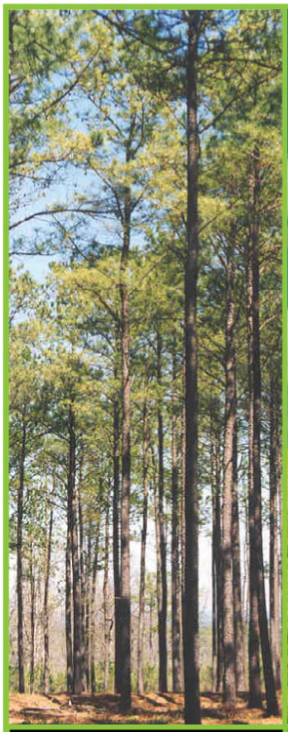
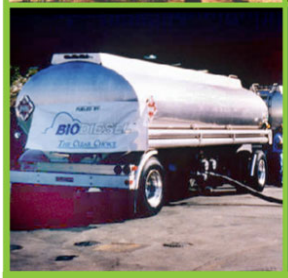


U.S. Department of Energy Office of Energy Efficiency and Renewable Energy

Biomass Program



National Biofuels Action Plan Workshop Summary Report

A report to the Biomass Research and Development Board on efforts to coordinate Federal activities to meet the President's Biofuels Initiative

May 2007

Prepared by participating agencies in the
Biomass Research and Development Initiative

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

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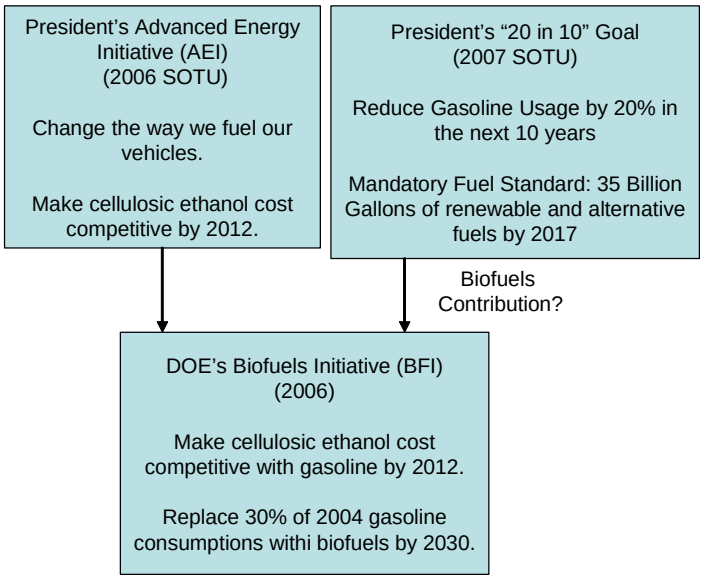
List of Acronyms	
“20 in 10”	President Bush's goal to reduce gasoline consumption by 20 percent in the next 10 years and increase our supply of renewable and alternative fuels
30x30	Biofuels Initiative goal to replace 30 percent of current levels of gasoline consumption with biofuels by 2030
AEI	Advanced Energy Initiative
ARS	USDA Agricultural Research Service
AS-IA	Assistant Secretary - Indian Affairs
ASTM	American Society for Testing and Materials
BEES	Building for Environmental and Economic Stability (Lifecycle Analysis Software)
BFI	DOE’s Biofuels Initiative
CHP	Combined Heat and Power
CSREES	USDA Cooperative State Research, Education and Extension Service
DOC	Department of Commerce
DOE	Department of Energy
DOI	Department of Interior
EERE	DOE office of Energy Efficiency and Renewable Energy
ENG	NSF Engineering Directorate
EPA	Environmental Protection Agency
ETVP	EPA Environmental Technology Verification Program
FIA	USDA Forest Inventory and Analysis
GM	Genetically Modified
GTL	Genomes to Life
HFCIT	DOE Hydrogen, Fuel Cells and Infrastructure Technologies Program
ITA	DOC International Trade Administration
M&E	Mortality and expense risk charge
MCB	National Science Foundation Division of Molecular and Cellular Biosciences
MEWG	Metabolic Engineering Working Group
MPS	NSF Mathematical and Physical Sciences Directorate
MSW	Municipal Solid Waste
NEPA	National Energy Policy Act
NIST	National Institute for Standards and Technology
NRI	USDA Natural Resources Inventory
NSF	National Science Foundation
NSR	New Source Review
OAR	EPA Office of Air and Radiation
OBP	DOE Office of Biomass Program
OCE	USDA Office of Chief Economist
OEPNU	USDA Office of Energy Policy and New Uses
OFEE	Office of the Federal Environmental Executive
OMB	Office of Management and Budget
ORD	EPA Office of Research and Development
OSTP	Office of Science and Technology Policy
OTAQ	EPA Office of Transportation and Air Quality
POC	Point of Contact
SBIR	Small Business Innovation Research
SC-BER	DOE Office of Science, Office of Biological and Environmental Research
SC-BES	DOE Office of Science, Office of Basic Energy Science
SRWC	Short Rotation Woody Crops
USDA	United States Department of Agriculture
USGS	United States Geological Service

Executive Summary

Figure 1. The President's and Department of Energy's Biofuels Related Goals



The President announced goals to increase the nation's use of biofuels in his 2006 and 2007 State of the Union addresses. Subsequently, the Department of Energy announced a Biofuels Initiative (BFI) (Figure 1).

The announcements of these goals and initiatives have re-emphasized the need to coordinate the biofuels activities within the Federal government. This document is the result of a Federal agency workshop held November 28-29, 2006 in Washington, DC to initiate the coordination process (http://www.biofuelspostureplan.govtools.us/). The main objectives of the workshop were to define current and future Federal agency and program roles and activities, identify gaps and opportunities to collaborate, and assess budgets related to biofuels production and use to meet the President's AEI and the DOE's "30x30" goals. At the time of this workshop, the President's 2007 State of the Union "20 in 10" goal was not announced. However, the results of the November workshop are still relevant to the interagency coordination and collaboration needs to meet this additional biofuels goal, albeit at an accelerated schedule, which reinforces the need for timely action on the report's recommendations.

This *National Biofuels Action Plan Workshop Summary Report* (*Workshop Summary Report*) is being prepared for the interagency Biomass Research and Development Board (Board), established by the Research and Development Act of 2000 and revised by the Energy Policy Act of 2005. The interagency Board acts as the governing body that brings coherence to Federal strategic planning by coordinating research and development activities related to biobased fuels and biobased products. This *Workshop Summary Report* is intended to provide the Board with a framework to begin to bring coherence to Federal strategic planning in the area of biofuels to meet these goals and develop a more detailed *National Biofuels Action Plan (Action Plan)*. The Board is co-chaired by DOE and the U.S. Department of Agriculture (USDA), and includes members from:

- National Science Foundation (NSF)
- U.S. Environmental Protection Agency (EPA)
- U.S. Department of the Interior (DOI)
- Office of Science and Technology Policy (OSTP)
- Office of the Federal Environmental Executive (OFEE)
- U.S. Department of Transportation (DOT)
- U.S. Department of Defense (DOD)
- U.S. Department of Commerce (DOC).
- U.S. Department of Treasury (Treasury)

Treasury, DOD, and DOC were not on the Board at the time of the workshop but have recently joined. DOD and DOC were invited to attend the November 2006 workshop. Continued interagency collaboration will be needed to implement the recommendations in this report and to take the next step toward developing a more detailed *Action Plan*, as requested by the Office of Management and Budget (OMB). Ultimately, this *Workshop Summary Report* and the *Action Plan* (to be developed) will help increase the ability of these government agencies to work with each other and with key stakeholders to successfully meet the President's and the DOE's goals.

A *Needs Requirement Document* was prepared and distributed prior to the workshop to provide guidance to participating agencies for identifying their biofuels activities. The *Needs Requirement Document* summarized input from various stakeholder meetings on the RD&D, policy, infrastructure, deployment, education/outreach, and regulatory (policy, permitting, etc.) needs required to meet the President's AEI and the DOE's BFI goals.

