a minimum price for the standard technology yet it also involves international trade issues and economic values.

Benefits resulting from options analysis will probably mirror those of the expected prospective analysis. They will most likely report the same criteria but have different values due to the different constraints on the energy quadrant.

Since the expected prospective analysis has been calculated historically it is the highest priority for EERE. Option analysis is the medium priority because it should require little extra effort from OBP. Retrospective analysis has not been well defined at this time so it is the lowest priority timeframe.

Criteria categories

The benefits or end outcomes that EERE reviews and reports are broken into four categories:

1. economic (e.g., energy cost savings),
2. environmental (e.g., reduction in emissions),
3. security (e.g., reductions in imported petroleum), and
4. knowledge (e.g., increases in fundamental knowledge useful for society).

PBA is currently in the process of determining which end outcomes will be used for selection and reporting. Different technologies address different issues, providing improvements that they want reported as end outcomes. For example, some technologies improve power grid security by increasing the distribution of electricity production. On the other hand, OBP projects can reduce the amount of imported oil used for transportation. Because different technologies have different needs, OBP needs to play a role in determining the outcomes reported.

PBA is leading the effort to determine the security, environment, and economic benefits. The knowledge criteria will not be included in the near future but EERE may eventually use the benefits that are being developed by DOE's Office of Science. The OBP needs to play a role in selecting the economic, environmental, and security criteria so that its unique benefits are included in the ultimate criteria. Those unique benefits are primarily due to the material nature of biomass. It is more efficient to produce most solids, liquids, and gases like polymers, transportation fuels, and syngas products from biomass than from energy forms like sunlight and wind. That uniqueness puts the OBP in an interesting position with regard to benefits; it is working on products that are more likely to replace crude oil based products than the other programs in EERE.

Currently, the benefits list is only for the expected prospective case. It does a good job of presenting the benefits of the Biomass Program by reporting cellulosic ethanol and oil savings as 2 of the 8 reported benefits in the 2005 budget. The following is a complete list of reported benefits:

- Electricity capacity (gigawatts)
- Electricity generation (billion kWh)
- Cellulosic ethanol production (billion gallons)
- Non-renewable energy savings (quads)
- Oil savings (quads)
- Carbon savings (million metric tons – MMT)
- Energy expenditure savings (billions $ in year 2000$)

The criteria reported in the budget were not broken into categories; however, other criteria were included in the GPRA data call, broken into the four categories listed above. The categories and criteria listed in the GPRA data call are:

- Economic
    - Energy cost savings (millions $)
    - Non-energy cost savings (millions $)
    - Net economic benefit (millions $)
- Environmental
    - Emission reductions (MMT carbon, NO_x, SO_x, PM, VOCs, CO)

- Security
    - Primary energy displaced (trillion Btu)
    - Petroleum displaced (million barrels)
    - Natural gas displaced (billion cubic feet)
    - Electricity displaced (billion kWh)
    - Coal displaced (million short tons)
    - Other energy displaced (trillion Btu)
    - Peak load reduction (megawatts)

Possible criteria for economic, environmental, and security benefits were included in the GPRA data call but knowledge benefits were not because they are not well enough defined. The security criteria will likely change from quantified savings (as listed above) to those that deal with security upsets to the country. The standard approaches to quantifying upsets include probability of potential occurrences, severity of potential occurrences, duration of the potential occurrences, and time to recover following an occurrence.

The biomass program needs to choose which products will be used to estimate the program's benefits. These products need to have a potentially high impact on the nations energy future. For example, within EERE the Vehicle Technologies and the Hydrogen and Fuel Cells Infrastructure Technology programs use transportation fueled by hydrogen, and the Solar Energy Technology and the Wind and Hydropower Technologies programs use power. Historically, the Biofuels program used cellulosic ethanol, the Biopower program used power, and the Office of Industrial Technologies used energy reductions (natural gas, coal, and others) by bioproducts.

For each product, the program needs to provide feedstock cost curves and conversion information. The feedstock cost curves provide the costs of biomass at different market sizes so that the macroeconomic models can vary the product prices depending upon the market size. Conversion information does not vary by feedstock market size but over time as technology is predicted to change. The necessary conversion information is 1) feedstock rate to a single conversion facility, 2) annual product production rate of that facility, 3) total project investment, 4) annual non-feedstock raw material cost, 5) annual waste disposal costs, 6) annual fixed costs, 7) other product yields (e.g., electricity), and 8) on-line time.