Prior to the workshop, each agency was asked to submit detailed accounts of activities related to biofuels in their current portfolios and to prepare summary presentations of these activities to be discussed during the workshop. The workshop was organized into breakout sessions and the session attendees were selected by their own agencies' Points-Of-Contact (POCs), who were appointed by the Board. The breakout sessions covered the main biofuels topic areas of:

- Feedstocks (from field/forest to plant gate)
- Biochemical Conversion Technologies (fuels and co-products opportunities)
- Thermochemical Conversion Technologies (fuels and co-products opportunities)
- Technology Integration, Deployment, and Permitting for Biorefineries
- Biofuels Infrastructure (from plant gate to vehicle technologies)
- Communication, Education, and Outreach

The breakout sessions began with agency presentations summarizing their activities. Due to time limitations, the session participants focused on 4 to 5 sub-elements in each topic area to discuss in depth, including identifying the key barriers, timeline of activities to overcome these barriers, current and future agency activities, and related budgets. The participants also identified gaps and synergies and developed recommendations to address them.

After the workshop, interagency drafting teams were formed from each breakout session to finish reviewing all sub-elements in detail and develop a draft *Workshop Summary Report*. Each section contains tables that capture the major barriers, a timeline of activities to overcome the barriers, and an attempt to identify funding by each agency for these activities. Each section also includes detailed recommendations made during the workshop. These tables and recommendations were further developed during the interagency team's drafting of this document and during each agency's review of the draft.

The recommendations in the following section capture all the administrative and management needs expressed during the workshop that should be addressed by the Board, first and foremost. The detailed recommendations provided during each breakout session are captured within the related sections of this report and are more relevant for interagency team consideration. This *Workshop Summary Report* is intended to support the development of a *National Biofuels Action Plan*, tentatively due in fall 2007. One of the key recommendations to the Board is to establish or formalize the existing interagency teams to further develop this report into an *Action Plan* (see Appendix A for suggested interagency teams and agency members).

Summary of Overall Administrative and Management Recommendations

1. **Set up focused interagency teams and a framework for reporting to the Board.**
    a. Team membership should include knowledgeable and active representatives from agencies and programs identified as having roles in each biofuels area (Table 1). See Appendix A for a list of the interagency teams based on agency input and a summary of their proposed activities.
    b. The team action items should include:
        i. Further develop this *Workshop Summary Report* into a comprehensive *Action Plan* for meeting the President's goals, that include:
            - A schedule and timeline that supports the goals, objectives, and targets and includes key milestones and decision points.
            - Current federal activities and associated funding.
            - Opportunities for interagency collaboration and partnership building.
        ii. Evaluate the progress in federal activities toward implementing the *Action Plan*;
        iii. Implement the recommendations from the Board and the *Workshop Summary Report*;
        iv. Develop additional recommendations to improve the coordination of federal agency biofuels activities and budgets to the Board.
        v. Report progress to the Board as needed but at least biannually;
    c. A framework for team functionality such as frequency of meeting and reporting to the Board needs to be developed.
        i. The Board should leverage already existing interagency teams (e.g. Woody Biomass Utilization Group) for setting up interagency teams or sub teams to focus on specific issues.
        ii. Sub-teams may be formed to focus on specific issues within each biofuels area. These sub-teams could conduct periodic collaborative interagency meetings on overcoming specific barriers.
        iii. A lead agency should be designated specifically to focus on technology development. That lead agency must establish decision point milestones and technology development milestones. A decision body and advisory panel needs to be established that will make technology development decisions, and funding decisions.

2. **Reassess the Technology Integration, Deployment, and Permitting section of this document**. This workshop breakout session did not cover the topic area and also did not involve the right personnel from each agency - as a result the session did not cover the necessary material. The team needs to reassess this topic area and make specific recommendations for Board action. The related section in this report attempts to frame up this future discussion.

3. **Identify other Federal agencies' biofuels related goals and gain consensus on how they support the President's goals.** DOE set internal goals to align with the President's AEI goals and set a longer term "30 x 30" goal. Note, at the time of the workshop, the President's "20 in 10" goal was not announced. Other agencies may have developed, or want to develop, biofuels goals. Agencies may elect to interpret the President's goals and set their own agency's goals differently, based on their agency's role(s), mission, and

performance measurements. The Board should develop consensus on these agency goals and performance metrics, and gain an understanding of how they fit together in support of the President's goals and include this in the *Action Plan.*

4. **Create a detailed agency activity database with funding**. For the interagency teams to further develop and implement the *Action Plan,* a detailed accounting of agencies' activities is needed that incorporates and goes beyond the information in Tables 1 through 4 of this document. For this amount of information, a "living" database maintained and accessible by all agencies is the most efficient and effective mechanism for assembling and sharing the data. This database would be useful in coordinating activities and funding (current and planned).

5. **Conduct annual reviews of progress in implementing the *National Biofuels Action Plan* (to be developed). Update the *Action Plan* as needed.** The review will monitor progress, identify new focus areas, reassess priorities, and evaluate the effectiveness of the interagency teams for coordinating federal biofuels activities. Consider adjustments to the *Action Plan* as other potential consumers (e.g. aviation) of biofuels emerge.

6. **Identify level of investment needed**. A study should be conducted to put a "price tag" on the necessary level of investment to reach the President's biofuels goals. This *Workshop Summary Report* and the *Action Plan* (to be developed) will only account for current and future Federal (an possibly State or local government) agency investments. The actual level of funding required to meet the President's AEI and "20 in 10" goals should be evaluated more fully so that decision-makers are aware of the sizable investments that will be needed. This can be used by the interagency teams and the Board to identify under-funded biofuels activities and justify budget requests. The next iteration of this report, or the *National Biofuels Action Plan,* should include funding information (Table 4 in each section of this document) at the activity level vs. the agency level.

7. **Board membership should be expanded** to include other agencies such as the Departments of Commerce, Defense and Treasury. An expanded Board is better positioned to coordinate multi-agency efforts to achieve the President's biofuels goals.

8. **Discuss and define the needs for an interagency policy team**. The *Workshop Summary Report* and workshop focused on research, development, and deployment (RD&D) and did not focus on policy. The development of an interagency policy team to evaluate past and pending legislation, relevance to agency missions and regulations, and the development of joint federal policy within the Executive Branch is recommended.

Summary of Agency Roles within Each Biofuels Area

Agency roles in each biofuels topic area described in Table 1 are not intended to be an exhaustive list of activities but rather a brief overview. Agencies roles and activities are described in more detail in each biofuels topic area of this report. When interagency teams are established, it is recommended that those agencies listed in Table 1 for each biofuels area be included on the relevant team. A list of acronyms is included at the beginning of this report.

Biofuels Area	Table 1. Summary of Agency Roles Within each Biofuels Development Area
Feedstock and Feedstock Infrastructure	**USDA- Lead role** for a range of research activities including sustainable land management and conservation; effective crop management and sustainable forest management practices and production; sustainable harvesting and handling of biomass; plant science, genetics and breeding (including participation in the National Plant Genome Initiative with DOE and NSF; DOE-OBER and USDA-CSREES-NRI Joint Feedstock Genomics for Biofuel Production Program); integrated feedstock supply systems; on-farm crop and grasses research; sustainable crop and forest residue removal; sustainable forest energy feedstock production; relative carbon sequestration of corn, switchgrass and forest residues; small-scale demonstrations; and life-cycle analysis.
	DOE (OBP, SC-BES, and SC-BER) - Supporting role in feedstocks for bioenergy. Conducts research in preprocessing, including integrated systems to support collection and harvesting, and storage concepts; leads the Biomass Regional Partnerships; manages Congressionally-directed work on hybrid poplar and switchgrass plantations (demonstration); conducts basic research in plant science, including photosynthesis, plant physiology and genomics (National Plant Genome Initiative), and development of biotechnology tools, especially model organisms that may accelerate trait development and improvement of future bioenergy crops.
	EPA - Role in understanding human health and multi-media environmental risks and impacts of the full lifecycle of the biofuels system. **Mandatory TSCA "safety" reviews** of all new chemicals and new biotech microbes including those involved with biofertilizers (N 2 fixation) such as new rhizobia. **Lifecycle analysis of fuels** conducted by National Vehicle Fuel and Emissions Laboratory for Renewable Fuel Standard Program – [RFS] Regulatory Impact Analysis, feasibility of sustainable volumes of fuels. ORD supports a **Waste to Energy Team Network.** Regional collaboratives conduct some **market development** programs and small-scale demonstrations of bio-waste to energy. Member of **Metabolic Engineering Working Group** with joint funded projects, many relevant to feedstock improvement.
	DOI – **Major role in recovery of forest thinnings and other biomass materials** from land management and fire prevention activities; Co-chairs the Federal Task Force on Woody Biomass Utilization Working Group that promotes the utilization of woody biomass for fuels and other uses. This Group reports to the Biomass R&D Board; provides renewable energy grants to address feedstock transport (Indian Affairs).
	NSF - Provides grants to **support basic cross-cutting research** to improve biofuel feedstocks (National Plant Genome Initiative), to use wastes as energy sources, and to improve pre-processing of feedstocks.
	DOT - Role as **participants in Sun Grant Initiative** (environmental sustainability and feedstock research); conducts some economic and environmental analysis. Analysis and planning for feedstock transport infrastructure across all modes.
	DOD - Basic research, demonstration, and validation on feedstock preprocessing for MSW/waste biomass; **potential for greater role in large-scale demonstrations**.
Biochemical Conversion	**USDA -** ARS plays a major role in facilitating the biochemical conversion of lignocellulosic material. Specifically, **ARS funds R&D to reduce the pretreatment and enzymatic costs.** USDA-CSREES-NRI and SBIR play major roles supporting competitively funded applied and fundamental research to advance the conversion of lignocellulosic biomass to ethanol**. FS plays a major role in overcoming recalcitrant nature of forest resources**.
	DOE – OBP has a **major role** in the biochemical conversion of lignocellulosic material to fuels and products. Conducts research in pretreatment, enzymatic hydrolysis, fermentation, process integration and the demonstration of these technologies. **SC-BER supports fundamental research** on feedstock genomics, biodegradation of lignocellulose, and bioethanol and biohydrogen production. **SC-BES** supports basic research pertaining to the development and architecture of energy transduction systems including the photosynthetic apparatus, carbon fixation enzymes, and biophysical and biochemical mechanisms of cell wall formation. **DOE-EE-HFCIT - Conducts research on hydrogen production** utilizing micro-organisms.

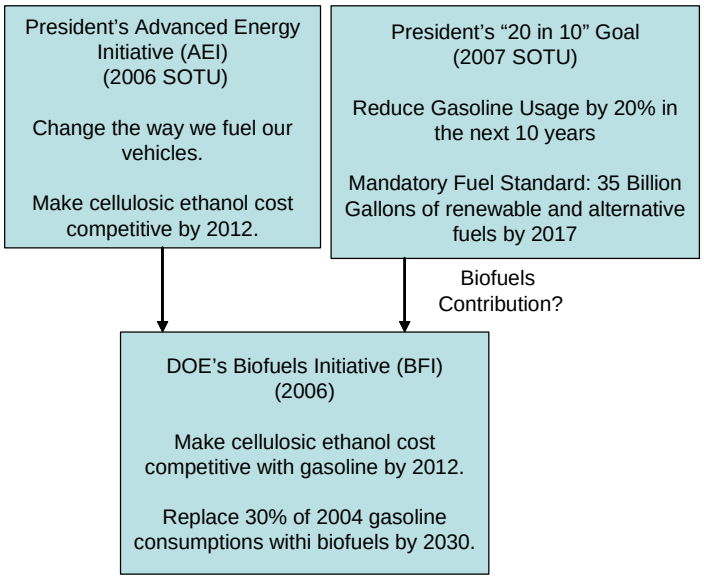
Biofuels Area	Table 1. Summary of Agency Roles Within each Biofuels Development Area
	EPA - Role in understanding human health and multi-media environmental risks and impacts of the full lifecycle of the biofuels system with focus on sustainable feedstocks. **Mandatory TSCA "safety" reviews** of all new chemicals and new biotech microbes would include, among others, those involved with biorefinery operation and such as new enzymes and microbes producing them, or doing other transformations of interest. EPA is a member of the **Metabolic Engineering Working Group** with joint funding of projects mostly relevant to biochemical conversion. **ETVP** develops testing protocols and verifies the performance of innovative technologies (biochemical and thermochemical). **NVFEL** evaluates environmental and potential market impact of vehicle and fuel production technologies. EPAct authorizes EPA to establish an **Advanced Biofuel Technologies Program** for production of transportation fuels. ORD will assist regions and states in **assessing the environmental impacts** of feedstocks and biorefineries. ORD investigates membrane-based alternatives to distillation systems and molecular sieve dryers for the recovery and dehydration of biofuels from dilute fermentation broths.
	NSF -ENG and MPS Directorates support basic research on the enzymatic and catalytic conversion of lignocellulosic material to fuels and other chemicals.
	DOC - NIST supports characterization and standardization of **catalyst design, biocatalytic processing and quantization of biochemical properties** of biomass feedstocks and their constituents. NIST provides Standard Reference Materials that help to enable this effort. Staff serve in ASTM and other voluntary standards organizations that deal with matters pertinent to biochemical conversion.
Thermochemical Conversion	**USDA - FS focuses on issues surrounding the conversion of forest resources** to biofuels and biopower, and also is collaborating with other federal agencies through a formal inter-agency woody biomass utilization working group**. CSREES funds basic and applied thermochemical conversion** research mainly at state universities and small businesses. **ARS conducts research on developing technologies** leading to new and improved biofuels focusing on systems which can be used either on-farm or within a farmer cooperative.
	DOE -OBP conducts research, testing, integration, and feasibility studies on thermochemical conversion of biomass to provide the technology for advanced and integrated biorefinery systems. **HFCIT conducts research on the production of hydrogen through biomass** gasification and the distributed reforming of bio-derived liquids to hydrogen including pyrolysis based bio-oils, ethanol, and sugars.
	EPA – Role in understanding human health and multi-media environmental risks and impacts of the full life cycle of the biofuels system with focus on sustainable feedstocks. **NVFEL** evaluates environmental and potential market impact of vehicle and fuel production technologies. EPAct directs and authorizes EPA to establish an **Advanced Biofuel Technologies Program** for production of transportation fuels. EPA is initiating a **general investigation** into advanced renewable fuel production technologies which are close to commercialization. ORD will assist regions and states in **assessing the environmental impacts** of feedstocks, various biofuel technology pathways and sustainable biorefinery production.
	NSF - Conducts basic research on thermochemical conversion technologies.
	DOC –NIST - Supports the missions of other federal agencies through its work in **developing standards, measurements and modeling.**
	DOD - Program to evaluate the use of **gasification technologies** as a means of producing energy from solid wastes.
Technology Integration	**USDA – Forest Service** – Development of functional integrated biorefinery processes for forest feedstocks
	EPA – Role in understanding human health and multi-media environmental risks and impacts of the full lifecycle of the biofuels system with focus on sustainable feedstocks. ORD will assist regions and states in **assessing the environmental impacts** of feedstocks, various technologies, and biorefineries.
Deployment	**EPA – OTAQ Implements National Renewable Fuel Standard Program**. **Establishes market awareness** for further development of biofuels through SmartWay Transport Partnership Grow and Go Program. Carries out **National Clean Diesel Campaign**, including Regional Collaboratives. EPA is initiating a **general investigation** into advanced renewable fuel production technologies which are close to commercialization. ORD will assist regions and states in **assessing the environmental impacts** of feedstocks, various biofuel technology pathways and sustainable biorefinery production.
Permitting	**DOI** – Permits the removal of woody biomass from federally-managed lands and may permit biofuels facilities, or rights of ways, on DOI-managed lands.
	EPA- Varies depending on media program and state delegation status.
Biofuels Infrastructure	**DOE -** Activities managed by the **FreedomCAR and Vehicle Technologies Program (FCVT) and OBP**. FCVT is responsible for the **improvement of vehicle and engine efficiency and the establishment of fuel requirements to attain efficiency targets**. OBP is responsible for the **development of cost-effective technologies for storage and deployment of the fuels**.