Life cycle assessments are used to investigate showstoppers (like farming sustainability) and to quantify changes for benefit modeling. Benefit models like NEMS only calculate market sizes for products within the energy sector so they require additional information from LCAs to report environmental benefits. All emission reduction calculations from benefit models require life cycle assessment results on the products within the product slate. Since much of that information has not been available, all emissions have been considered negligible for renewable energy sources. That technique has reduced the benefits estimated for ethanol in the past because ethanol derived from corn starch is assumed to have the same emissions characteristics as ethanol derived from biomass; whereas, life cycle assessments have shown that ethanol derived from biomass has lower emissions than that derived from corn starch. Beginning with the FY2005 budget, life-cycle data from the GREET model has been used to quantify the benefits of ethanol from corn grain and ethanol from biomass. That data will improve the outcomes produced by the Biomass Program reported in the annual GPRA data.

4.8.2 Intermediate Outcomes

Intermediate outcomes are individual market effects of EERE research projects. For transportation fuels and commodity chemicals, they are the market size and should be linked to price – the calculated output. End outcomes are then calculated using the market sizes.

Often the intermediate outcomes are transparent or reported with the end outcomes because they are calculated in NEMS or MARKAL. NEMS and MARKAL are based exclusively on least-cost calculations with minimal modeled regions; therefore, they miss other market drivers including “greenness” and regional issues. Due to those shortcomings, NEMS and MARKAL underestimate the market sizes of emerging and minority technologies. To overcome this issue, the market sizes for renewable technologies are estimated exogenously to NEMS and MARKAL and the results are hard coded into the macroeconomic models (e.g., using EERE’s “GreenPower” market models for electricity generation and RYM and ELSAS for E10 blending into the liquid fuel market).

The OBP will need to determine whether or not the currently used specialized biofuels market models provide adequate demand curves for the high-energy impact products which are being used model products for the sugar and thermochemical platforms. The demand curves will be time specific; in other words, one demand curve will be used for 2010, another for 2015, and a third for 2020. PBA needs to be consulted when developing these curves to provide input.

Appendix A: Individual Analysis Write-ups from MYTP
(edited 9-2004)

Biomass Feedstock Interface Analysis (WBS 1.1.1.1 and 1.3)

Supply Forecasts and Analysis (WBS 1.3.1)

Project Overview: Biomass supply schedules for energy crops, agricultural residues, and other feedstocks have been prepared. A county-level database on feedstock supplies is currently under development. This database will be useful for DOE-specific work such as life cycle analyses and analyses undertaken by EIA and PBA and for the public. To align future supply forecasts with advancements in harvest and collection technology improvements and optimized feedstock supply, this work links to the projects under the Emerging Feedstock Barrier area and the Supply Systems Logistics task.

Project Participants: USDA, ORNL, INEEL, NREL

Objective: Develop forecasts of future and existing biomass supplies and develop and document a vision for achieving an annual biomass supply of 1 billion dry tons.

Stated Benefits: Forecasts and feedstock supply data are important in shaping the design of cost and performance-competitive biorefinery technologies and in formulating the strategy needed for supplying a biorefinery industry capable of effecting a major reduction in our dependence on foreign oil.

Barriers Addressed: Lack of credible data on price, location, quantity, and quality of biomass.

Milestones	Completion Date
Corn stover and wheat straw supply schedules – document FY2003 analysis of current sustainable corn stover and wheat straw supplies	9/2004
Billion ton vision paper – develop and document a vision for achieving an annual biomass supply of 1 billion dry tons.	9/2004
Forest residue and urban wood waste supply schedules – re-evaluate forest residue and urban wood waste supply schedule forecasts based on assumptions developed for the billion ton vision paper. Post information on resource website.	9/2005
Perennial energy crop and agricultural crop residue supply forecasts. Update energy crop and agricultural residue supply forecasts using the POLYSYS model. Post information on resource website.	9/2006
Agricultural residues supply forecasts with advanced technology assumptions – estimate agricultural residue supply forecasts using advanced technology assumptions (e.g., single-pass harvester). Post information on resource website.	9/2007
Transport cost functions – develop regionally-specific transportation cost functions with variable facility demand to support crop and forest residue supply schedules. Post information on resource website.	9/2008
Supply forecast review – conduct review and update, as needed, of all major feedstock supply forecasts. Post information on resource website.	9/2009

Supply System Logistics (WBS 1.1.1.1 and 1.3.2)

Project Overview: A dynamic simulation feedstock supply model has been developed to represent the various stages of biomass collection, processing, storage, and distribution activities associated with supplying biomass to a biorefinery. The model is used to investigate the effects that climate, geographical, and biological factors have on the cost of delivering biomass. It will minimize the cost of delivered biomass by selecting an optimum mix of biomass sources, machinery, handling processes, capacities, storage, transportation systems and preprocessing options. Additional types of information to be provided will be energy input-output relations, labor demands, effects of feedstock quality requirements on costs, energy and labor, air and water emissions (for LCA), soil compaction from harvest equipment, waiting times and bottlenecks and implications of various storage options. The tool can also be modified to also simulate collection of other agricultural residues, forest products and a mixture of biomass resources.