Biofuels Area	Table 1. Summary of Agency Roles Within each Biofuels Development Area
	EPA - OTAQ has activities related to **biofuels engine optimization and certification;** setting regulations and policies related to biofuels (National Renewable Fuel Standard – RFS). Assists in **determining emissions impacts** of ethanol (vehicle engine testing, statistical analysis, emission inventory, air quality analysis) and certification of alternative fuel vehicles produced by original equipment manufacturers and alternative fuel system/component converters. **Conducts EPAct fuel studies** on ethanol and sets and enforces standards for biofuels. **Establishing the definition of fuels certification**, currently under-funded. **OAR issues guidance** allowing states to remove Stage II requirements for E85 pumps and leads the National Clean Diesel Campaign, bringing greater access to biodiesel and E85 along key corridors. Initiating a **general investigation** into advanced renewable fuel production technologies close to commercialization. ORD will assist regions and states in **assessing the environmental impacts** of feedstocks, various biofuel technology pathways and sustainable biorefinery production. ORD conducts field research and develops conceptual and predictive models to understand the impact of fuel spills, including the impact of ethanol on petroleum hydrocarbon plumes in ground water. ORD also conducts research on the fate and transport, active and passive treatment techniques, and the assimilative capacity of the environment to attenuate these fuel constituents and their by-products.
	DOD - Testing biofuels (B20 & E85) for government activities to comply with 1992 EPAct and EO 13149. This includes the purchasing biofuels, FFVs ,and conducting demonstrations and deployment of biofuels in non-tactical vehicles. Performs **biodiesel emissions testing,** studying biodiesel usage, stability for tactical vehicles, and developing specifications and test methods to assure biofuel quality.
	DOC - NIST - Performs R&D on materials reliability for storage containers, pipelines and end use fuel delivery systems. This does not include materials compatibility research for biofuels with high alcohol content. Develops legal metrology specifications, tolerances and methods of sale for use in the commercial distribution of petroleum-based fuels. Provides underpinning **Standard Reference Materials and Data**, as well as providing measurement traceability through calibrations. This has not yet been fully extended to E85 and other biofuels. Develops life cycle analysis software (BEES) required by federal rule for use in measuring the environmental and economic impacts of biobased product manufacturing, use, and disposal. BEES could be applied to measure and reduce the life cycle impact of biofuel production and to optimize biorefinery design. Strengthening BEES Land Use and Water Use metrics to better evaluate land sustainability.
	DOT - Ensures safe and efficient distribution of the fuels. Includes transportation/distribution systems development, consumer/end-use issues studies, education and outreach, economic and environmental assessment, quality assurance, supply chain analysis, and data and information dissemination to transit agencies.
	FEMP – Works with the Federal fleet to increase the use of FFVs.
Communication, Education, and Outreach	**USDA** – Full range of **communication, education, and outreach** activities to facilitate production and use of biomass, crop materials, other biomass (e.g. animal manure),respond to environmental, community and regional interests, link to sustainable forestry and agriculture practices; and increase markets for all biomass.
	DOE - Education and information on the R&D activities and advancements within the biofuels industry
	EPA – OTAQ develops voluntary partnerships with key stakeholder groups that are essential to biofuels adoption and market transformation such as the National Clean Diesel Campaign and Regional Collaboratives. Is initiating a **general investigation** into advanced renewable fuel production technologies close to commercialization. **Communicates** environmental and human health risks associated with biofuels production and use. ORD will assist regions and states in **assessing the environmental impacts** of feedstocks, various biofuel technology pathways and sustainable biorefinery production. ORD's Waste-to-Energy Team is compiling an informational matrix summarizing biomass conversion technologies, compatible feedstocks and potential products.
	DOI - Role in communicating forestry and other biomass recovery methods and land management activities that promote woody biomass use. Partners with National Association of Conservation Districts to increase public understanding of the benefits of using wood biomass to reduce fuel buildup on public lands.
	NSF - Developing the next generation of scientists and engineers to further biofuels R&D.
	DOC – ITA - Fostering international markets for US biofuels technologies and educating industry on the domestic economic benefits of a biofuels market.
	DOT - Educates transit agencies and develops best practices and guidance documents on the effective use of biofuels in medium and heavy-duty vehicle fleet applications. Maintains emergency response guidebook and works with state and local emergency response and code officials on permitting and procedures. Promotes the use of biofuels through the DOT center for Climate Change and Environmental Forecasting.

Scope and Background

The President announced goals to increase the nation's use of biofuels in his 2006 and 2007 State of the Union addresses. Subsequently, the Department of Energy announced a Biofuels Initiative (BFI) (see Figure 1).

Figure 1. The President's and Department of Energy's Biofuels-Related Goals



The announcements of these goals and initiatives have re-emphasized the need to coordinate the biofuels activities within the Federal government. Shifting from the established petroleum-based transportation fuel industry to an environmentally sustainable biofuels-based industry will require large sustainable feedstock supplies; major feedstock infrastructure and conversion technology advancements; large-scale integrated biorefinery demonstrations, and massive biofuels infrastructure development. Additionally, a full life-cycle of environmental and human health impacts needs to be addressed throughout the supply chain (Figure 1) when developing this industry. Policy and other market-based incentives will be needed to stimulate investments in the industry. Permitting and standards issues will also factor into industry growth and will need to be understood and resolved. Communication, education, and outreach programs will be necessary to catalyze the transition on many fronts.

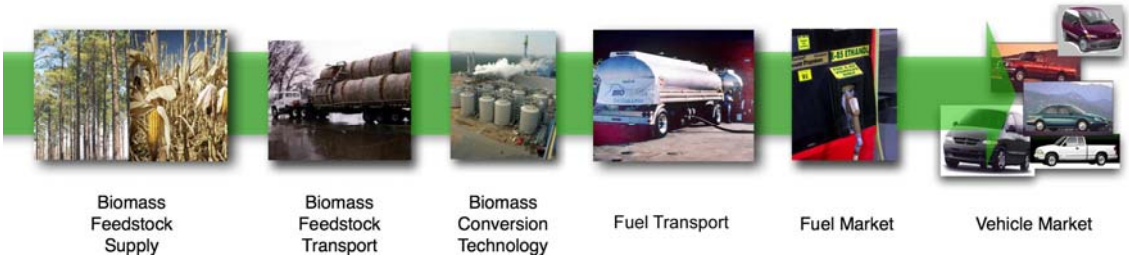


Figure 2: Biofuels Supply Chain

This report is the result of a Federal agency workshop held on November 28-29, 2006 in Washington, DC to initiate the coordination process (http://www.biofuelspostureplan.govtools.us/). The workshop objectives were to define current and future agency roles and activities, identify gaps and opportunities to collaborate, and assess budgets related to biofuels production and use to meet the President's AEI and the DOE's "30x30" goals. At the time of this workshop, the President's 2007 State of the Union "20 in 10" goal was not announced. However, the results of the November workshop are still relevant to the interagency coordination and collaboration needs to meet this additional biofuels goal, albeit at an accelerated schedule, which reinforces the need for timely action on the report's recommendations.

The 2030 market goal is aggressive, calling for a more than ten-fold expansion in biofuels production and use over the next 23 years. Growing the biofuels industry to displace 30% of gasoline demand by 2030 not only implies extraordinary rates of expansion of the existing industry, but also relatively rapid development and market adoption of new technology for converting lignocellulosic biomass and other feedstocks into biofuels, as well as for fuel distribution and vehicle technology.

Ethanol is the focus of the 2012 technology goal to make cellulosic ethanol cost-competitive with gasoline. In reality, the long-term strategy must remain flexible to other biofuels that may enter the market over time (e.g., biobutanol, hydrogen and methanol from biomass, FT-liquids from biomass). As the feasibility of technology options are examined through research, development, and demonstration (RD&D) and other avenues (e.g., policy), decisions can be made on which options for producing biofuels are the most likely to succeed and have the largest impact.

The 2030 volumetric goal was based on a joint study by USDA and DOE on *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: the Technical Feasibility of a Billion-Ton Annual Supply* (the *Billion Ton Study*).[1] The study estimates that the U.S. has the potential to produce up to 1.4 billion tons of biomass annually on a sustainable basis without affecting food, feed, and fiber uses. The study did not attempt to outline R&D and policy agendas to attain this goal, nor did it attempt to assess the economic competitiveness of a billion-ton bio-industry, and its potential impacts on the energy, agriculture (food and feed production), and the forest sectors of the economy. To put the biomass-to-biofuels potential into perspective, the study estimates that almost 60% of 2004 motor gasoline demand, on a Btu-adjusted basis, could be met with ethanol from grain and biomass, twice the volume defined by the 2030 market goal.

[1] *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: the Technical Feasibility of a Billion-Ton Annual Supply,* April 2005
http://www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

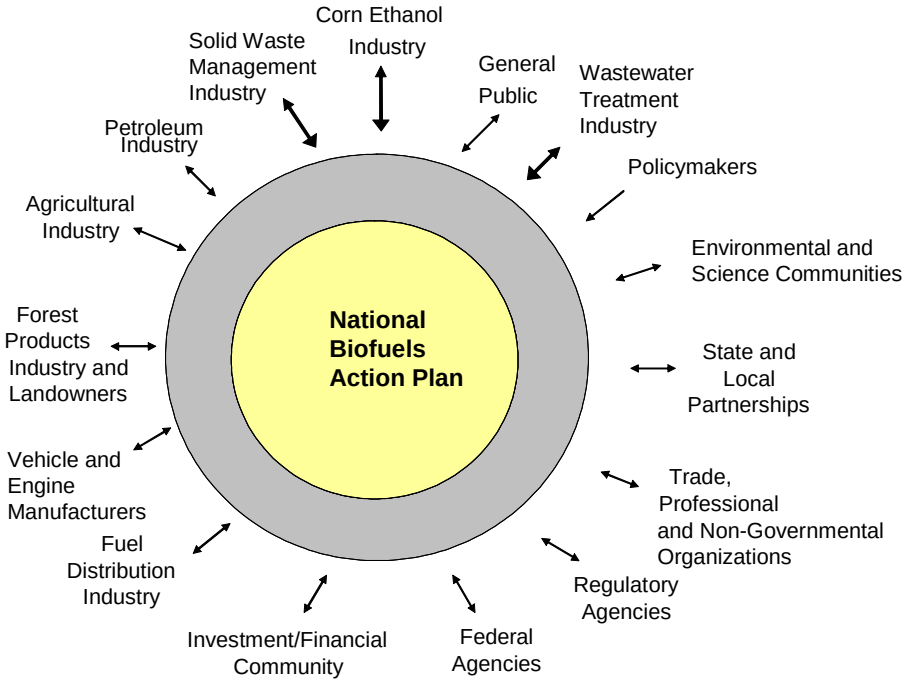


Figure 3. Stakeholders in the Biofuels Initiative

Achieving the President's and DOE's biofuels goals will require the coordinated efforts of a large and diverse group of stakeholders, as illustrated in Figure 3. These stakeholders also provide valuable input and perspective that can be used to identify the critical RD&D challenges and better define the optimum strategic plan for achieving the these goals.

This *Workshop Summary Report* is being prepared for the interagency Biomass Research and Development Board (Board), established by the Research and Development Act of 2000 and revised by the Energy Policy Act of 2005. The interagency Board acts as the governing body that brings coherence to Federal strategic planning by coordinating research and development activities related to biobased fuels and biobased products. This *Workshop Summary Report* is intended to provide the Board with a framework to begin to bring coherence to Federal strategic planning in the area of biofuels to meet these goals and develop a more detailed *National Biofuels Action Plan (Action Plan)*. The Board is co-chaired by DOE and the U.S. Department of Agriculture (USDA), and includes members from:

- National Science Foundation (NSF)
- U.S. Environmental Protection Agency (EPA)
- U.S. Department of the Interior (DOI)
- Office of Science and Technology Policy (OSTP)
- Office of the Federal Environmental Executive (OFEE)
- U.S. Department of Transportation (DOT)
- U.S. Department of Defense (DOD)
- U.S. Department of Commerce (DOC).

- U.S. Department of Treasury (Treasury)

Treasury, DOD, and DOC were not on the Board at the time of the workshop but have recently joined. DOD and DOC were invited to attend the workshop in November 2006. Continued interagency collaboration will be needed to implement the recommendations in this report and to take the next step toward developing a more detailed *Action Plan*, as requested by the Office of Management and Budget (OMB). Ultimately, this *Workshop Summary Report* and the *Action Plan* (to be developed) will help increase the ability of these government agencies to work with each other and with key stakeholders to successfully meet the President's and the DOE's goals.

Workshop Preparations: The Needs Requirement Document

Leading up to the workshop to develop this *Workshop Summary Report*, DOE's Biomass Program and other offices within the Department held various stakeholder meetings to identify the key needs and opportunities for biomass and biofuels in the U.S. Stakeholders represented Federal and State government agencies, industry, universities, trade associations, and environmental organizations. These stakeholders provided input regarding the key research, development and technology needs; potential distribution and infrastructure requirements; permitting issues; and policy and deployment drivers that could contribute to achieving the DOE's BFI goals. This stakeholder input was compiled and summarized into a *Needs Requirement Document* and provided to participants prior to the November workshop (http://30x30workshop.biomass.govtools.us/). The *Needs Requirement Document* was distributed prior to the workshop to provide guidance to federal agency participants for identifying activities related to biofuels.

Organization of the Workshop

Based on guidance provided in the *Needs Requirement Document* prior to the workshop, each Federal agency was asked to submit detailed accounts of activities related to biofuels in their current portfolios and to prepare summary presentations of these activities to be discussed during the workshop. The workshop was organized into breakout sessions and the session attendees were selected by their own agencies' Points-Of-Contact (POCs), who were appointed by the Board. The breakout sessions covered the main biofuels topic areas of (in no priority order):

- Feedstocks (from field/forest to plant gate)
- Biochemical Conversion Technologies (fuels and co-products opportunities)
- Thermochemical Conversion Technologies (fuels and co-products opportunities)
- Technology Integration, Deployment, and Permitting for Biorefineries
- Biofuels Infrastructure (from plant gate to vehicle technologies)
- Communication, Education, and Outreach

The breakout sessions began with agency presentations summarizing their activities. Due to time limitations, the session participants focused on 4 to 5 sub-elements in each topic area to discuss in depth, including identifying the key barriers, timeline of activities to overcome these barriers, current and future agency activities, and related budgets. The participants also identified gaps and synergies and developed recommendations to address them.

After the workshop, interagency teams were formed from each breakout session to develop a draft *Workshop Summary Report* (See Appendix A). Tables 1 through 4 in each section of this report contain the information gathered at the workshop, along with the detailed

recommendations made by workshop participants. These tables and recommendations were further developed during the interagency team's drafting of this document and during each agency's review of the draft. It is the intent that this *Workshop Summary Report* will support the development of a *National Biofuels Action Plan*. The Board plans to formally establish interagency teams to better define Federal roles, agency activities, and related budgets; evaluate state and local government roles implement the recommendations in this plan; and continue to make recommendations to the Board (See Appendix A).

Detailed Descriptions of Federal Activity in Each Biofuels Area

Feedstocks

Technology Status and Challenges

The creation of a sustainable bioindustry producing biofuels on a large scale is critically dependent on having a large, sustainable supply of high-quality biomass at a reasonable cost. The *Billion Ton Study*[1] estimates that the U.S. has the potential to produce up to 1.4 billion tons of biomass annually on a sustainable basis without affecting food, feed, and fiber uses. However, capturing the potential of these biomass resources will not happen without addressing some major challenges such as reliability and sustainability of supply, land use change and competition, and reducing costs for growing, recovering, transporting, and storing feedstocks. Sustainability entails minimal or no harmful impact on the environment, ecosystems, and water supplies.

Figure 1. Feedstocks for the Future Bioindustry

Agricultural Residues
- Corn stover, various straws and hulls, bagasse, orchard prunings

Forestry
- Residues (logging slash, forest thinnings, fuel reductions, understory brush) and pulping process wastes (e.g., black liquor, other wastes)
- Conventional (e.g., Southern pine)

Dedicated Energy Crops
- Starch and sugar (e.g., corn, wheat, sorghum, sugarcane)
- Oil crops (e.g., soybeans, canola, other minor oilseeds) and other oils (microalgae)
- Lignocellulosics
- Herbaceous (e.g., alfalfa, reed canary grass, switchgrass, large grass)
- Short Rotation Woody Crops (e.g., poplar, willow)

Other Wastes
- Municipal Solid Wastes (MSW) (includes landfill gases)
- Industrial (includes food processing)
- Domestic wastewater
- Animal wastes
- Construction/demolition
- Yard waste
- Biosolids (wastewater treatment sludge)
- Waste oils
- Disposal method for invasive species

In 2007, U.S. ethanol production capacity based on corn and grains was about 4.8 billion gallons per year (gpy), with an additional 6 billion gpy under construction[2]. A significant amount of biodiesel was also produced in 2005 (~ 75 million gallons), primarily from soybeans; actual capacity is near 600 million gpy, and producers plan to add 820 million gallons of capacity over the next 16 months[3]. In the future, the expanded biofuels industry will require going beyond the traditional use of corn, grain and soybeans to the broader spectrum of feedstocks shown in Figure 1.

The corn used in today's ethanol facilities is produced using conventional agricultural production, harvesting and collection practices, and is stored and transported via the existing infrastructure which also serves the food and feed industry. Biomass is also used for electricity generation via the existing fiber production systems. As the production of biofuels ramps up over the next decade, current feedstock production and harvesting technologies will not be adequate to meet the demands of the growing bioindustry. This will become more of a challenge as the U.S. moves toward the use of cellulosic and other non-traditional feedstocks such as agricultural and forest residues, wood, and energy crops.

To meet expected future demands for biomass, biomass production capability will need to be improved. One way is to enhance the capacity of agricultural and forest lands to produce more biomass without having to convert other land uses to biomass production. Another way is to improve the utilization of agricultural and forest residues and industrial and urban wastes for biofuels. In all cases, the goal is to ensure that biomass can be produced sustainably over the long-term, i.e., having a reliable feedstock supply while maintaining environmental quality.