Project Participants: USDA, INEEL, ORNL, NREL

Objective: Evaluate and define equipment and infrastructure options that will reduce the cost of delivered biomass from the present baseline of baling system of $53/dry ton to the cost goal of $35/dry ton. The task uses an integrated systems approach to establish minimum cost pathways.

The objective is realized by developing and applying a supply model that simulates the flow of biomass through collection, transport, storage, and preprocessing steps. The model will identify the incremental improvements at every step of the supply chain (optimum designs) and critical improvements for the integration of the entire feedstock supply infrastructure (logistics). Other industries have developed some very sophisticated systems analysis techniques to make their industries competitive. The biomass model is equally robust to take advantage of all of the innovative biomass supply options and logistical arrangements to determine least cost opportunities to produce and deliver biomass.

Stated Benefits: Facilitates the development of integrated biorefineries with optimized feedstock supply logistics to assure competitive delivered costs and year-round reliability in supplies of biomass feedstocks. Development of a biomass feedstock supply logistics model will help biorefinery business plan developers to assure the reliability of supply and cost competitiveness of feedstock planned and help infrastructure engineers and researchers develop equipment and systems that will assure timely collection, storage, and transporting of biomass to the biorefinery.

Barriers Addressed: This task addresses two major technical barriers as outlined in Roadmap for Agricultural Biomass Feedstock Supply in the United State: (1) uncertainty and risks associated with availability of adequate biomass supply to a biorefinery; (2) uncertainty in success and the high costs associated with the development of new equipment and supply infrastructure like single pass harvest and bulk storage. By explicitly accounting for actual yield (yield minus allowance for conservation), climatic impacts on the supply system and accurate cost information, the task seeks to reduce the uncertainty of feedstock supplies. Fear of unreliable feedstock cost and supply is a major barrier to procuring capital for start-up biorefineries. Our biomass model shows clearly how we can eliminate potential bottlenecks and how we can take advantage of multiple feedstocks to minimize storage and thus reduce costs.

Milestones	Completion Date
Develop feedstock assembly model – define optimal (least cost) baseline collection systems for straw and stover	8/2004

Verify and publish feedstock assembly model – optimize agricultural residue supply system incorporating novel packaging, storage, and transport options (single feedstock)	8/2005
Optimize feedstock assembly model using multiple agricultural residues – integrate physical and system dynamics models through virtual engineering tools	8/2006
Optimize feedstock assembly model for a forest biorefinery system – integrate forest biorefinery models through virtual engineering tools	8/2007
Optimize feedstock preprocessing systems using fractional milling concepts – develop a low cost, high value, densified, and flowable feedstock for a biorefinery	8/2008
Integrate feedstock assembly model with chemical process models (ASPEN) – integrate models through virtual engineering tools	8/2009

Funding (000):

	FY04	FY05	FY06	FY07	FY08	FY09
Biomass Feedstock Interface WBS 1	**602**	**945**	**1090**	**1000**	**925**	**800**
Supply Forecasts & Analysis WBS 1.3.1 (ORNL)	52	245	250	200	200	150
Supply Systems Logistics WBS 1.1.1.1 (INEEL)	160	200	290	250	225	200
Supply Systems Logistics WBS 1.3.2 (ORNL)	390	500	550	550	500	450

Sugar Platform Analysis (WBS 2.5)

Project Overview: This project supports the on-going research in the sugar platform, providing direction and focus to the research by evaluating the technical, economic, and environmental aspects of biomass sugar production and conversion. Much of the analysis work to be done is a continuation of past support to the sugar route to ethanol from lignocellulosic biomass. The process to produce ethanol will still be used as a base case process to evaluate economic impact of technology developments. However, emphasis will be given to the production of other products from the sugar streams. Specific activities include:

- Support will continue to be given to the Novozymes and Genencor subcontracts to determine impacts of the developments.

- The effect on MESP from the variability of a second large sampling of corn stover will be analyzed using techniques developed in FY03.

- The "State of Technology" case will be updated to properly reflect technologies demonstrated in the lab and pilot plant. It is anticipated that this case will be updated annually.