Another barrier is the initial high costs for the production, recovery, and transportation of feedstocks. A systems approach is needed to overcome these two substantial barriers of sustainable production and high cost. This approach needs to integrate production and conversion through the entire life cycle to optimize capacity, minimize costs, and maintain environmental quality. Caution needs to be exercised with respect to longer term water supply and demand. Some areas under consideration for enhanced corn production are the same areas with limitations in future water supplies. Given increasing water demands, there is also a need to assess the impact of pesticide usage and limits in crop rotation on potential water impairment.

Sustainable crop management and production practices are necessary to meet the greater demands placed on land and water by increased production. Sustainable practices will also need to include additional protections to ensure that increased crop production does not exacerbate excess levels of nutrients and sediment in surface and ground waters. Implementation of improved agricultural best management practices is critical in preventing further degradation of water quality. (See the Detailed Recommendations in this section for discussion of a necessary common definition of "sustainability.")

A better understanding of plant science, plant genetics, and ecological processes and development of improved agricultural and silvicultural practices will play a key role. Advances in these areas will provide feedstocks with improved characteristics or reduced requirements for fertilizer, pesticides or water during production, and enhanced qualities for improved conversion. Many advances have already been made with conventional breeding and using biotechnology and genomics to significantly improve crops for use as energy feedstocks. In the future, engineered plants may be the solution to low-cost, abundant feedstocks.

Producers and end-users will face challenges in harvesting, collection, storage and transport of large quantities of biomass because of the limited capacity of current systems and technology that is not optimized for energy feedstocks. To meet these needs over the long-term will require new engineering and technology development with emphasis on economics and strategic decision-making.

The major elements of the feedstock infrastructure and the critical challenges facing each are shown in Table 1.

Table 1. Feedstock Infrastructure Elements and Key Barriers

Feedstock Element	Key Barriers
A. Production Sustainable, cost-effective, high-yield feedstock production practices will support large-scale use of agricultural and forest biomass and dedicated energy crops. Land sustainability at higher production levels, including impacts on soil and water and the many services that ecosystems provide, must be addressed. New crop management practices may be required, particularly for more unconventional feedstocks such as switchgrass and short woody rotation crops. Plant science and genetics may provide knowledge and techniques for improving the characteristics and yield of crops. Comprehensive regional data on feedstock availability, including non-agricultural crops and residues such as manures, biosolids, woody waste, and municipal solid waste, will be critical in reducing supply uncertainties and risk. Understanding the potential of residues and wastes as well as integrated management systems and changes in infrastructure that may be necessary will be crucial for enhancing supply and sustainability.	• A1. Limited understanding of potential impacts of large-scale energy feedstock production on land uses, land, water, carbon sequestration and ecosystems (particularly excess fertilizers, pesticides, and sediment in surface waters) and ecosystems and ecosystem services • A2. Lack of a common definition of sustainability • A3. Achieving higher yield per acre for feedstocks • A4. Energy crop support of commodity crops under existing Farm Bill provisions • A5. Uncertain acceptance of genetically-modified crops and environmental impacts • A6. Lack of regionally-specific data on price, location, quality and quantity of biomass, and regional environmental considerations • A7. Uncertain impacts of residue harvest on soil quality

Table 1. Feedstock Infrastructure Elements and Key Barriers	
Feedstock Element	**Key Barriers**
	• A8. Production capacity limitations are unknown • A9. Poor understanding of basic plant architecture and development (e.g., basic structure of plant cell wall) • A10. Fertilizer and other inputs that run-off cause harmful environmental, ecosystem, and water system impacts
B. Harvesting and Collection Equipment for selectively harvesting and collecting the desired components of biomass for energy production will be needed to sustain large-scale use of biomass feedstocks. Cost-effective harvesting and bulk handling systems that are designed to handle the demands of feedstock variability and other factors present new engineering challenges. Techniques such as crop densification may hold promise for increasing the transportation efficiency of crops and residues. Existing infrastructures and technologies able to separate biomass component of variety of wastes from non-biomass portions will allow integration of wastes as another feedstock source.	• B1. Inadequate equipment for selective harvesting • B2. Lack of cost-effective equipment to handle biomass variability and high volumes • B3. Limitations and cost of current bulk handling systems (e.g., bales) • B4. Need to retain adequate crop residue to prevent soil erosion and reduction in soil quality (i.e., soil organic carbon). • B5. Lack of environmental impacts verification
C. Storage and Transportation Storage and transport systems for large-scale bulk biomass will be needed to support a domestic bioindustry producing fuels and other products. Both wet and dry systems are under investigation. The impacts of storage on feedstock quality will require an understanding of the chemical and physical behavior of the biomass in response to external factors (location, temperature, moisture, etc) over time. More analysis of wet and dry storage methods, long-term storage issues, and centralized versus distributed storage and transport is needed to define requirements and impacts on yield. There is also a need to understand and characterize existing waste management infrastructures to allow integration of a variety of wastes as alternative feedstock source.	• C1. Maintaining and monitoring biomass quality • C2. Susceptibility of biomass to spoilage, spontaneous combustion and odor problems • C3. Limited understanding of storage requirements at a very large-scale • C4. Efficiency and cost of existing biomass distribution infrastructure at large scale • C5. Capacity and logistics of large-scale feedstock transport (intra and interstate)
D. Preprocessing Preprocessing of biomass to enhance its feedstock characteristics may take place prior to arrival at the factory gate. For example, biomass can be partially degraded during storage, fractionated during preprocessing, or densified. Centralized biomass preprocessing (i.e., the depot concept) is one option where multiple feedstocks could be enhanced on a very large scale (e.g., cleaned, sorted, ground, dried, densified).	• D1. Limited data on fundamental biomass quality and physical property characteristics • D2. High levels of impurities in harvesting biomass and potential for fouling of preprocessing equipment
E. Feedstock Demonstration, Extension & Education Demonstration is needed for all components of a large-scale biomass feedstock infrastructure, from integrated management of crops, forests and dedicated energy crop production, and various wastes, to transport and preprocessing, to reduce uncertainties and stimulate industrial investment. Demonstrations would address issues such as biomass variability, degradation in storage, shelf life, processing yields and impacts of climate, location and other factors over time. Integrated demonstrations of all components will be key for utilizing biomass in biorefineries envisioned for the future, where a time-sensitive, large-scale reliable supply of high-quality biomass will be required.	• E1. Lack of proven practices and infrastructure at large scale production levels • E2. Lack of experience with large-scale time-sensitive harvesting, collection, storage and transport • E3. Limited large-scale feedstock production demonstrations (e.g., residues, switchgrass, short rotation)

The key challenges shown in Table 1 reflect the impacts of two major factors: the need to dramatically increase sustainable production of feedstocks to meet the volumetric goals for 2030; and moving from the use of corn and grains (well-established technology and infrastructure) to a broader range of feedstocks (lignocellulosics, herbaceous, residues, and others).

Table 2 outlines the major activities needed, in the near-, mid-, and long-term, to meet the challenges described in Table 1. Each agency that currently contributes to each activity described in Table 2 is noted after that activity [e.g., ***(USDA, DOE…)***]. The key barriers addressed by each Table 2 activity align with the numbered barriers in Table 1, and are also noted after each activity in Table 2 [e.g., ***(A1, B2…)***]. Table 3 lists specific agency activities based on the information provided by each agency during the November workshop and during the drafting of this document. Table 4 describes each agency's funding that supports its activities. Tables 3 and 4 are not complete or linked with Tables 1 and 2; interagency teams should continue this effort.

Together, these four tables represent the most complete interagency biofuels activity reference to date, and should serve as a guide for future interagency teams. Development of a detailed, shared agency activity database is recommended to further illustrate these collaborations and identify gaps (see *Summary of Overall Recommendations*).

Note: These notations are based on agency input at the time of this document's drafting, and the November workshop proceedings. They do not necessarily reflect established future work plans by these agencies, but rather reflect their current or potential future activities.