- Incremental developments that are required to get to $1.07 per gallon MESP target case will be clearly outlined. Particular focus will be given to determining the economic benefit of performing Saccharification at high solid and high temperature cellulases.

- The Clean Fractionation ideas will be analyzed as a way to process portions of intermediate streams to produce high value chemicals.

- The hot wash experiments will be analyzed for the material balance and the potential impact on the MESP of the biomass to ethanol process.

- Exploratory evaluations will be performed of the benefit of futuristic strategies for harvesting, biomass storage, and pre treatment of storage piles.

- Future directions for kinetic modeling in Pretreatment will be developed. One possibility will to combine CFD (Computational Fluid Dynamics) with accepted biomass depolymerization pathways.

Project Participants: NREL

Objective: Support ongoing research in the sugar platform via analysis activities.

Stated Benefits: Research will be prioritized based on technoeconomic analysis.
Barriers Addressed: Biomass recalcitrance. Cost of biomass conversion to sugars.

Milestones	Completion Date
Publish Corn Stover LCA Results	5/2004
Rigorous, Optimized Sugar Model	6/2005

Funding (000):

	FY04	FY05	FY06	FY07	FY08
Sugar Platform Analysis	$150	$300	$500	$300	$300

Thermochemical Platform Analysis (WBS 3.5)

Project Overview: Analysis is performed under this task to support the on-going research in the thermochemical platform. Analysis helps to provide direction and focus to the research by evaluating the technical, economic, and environmental aspects of biomass thermochemical conversion. Specific activities include:

- Biomass feed systems. Work will be done for biomass feed systems to determine the state of the art. This will involve gathering data on the various types of equipment including past experience, advantages and disadvantages for each.

- Gas cleanup. Work in the gas clean up area will focus on obtaining better costs for the various pieces of equipment for several scales and different operating conditions. This information will be used in the syngas models and costing spreadsheets to help focus on the most economical combinations for clean syngas production from both direct and indirect gasification.

- Oxygen and fuel synthesis as a function of oxygen purity. Reduced oxygen purity may improve the economics of direct gasifier systems. Producing lower purity oxygen will reduce the cost of oxygen generation; however, more nitrogen in the syngas will affect the downstream equipment sizes and possibly conversion efficiencies. The trade offs of oxygen purity with capital cost will be examined.

- Fuel synthesis. Producing a fuel product is another potential opportunity for biomass syngas. Examine the advantages and disadvantages of various fuel synthesis processes integrated with biomass gasification. Initial work will look at the potential of mixed alcohols. Future work is anticipated to examine Fischer-Tropsch liquids and methanol.

- State of gasification technology. Each year the state of biomass syngas technologies will be summarized. Initially a detailed design report will be constructed with material and energy balances, process flow diagrams, and economics for biomass to hydrogen production.

- Pyrolysis. Pyrolysis is one of the thermochemical conversion options that could play a role in biorefineries. Initial work will summarize the state of the technology followed by pyrolysis model development. Additional work will include analysis of upgrading methods for crude pyrolysis oil.

- Life cycle assessment/environmental analysis. Initially there will be a preliminary examination of the environmental impacts of biomass production. This will help to set priorities for future work.

Project Participants: NREL.

Objective: Crosscutting Activity—Support on-going research in the thermochemical platform via analysis activities.

Stated Benefits: Provide direction and focus to research by evaluating the technical, economic, and environmental aspects of biomass thermochemical conversion.

Barriers Addressed: Provide direction and focus to R&D by evaluating the technical, economic and environmental aspects of biomass thermochemical conversion.

Milestones	**Completion Date**
Pyrolysis process design and model	3/2004
Biomass syngas to hydrogen production design and model	9/2004
Biomass syngas to hydrogen production design report	12/2004
Effect of oxygen purity on direct-fired gasifier	8/2005
Evaluation of pyrolysis oil upgrading	9/2005

Funding (000):

	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Thermochemical Platform Analysis	507	728	1,100	1,100	1,100	1,100	1,100

Technical and Market Studies (WBS 4.4.1)

Project Overview: Activities included in the Products R&D portfolio include a very broad array of technologies. In part, this is because prior to creation of OBP, three different EERE Programs conducted work in “products”. As described in the MYPP, the Products R&D work has a significant near-term focus on the sugars and thermochemical platforms. However, it also includes work on oil-based products, biooil products, and potential platform co-products. Analysis is needed to support all of these platforms and their respective potential co-products and markets. An outcome of FY03 work included the identification of the “Top Ten” opportunities for the production of value-added chemicals from biomass that would support an integrated biorefinery, and the associated technologies that would offer the greatest impact in production of these intermediates. Follow-on to that work includes developing solicitation topics and core R&D efforts.