Table 2. Key RD&D Activities Needed to Overcome Barriers for Feedstocks *(Agency Whose Activities Currently Relates to Barrier)*			
Biofuels Industry RD&D Area	**Near Term (0-5 Years)**	**Mid Term (5-10 Years)**	**Long Term (10+ Years)**
Production			
Soil Sustainability Understanding impacts of feedstock production and residue removal on land, water, carbon sequestration and organic material, and ecosystems to facilitate sustainable production	• Understand soil, water, and wildlife habitat processes and functions for sustainability (includes pest management) ***(EPA, USDA) (A1, A2, A6, A7, A8, A10, B4, B5, E3)*** • Understand potential land cover and use changes ***(USDA) (A1, A3, A6, A7, A8, A10, B4, B5, E3)*** • Understand the environmental impact of using high phosphorus by-products of ethanol production as livestock feed ***(EPA, USDA) (A1, A6, A8, A10, B5, E3)*** • Initiate extensive water supply/ quality research to answer near-term questions ***(EPA, DOI) (A1, A3, A6, A7, A8, A10, B4, B5, E3)*** • Answer sustainability questions for crop residues and forest biomass (e.g., what % of biomass can be sustainably harvested? What is effect of residue removal on site productivity?) ***(USDA) (A1, A2, A3, A6, A7, A8, A10, B4, B5, E3)*** • Study forest sustainability and wildlife habitat impacts from removing thinnings ***(USDA, DOI) (A1, A2, A6, A7, A8, A10, B5, E3)*** • Improve crop robustness (pest and drought resistance, optimize use of fertilizers, nutrients, water, etc) ***(USDA) (A1, A3, A5, A7, A8, A9, A10)*** • Understand ecological implications of robust crops, such as whether they will become invasive species ***(EPA, USDA) (A1, A2, A6, A8, A9, B5, E3)*** • Develop and test alternative crop production options with reduced ecological footprints ***(EPA, USDA) (A1, A2, A3, A6, A7, A8, A9, A10, B4, B5, E3)*** • Conduct regional comparative analysis of ecosystem service trade-offs under different feedstock production scenarios ***(EPA) (A1, A6, A7, A8, A10, B4, B5, E3)***	• Continue study of longer-term land cover and use, soil productivity and water supply/quality issues ***(EPA, NSF, USDA) (A1, A2, A3, A6, A7, A8, A10, B4, B5)*** • Develop forest management systems that integrate energy feedstock production into conventional production ***(USDA) (A1, A3, A5, A7, A8, A10, B2, B3, E3)***	• Continue long-term monitoring and analysis of studies ***(EPA, USDA) (A1, A2, A3, A6, A7, A8, A10, B4)***

Table 2. Key RD&D Activities Needed to Overcome Barriers for Feedstocks *(Agency Whose Activities Currently Relates to Barrier)*			
Biofuels Industry RD&D Area	**Near Term (0-5 Years)**	**Mid Term (5-10 Years)**	**Long Term (10+ Years)**
Plant Science, Genomics and Possible Genetically Modified (GM) Feedstocks Improve plant material for enhanced productivity and/or specific characteristics. Includes breeding, genomics, biotechnology, and genetic modification of crops	• Expand basic plant breeding program to achieve results in mid to long term ***(A3, A5, A8, A9)*** • Achieve understanding of the plant system ***(A3, A5, A8, A9)*** • Develop new varieties and clones ***(A3, A5, A8, A9, B5)*** • Test plants at specific locations using common protocols ***(A1, A2, A3, A5, A6, A8, A10, B4, B5)*** • Determine genome sequence for most promising feedstocks ***(A3, A5, A8, A9)*** • Develop genomic tools for model organisms ***(A3, A5, A9)*** • Evaluate role of GM feedstocks ***(A3,A5, A10, B5)*** • Improve genetics for yield ***(A3, A5, A8, A9, B5)*** • Reduce recalcitrance of cellulose to ease digestion ***(A3, A5, A9)*** ***(USDA/NSF/DOE-BER addressing all through National Plant Genome Initiative and other research programs)***	• Better understand photosynthesis, carbon dioxide fixation and plant physiology ***(DOE-BES, NSF, USDA) (A1, A3, A8, A9, C1, D1)*** • Understand plant biochemistry mechanisms for synthesis and accumulation of desired compounds such as starch, cellulose, oils, etc. ***(DOE-BES, NSF) (A3, A8, A9, C1, D1)*** • Determine genes responsible for desired trait improvements to enhance yields (***USDA/NSF/DOE-BER) (A3, A5, A8, A9, A10, B5, C1)*** • Continue genome sequence for expected set of feedstocks ***(USDA/NSF/DOE-BER) (A1, A3, A5, A9, A10, C1)*** • Evaluate beneficial and detrimental environmental impacts of GMO ***(EPA) (A1, A2, A3, A5, A6, A7, A8, A9, A10, B5, E2, E3)***	• Implement breeding technologies to produce cell walls modified for deconstruction ***(USDA) (A3, A5, A9, C1, E3)*** • Develop 'tool kits' for plant engineering (herbaceous energy crops) ***(USDA) (A3, A5, A7, A8, A9, C1)*** • Translate knowledge gained from model species to real energy crops ***(USDA) (A1, A3, A5, A7, A8, A9, B5)*** • Develop mechanisms (e.g., sterility) for field application of GM feedstocks ***(USDA) (A1, A3, A5, A6, A7, A10)*** • Evaluate beneficial and detrimental environmental impacts of GMO ***(EPA) (A1, A2, A3, A5, A6, A7, A8, A9, A10, B5, E2, E3)***

Table 2. Key RD&D Activities Needed to Overcome Barriers for Feedstocks *(Agency Whose Activities Currently Relates to Barrier)*			
Biofuels Industry RD&D Area	**Near Term (0-5 Years)**	**Mid Term (5-10 Years)**	**Long Term (10+ Years)**
Regional Inventory Development of regionally-specific comprehensive data on feedstock availability to reduce supply uncertainties	• Understand recovery factors associated with different feedstocks and regions ***(USDA, DOI) (A1, A3, A5, A7, A8, B1, B4, B5, E3)*** • Develop county-level resource list and economic feedstock analysis (including expansion on the *Billion Ton Study*) ***(EPA, USDA, DOI) (A4, A6, A8, E1)*** • Build on existing data inventories such as the USDA's Forest Inventory and Analysis (FIA) and Natural Resources Inventory (NRI) ***(USDA, DOI) (A4, A6, A8, B1, C1, E1)*** • Evaluate and compare demand of natural resources required for energy crops vs. other uses ***(EPA) (A1, A6, A7, A8, A10, B4, B5, E3)*** • Conduct regional testing to determine which herbaceous and other perennial energy crops are best suited for specific areas ***(USDA) (A1, A3, A4, A5, A6, A7, A8, A10, B4, B5, C1, C3, E3)*** • Model energy crops to assess regional suitability ***(USDA) (A1, A2, A3, A5, A6, A7, A8, A10, B4, B5, C1, E3)*** • Evaluate environmental and economic tradeoffs for distributed versus centralized feedstocks and coupled production systems ***(EPA) (A1, A2, A3, A6, A7, A8, A10, B2, B3, B5, C3, E1, E2, E3)*** • Conduct regional studies, where appropriate, to evaluate availability and potential recovery rates of waste to energy accompanied by economic feasibility and cost-comparison to other distantly available feedstocks ***(EPA) (A1, A2, A6, A8, A10, B1, B2, B3, B5, C1, C4, C5, E1, E2, E3)***	• Refine Billion Ton study for an updated inventory ***(USDA, DOI, EPA) (A5, A6, A7, A8, C1)*** • Develop long-term assessments and scenarios ***(USDA, DOI, EPA) (A2, A3, A6, A7, A8, B5, C1, E1, E2)*** • Evaluate potential land-use change and competition between food, feed, fiber, and bioenergy in light of changing global resource markets ***(USDA, NSF) (A1, A2, A3, A4, A5, A6, A7, A8, A10, B5, C3, C5, E1, E2, E3)***	• Update inventory ***(USDA, DOI) (A6, A7, A8, E1)*** • Improve rate of delivery of updated information ***(DOI) (A6, A7, A8, A10, C10)***
Feedstock Management Practices and methods geared toward large scale dedicated bioenergy crops, and integrating energy feedstock production into conventional management systems	• Optimize crop management practices for bioenergy feedstocks (sustained effort over several years); focus on, but not limited to, large scale dedicated production ***(USDA) (A1, A2, A3, A6, A7, A8, A10, B2, B3, B4, B5, C1, C3, C5, E1, E2, E3)*** • Develop new technologies to minimize inputs and maximize outputs, and optimize input efficiency ***(USDA) (A1, A3, A7, A8, A10, B1, B2, B3, B5, C4, C5)*** • Conduct economic analysis (energy versus other uses) and provide management tools ***(EPA, DOE-EE-OBP) (A6, A7, B2, C4, C5, E1)***	• Continue optimization of crop management practices ***(USDA) (A1, A2, A3, A7, A8, A10, B1, B2, B3, B4, B5, C1, C3, E1, E2, E3)*** • Improve regional management systems ***(USDA, DOE-EE-OBP, DOI, EPA) (A1, A2, A3, A6, A7, A8, A10, B1, B2, B3, B5, C1, C4, C5, E1, E2)***	• Develop herbicides, pesticides and fungicides for feedstocks ***(EPA) (A1, A3, A5, A8, A9, A10, B5)***