Project Participants: NREL, PNNL

Objective: The objectives for these analyses efforts include:

- To prioritize the technical barriers identified during the “Top Ten” Products analysis, to establish R&D targets, and to provide detailed analysis for other potential biomass platforms, co-products, and co-processing opportunities.
- Conducting market based analyses for bioproduct opportunities by assessing the current chemical market segments and identify growth areas for polymers, plastics, coatings, and solvents, by identifying the needs of these market segments with respect to new functionality needed to meet consumer and processors needs and by assessing the relationship between cost structure and performance for each major market segment.
- Completion of the Top Ten analysis by completing the data base; defining specific technical barriers for the Top Ten selections; further defining technical opportunities for oil, lignin, polysaccharides and biooil based products; assessing other opportunities for sources of biomass components to produce products; and working with other technical analysis teams within OBP to address integration of biobased products within biorefinery scenarios.

Stated Benefits: More detailed analysis will provide data and information necessary to establish technical targets for products platform R&D. As barriers are overcome through research and specific targets are met, economic viability for value-added chemicals can be demonstrated. Analyses will support all platform R&D in achieving their technical goals and targets. This analysis also supports OBP’s goal to establish the industrial viability of at least four (4) commodity scale chemicals that can be co-produced in an integrated biorefinery by 2010. The Integrated Biorefinery element of the MYTP is also responsible for these four outcomes The Products R&D area will assist in facilitating some of these through reducing risks in assessing pioneer plant issues related to products.

Barriers Addressed:

- Prioritizing technical barriers that can be overcome with R&D
- Establishing technical targets and quantifiable metrics for Products Platform R&D

Milestones	Completion Date
Metrics for barriers related to producing products	4/2004
Market analysis with Top Ten Study	6/2004
Interim report on expanded pyrolysis oil upgrading concept to include new chemical products (PNNL).	6/2005
Model development and validation	9/2005
Process definition	6/2006

Funding (000) split between NREL and PNNL about 50/50:

	FY03	FY04	FY05	FY06	FY07
Analysis in Products R&D	0	300	497*	450	450

*2005 amount includes $47K to PNNL for pyrolysis upgrading analysis.

Integrated Biorefinery Analysis (NBC) (WBS 5.4)
In the MYTP – not funded by the program for FY04.

Project Overview: This project is aimed at maximizing the benefit of the integrated biorefinery projects to OBP and the biomass community as whole. By developing ways to show quantified progress to project goals and to help partners effectively share non-proprietary technical advances; the learning curve for biomass utilization can be reduced. The resource allocation to this task will change as the number of projects or funding in integrated biorefinery platform changes. Specific activities include:

- Understanding the different types of methods and levels of rigor suitable for quantifying progress in the various types of integrated biorefinery projects.

- Developing working relationships with members in the projects and at GO to develop routes for information dissemination.

- Selecting a method or set of methods to use and integrating it into the project structures in a way that is easy, efficient and useful to the project and OBP.

Project Participants: NREL

Objective: Develop methods for integrated biorefinery project partners to quantify their progress toward stated goals for DOE and provide a conduit for sharing of non-proprietary information that can benefit biomass utilization efforts as whole.

Stated Benefits: Provide metrics and methods for evaluating and reporting on the technical, economic, and environmental aspects of integrated biorefinery projects.

Barriers Addressed: Provides measures of success for process integration and identification and documentation of pioneer technology risks.

Milestones	**Completion Date**
Report on possible methods for quantifying biorefinery projects' progress	7/2004
Develop best method and use on 2 test projects	1/2005
Integrate method into multiple projects	1/2006

Funding (000):

	FY04	FY05	FY06	FY07	FY08
Integrated Biorefinery Analysis	0	0	0	0	0

HQ/Field Managed Analysis (WBS 6.2.1)
No MYTP write-up available. Information extracted from the FY05 AOP submission.

National Laboratory Cross-cutting Analysis (WBS 6.2.2)

Project Overview: The National Laboratory Cross-cutting analysis project covers work in areas that does not easily fit into a single research project. The majority of process engineering and analysis is performed as part of the research platforms; refer to the specific platform analysis projects for details. The integrated engineering and analysis team performs crosscutting analysis that benefits multiple Biomass projects and external collaborators, and provides direction and focus to the overall research program by evaluating the technical, economic, and environmental aspects of biomass utilization via integrated pathways.

Specific activities include:
Biorefinery process design and optimization
With the integration of the former biopower and biofuels programs and the efforts in identifying candidate products from biomass, we now have the information 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). A stage 1 analysis utilizing 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 4-5 emerging biorefinery process designs with integrated heat and power utilization will be developed, using the information from all platforms and the feedstock interface program. Mass and energy balances will be developed along with capital and operating cost estimates at a stage 2 level of 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 4 model products will be selected to complete the process design from the products platform Top 10 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, 1-2 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. A second round of biorefinery development is envisioned using advanced technologies in the FY07-08 timeframe.

Emerging technologies assessment
The biomass scientific community is continually developing technologies that could substantially improve the production of biomass intermediates. Initial assessment of emerging technologies that are not currently part of a research platform but have potential to improve biomass utilization is performed under this project to ensure biomass research stays at the cutting edge, reducing the time to commercialization and optimizing R&D dollars. A stage 1 level analysis will performed using available process and cost data and optimistic assumptions to create a best case scenario. If this scenario is feasible, then 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. Catalytic production of ethanol from syngas is an example of one such technology. This will be an ongoing task and the results feed both the research platforms and the biorefinery analysis discussed above.

Analysis infrastructure development

Analysis methods for biomass processes are as new as the processes themselves. While some methods and tools from other industries can be used with modification, others, like biomass physical property estimation methods, must be developed. Coordination, development of new methods, and communication are the three pieces to continuing 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 at NREL to combine the former biopower and biofuels analysis teams and align with the Hydrogen group are complete. The next step is to develop similar alignment between the national laboratories in the NBC, then the biomass community as a whole.

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 simple methods to track progress on all OBP projects including solicitations and earmarks), and continued pioneer plant analysis to understand first of a kind plant costs for stakeholders. Efforts to improve communication of analysis results to DOE and stakeholders include improved understanding of EERE analysis methods, tools and inputs, participation in an FAQ site for OBP staff, development of a multi-year analysis plan.

Project Participants: NREL

Objective: The project team has three objectives: 1) to integrate the results of platform analysis into biorefinery process designs and an optimization program, 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 supports platform analysis and industry-led projects.

Stated Benefits: This analysis project provides quantifiable measures of success towards OBP's goals and is a part of the multi-year analysis plan (MYAP) for OBP and its EERE analysis activities.

Barriers Addressed: Provides crosscutting analysis and methods development to improve program analysis.

Milestones	**Completion Date**
Risk analysis methodology for scientific processes	9/2004
Emerging technologies status report	6/2005
Comprehensive emerging biorefinery analysis	6/2006
Advanced technologies status report	9/2007
Comprehensive advanced biorefinery analysis	5/2008

Funding (000):

	FY04	FY05	FY06	FY07	FY08
National Laboratory Cross-cutting Analysis	$620	$1,600	$1,100	$1,100	$1,100

Appendix B: Stage Gate Engineering Guidelines
(discussed in section 2.2.1)

Technical and Financial Assessments in the Stage Gate Process

Conceptual process engineering design and techno-economic analysis is used extensively in the Program to carry out the detailed technical and financial assessments that are integral parts of the Stage Gate process. We practice a graded approach to these assessments meaning that as the projects move along the development pathway, the assessments become more robust and hopefully, more accurate. The Program has developed a series of detailed process models and assessment tools for the main process concepts under development. These tools are used where appropriate. However, when new ideas or process concepts are being considered, these models and tools must be developed. The information below describes the level of robustness appropriate for the assessments at each gate in the process.

New Ideas

Gate 1 – Idea to Preliminary Investigation

Objective: Process engineering validates research direction and provides engineering perspective.

New Idea Not Existing in an Available Process Concept Tool

1. Talk to engineering team about idea and any alternatives– get engineering perspective.
2. Possible profit margin calculation (value – feed costs=margin for process costs).
3. Possible simple fraction of revenue for feedstock (FRF) calculation
4. Determine what questions need to be answered in Stage 1.

New Idea Relates to Improving Existing Process

1. Talk to engineering team about potential cost reductions and design impact.
2. Possible calculation of best case cost reduction - total elimination of the associated cost, or use of previous sensitivity studies.
3. Determine what questions need to be answered in Stage 1.

Commercial Track

Gate 2 – into Detailed Investigation

Objective: Process engineering develops a Block Flow Diagram (BFD) and gross production cost.

New Idea Not Existing in an Available Process Concept Tool

1. BFD
2. Inside Battery Limits (ISBL) equipment only for process model
3. Preliminary modeling - Non-rigorous mass and energy balance (i.e. lignin model or transgenic cellulase from plant calculations)
4. Economic analysis capturing gross operating and capital costs (large ticket items)
5. Operating cost calculations use standard utility costs (need to determine standard)
6. Capital costs from database
7. Fixed costs as a percentage of capital costs
8. Use Lang factor to go from purchased equipment cost to Total Project Investment
9. Use Capital Charge Factor (a certain ROI embedded) to go from TPI to $/production unit for capital
10. Add Capital and Operating Costs for Initial Minimum Selling Price Estimate

New Idea Relates to Improving Existing Process

1. Use existing models to evaluate impact of improvement
2. Perform sensitivity on uncertain data/costs to direct research

Gate 3 - into Development
Objective: Develop Process Flow Diagrams (PFDs) and detailed production cost. New ideas and process improvements to otherwise existing processes are handled the same way at this stage.

1. PFDs
2. Add Outside Battery Limits (OSBL) equipment in process model
3. Detailed modeling - detailed mass and energy balance (i.e. enzyme and two-stage models) using data from Stage 2.
4. Economic analysis with all capital and operating costs to +/- 30 to 50%.
5. Capital costs from vendors, Engineering and Construction firms
6. Fixed costs broken out.
7. Break out installation, contingency and other indirect costs. Determine what contingency should be used.
8. Break out ROI, equity into inputted numbers.
9. Perform sensitivity analysis with more defined ranges to direct research.
10. Additional analyses as indicated by potential customer representatives.

Gate 4 – into Validation
Objective: Develop a detailed engineering and economic design report. Since it is expected that by Gate 4 an industrial partner will be very involved and positioned to take over project leadership, the technical and financial assessments carried in support of Gate 4 are at a minimum conducted jointly by NREL and the industrial partner.

1. Refine model using site-specific data if available.
2. Use customer or industry accepted financial parameters.
3. Generate design report.
4. Perform kinetic modeling on key reactions to verify scale up.
5. Perform risk analysis to support customer in seeking process guarantees, funding.
6. Transfer information to industrial partner.
7. Support detailed design development by industrial partner.

Research Track
The technical and financial assessments of projects on the research track are very different from the assessments for commercial track projects. The emphasis is on identifying the relative importance of the scientific questions and problems to be explored by estimating the kinds of benefits or improvements in technology that could accrue if we had answers to the scientific questions.

Gate A - into Exploratory Research
Related to a commercial track project
Use existing models to run sensitivities on possible technology improvements enabled by the research.

New and unrelated to a commercial track project
Develop new process concept sufficiently to determine potential cost savings compared to existing process concepts.

Gate B - into Development Research
In Gate B the project must be related to a commercial track project so existing models can be employed to run sensitivities on possible technology improvements enabled by the research.

Appendix C: National Laboratory Capabilities, Methods and Tools
(discussed in section 4.1)

Table C-1: Laboratory Capabilities

Area	ANL	INEEL	NREL	ORNL	PNNL
Supply and cost curves				feedstock	
Technical & Economic Analysis	processing, vehicle	Feedstock assembly and Processing separations	processing	feedstock delivery	processing
Life Cycle Assessment	X	Providing data to LCA activities	Fuels and power		X
Market changes (penetration & size)	X	Baselining feedstock assembly and processing separations systems			bioproducts
Benefits (Industry-wide GHG reductions, reduced oil imports)	X	Baselining feedstock assembly and processing separations systems	X?		
Infrastructure (feedstock)	hydrogen delivery	Feedstock harvest, collection, fractionation, storage, and transportation	X (in biomass to H2 -- Bob Evans)	feedstock	
Integrated Assessment of Global Change				Environmental Sciences Division	X

Table C-2: Laboratory Analysis Methods

Area	ANL	INEEL	NREL	ORNL	PNNL
Process Design		Software and hardware design systems	Conceptual	X	Conceptual
Mass/Energy balance		Steady state and dynamic models and apparatuses	Steady state (SS)		Steady state (SS)
Financial		Direct measurements of unit operation costs and delivered cost	DCFROR (10% hurdle rate) Plant gate cost	Farmgate cost Delivered cost	
Risk	Monte Carlo / single variable sensitivities	Monte Carlo / single variable sensitivities	Monte Carlo / single variable sensitivities	Monte Carlo in Dynamic simulation	Monte Carlo / single variable sensitivities
Capital costing		Direct measurements, and Agricultural cost generators	+50/-30% estimates scaling based on flow rates	Vendor info +/- 10%	+50/-30% estimates +/-10% when needed
Operating costs		Direct measurements, and Agricultural cost generators	Chemical Marketing Reporter, Bureau of Labor indices, CEP indices, Chemical indices	Department of Labor & EIA statistics	
Energy Savings estimation	Absolute energy use for specific systems & comparisons between them	Direct measurements; Steady state and dynamic models and apparatuses	Gross replacement of oil		
Emission Reduction estimation	Absolute energy use for specific systems & comparisons between them	Calculated from energy savings estimation	Gross replacement of oil		
Feedstock supply		Direct measurements; Local grower surveys; USDA crop surveys		SS production models (updating) Dynamic production model (in production)	
Market Penetration	See tools	Grower and industry surveys		POLYSIS is more of an ag economy transformation tool	Technology Planning and Deployment Group with its own techniques and tools
Rigor	ANL Quality Control Plan	Stage Gate Engineering Guidelines	Stage Gate Engineering Guidelines	Internal Lab Procedures / External review	Peters & Timmerhaus

Table C-3: Laboratory Analysis Tools

Area	ANL	INEEL	NREL	ORNL	PNNL
Feedstock supply		GIS (ARC/INFO); EXTEND; STELLA; VE-Suite, and a number of statistical analysis tools	Talk to Bob Evans	POLYSIS / Supply web site (in development) EXTEND (dynamic production model) / ORIBAS / BIOCOST / SAS (crop residue supply curve development) / MATLAB (every once in a while)	
Operations & Scheduling Tools		GIS (ARC/INFO); EXTEND; STELLA; VE-Suite	H2 Storage & Delivery model (Maggie Mann)	EXTEND	
Process Design	Talk to Jim Frank	AutoCAD; LabView; Developing virtual engineering tools	AutoCAD, Gatecycle	AutoCAD / Talk to Brian Davison	Visio
Unit Operation Design		PIV, FLUENT, CFX5, ABAQAS, and Hot wire anemometry	Corrosionpredictor.xls	FEMLAB	CFD (microchannel reactors)
Unit Operation Mass balance	Talk to Jim Frank	ASPEN Plus, ASPEN Dynamics, ChemCAD	Excel, Aspen Plus	Talk to Brian Davison	Excel & ChemCAD
Unit Operation Energy balance		FLUENT; CFX5; ABAQAS; Developing virtual engineering tools	Aspen Plus		ChemCAD
Equipment Costing		Direct measurements	Equipment database Aspen ICARUS software	Vendor information	ChemCost, Vendors, process design manuals, past project data
Life Cycle	GREET (Excel/VBA, Visual Basic front end is optional)		TEAM		LCAdvantage+ (ChemTools every once in a while)
Risk/Uncertainty	Crystal Ball	Physical and system dynamic models coupled through VE-Suite	Crystal Ball	EXTEND (dynamic simulation of supply logistics) / POLYSIS (stochastic analysis of temporal variability in residue supplies)	Crystal Ball
Data Management	Excel	GIS tools, Excel, Oracle, and Access	Access, VB, VBA	SAS, ORRECL (energy crop yields)	Access

Area	ANL	INEEL	NREL	ORNL	PNNL
Market changes (penetration and change)	VISION / AVS2		Talk to Eldon Boes	IMPLAN (quantifying macroeconomic benefits -- e.g., rural economy)	
Reporting	Design reports, Gate reviews, Peer-reviewed Publications, Conference Presentations, Websites	Design reports, Gate reviews, Peer-reviewed Publications, Conference Presentations, Websites	Design reports, Gate reviews, Peer-reviewed Publications, Conference Presentations, Websites	Design reports, Gate reviews, Peer-reviewed Publications, Conference Presentations, Websites	Design reports, Gate reviews, Peer-reviewed Publications, Conference Presentations, Websites
Data Display	Some Molecular Modeling tools	CFD postprocessing, Fieldview, Virtual Reality, TechPlot	Some Molecular Modeling tools		Some Molecular Modeling tools
Economic Evaluation	Ask Marianne Mintz	Physical and system dynamic models coupled through VE-Suite	Excel spreadsheet Metric equation	BIOCOST / Excel spreadsheet (Turhollow, Perlack)	Excel Spreadsheet
Energy Savings estimation		Physical and system dynamic models coupled through VE-Suite	Spreadsheet model (Spath)		Excel
Emission Reduction estimation		Physical and system dynamic models coupled through VE-Suite	Spreadsheet model (Spath)		Excel
Data translation between tools		Physical and system dynamic models coupled through VE-Suite	Excel spreadsheet (Ruth)		
Integrated Assessment of Global Change		Physical and system dynamic models coupled through VE-Suite			MiniCAM / SGM
Project Management		MS Project	MS Project		MS Project
GIS Information		GIS and Oracle		ARC/INFO & Oracle (linked with SAS)	
Statistical Analysis		Numerous statistical packages and people available			

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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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