Table 2. Key RD&D Activities Needed to Overcome Barriers for Feedstocks *(Agency Whose Activities Currently Relates to Barrier)*			
Biofuels Industry RD&D Area	**Near Term (0-5 Years)**	**Mid Term (5-10 Years)**	**Long Term (10+ Years)**
Harvesting and Collection			
Yield and Harvesting Equipment and practices to improve harvesting yield of desired biomass components; yield represents efficiency of harvesting, not productivity	• Implement crop densification (increased harvest and residue yields) using energy efficient, environmentally sound removal practices ***(USDA) (A1, A2, A5, A7, A8, A9, A10, B1, B3, B4, B5, C3, E1, E2, E3)*** • Develop tailored harvesting systems for herbaceous and other crops ***(USDA) (A1, A2, A5, A6, A7, A8, A9, A10, B1, B2, B3, B4, B5, C3, E1, E2, E3)*** • Develop cost-effective technologies to collect forest biomass ***(USDA) (A1, A2, A6, A7, B1, B2, B3, B4, B5, C1)***	• Systems approach for harvesting, storage, transport and preprocessing ***(USDA) (A6, A8, A10, B1, B2, B3, B4, B5, C1, C3, C4, C5)***	
Storage and Transportation			
Storage and Transportation and Logistics – Systems, technologies and infrastructure for storing and transporting biomass from field to plant gate	• Evaluate costs associated with harvesting and transporting feedstocks ***(USDA, DOI) (A3, A6, A8, B2, B3, C1, C3, C4, C5, E1, E2, E3)*** • Evaluate storage impacts on feedstocks ***(USDA) (A6, B2, B5, C1, C2, C3)*** • Evaluate need for densifying feedstocks for storage and transportation ***(A6, B2, B3)***	• Develop improved storage (wet and dry) and transport ***(A6, A8. B2, B5, C1, C2, C3, E1, E2, E3)*** • Improve wet feedstock infrastructure to reduce costs ***(A6, A8, B2, E1, E2, C2)*** • Analyze capacity needs on a national, regional, and local levels, and impacts of existing regulations ***(DOT) (A6, A8, C1, C3, C4, C5, E1, E2, E3)*** • Develop long term infrastructure development plan ***(DOT) (A6, A8, B2, B3, B5, C1, C3, C4, C5, E1, E2, E3)***	• Improve efficiency and cost-effectiveness of feedstock transport logistics ***(USDA) (A6, A8, B2, B3, C1, C4, C5, E1, E2)***
Preprocessing			

Table 2. Key RD&D Activities Needed to Overcome Barriers for Feedstocks *(Agency Whose Activities Currently Relates to Barrier)*			
Biofuels Industry RD&D Area	**Near Term (0-5 Years)**	**Mid Term (5-10 Years)**	**Long Term (10+ Years)**
Feedstock Densification and Material Handling Bulk handling and physical alteration of biomass (grinding, densification, blending) to enhance characteristics and reduce costs	• Explore densification of biomass for storage and transport ***(USDA, OBP) (A6, A8, B1, B2, B3, C1, C3, C4, C5, D1, E1, E2, E3)*** • Determine liquid solids properties to identify handling needs and equipment design ***(USDA)(A6, B1, B2, B3, C5, E1, E3)*** • Explore optimum handling for specific conversion technology to be used. ***(USDA) (A6, A8, A9, B1, B2, B3, C1,C3, C4, C5, D1, E1, E2)*** • Analyze in-woods processing and densification techniques for SRWC and Forest residues. ***(DOI) (A1, A2, A3, A6, A8, B1, B2, B3, B5, C1, C4, C5, D1, D2, E1, E2, E3)***	• Determine optimum particle sizing for transport and processing ***(USDA) (A6, B1, B2, B3, C1, C3, C4, C5, D1, E1)***	• Optimize feedstock handling systems for blend ed feedstocks ***(USDA)***
Feedstock Flexibility Systems for handling and processing multiple feedstocks to allow feedstock switching or blending	• Develop system to quickly assess feedstock quality ***(USDA)*** • Develop ability to process multiple feedstocks – residues (blending, depot, elevator) ***(USDA) (A8, B1, B2, B3, B5, C1, C3, C4, C5, D1, E1, E2, E3)***	• Develop ability to process multiple feedstocks – SRWC and dedicated herbaceous energy crops (blending, depot, elevator) ***(A6, A8, B1, B2, B3, B5, C1, C3, C4, D1, D2, E1, E2, E3)***	• Develop ability to process multiple feedstocks ***(A6, A8, B1, B2, B3, B5, C1, C3, D1, E1, E2, E3)***
Demonstration			
Small Scale and Large Scale Pilot Demonstrations Demonstration and validation of technologies and systems, from production to transportation	• Determine best scale for technical feasibility/sustainability demonstrations for a variety of feedstocks ***(USDA, OBP, DOI, EPA, DOD) (A1, A2, A6, A7, A8, A10, B2, B3, B4, B5, C1, C2, C3, C4, E1, E2, E3)*** • Evaluate economics for conversion of fiber to ethanol: 1) process whole, 2) fractionate fiber first, 3) integrate distiller dry grain production prior to fractionation ***(DOE-EE-OBP, USDA) (A6, C4, E1, E2)*** • Complete integrated pilot scale trials for dry agricultural residue and forest feedstocks ***(USDA, DOI) (A2, A7, A8, A9, A10, B2, B3, B5, C1, C3, C4, C5, E1, E2, E3)***	• Complete pilot scale trials for facilities processing multiple feedstocks – residues and crops ***(USDA, OBP, DOI, EPA, DOD) (A6, A7, A8, A10, B2, B3, B5 C1, C3, C4, C5, E1, E2, E3)***	• Complete integrated pilot scale trials ***(USDA, OBP, DOI, EPA, DOD) (A6, A7, A8, A10, B2, B3, B5, C1, C3, C4, C5, E1, E2, E3)***

Current Federal Efforts in Feedstocks

Seven Federal agencies are currently involved in some aspect of feedstocks for the biofuels industry. The illustration of the link between each barrier, activity, and agency is identified in Table 2. Highlights of the activities currently being conducted by Federal agencies are summarized in Table 3. Below is a summary of each agency role in the feedstock area.

USDA – **Lead role** for a full range of research activities including sustainable land management and conservation; effective crop and forest management practices; evaluation of environmental impacts (air, water, soil); evaluation of socio-economic changes in rural communities; sustainable harvesting and handling of biomass; plant science, genetics and breeding (including: participation in the National Plant Genome Initiative with DOE and NSF; the USDA-CSREES/DOE Feedstock Genomics for Biofuels Production Program; and other activities); integrated feedstock supply systems; on-farm crops and grasses research; sustainable crop residue removal; sustainable forest energy feedstock production; relative carbon sequestration of switchgrass for bioenergy and corn; small-scale demonstrations; and life cycle analysis of wood.

DOE - **Supporting role** in feedstocks for bioenergy. Conducts research in preprocessing, including integrated systems to support collection and harvesting, and storage concepts; leads the Biomass Regional Partnerships; manages Congressionally-directed work on hybrid poplar and switchgrass plantations (demonstration); conducts basic research to support feedstock sustainability and plant science, including photosynthesis, plant physiology and genomics (National Plant Genome Initiative), and development of biotechnology tools, especially of model organisms that may accelerate trait development and improvement of future bioenergy crops.

NSF - Provides grants to support basic cross-cutting research to improve biofuel feedstocks (National Plant Genome Initiative), to use wastes as energy sources, and to improve pre-processing of feedstocks.

DOI - As the manager of one fifth of the nation's lands, the Department is a major producer of forest thinnings and other biomass materials from fire prevention, healthy forest and other land management activities. This material is available for a variety of uses, including as an energy source. Working with the USDA, DOI has implemented several programs, such as stewardship contracting, that provide incentives for the removal of this material. The Department of the Interior also co-chairs a Federal interagency Woody Biomass Utilization Working Group that promotes the use of woody biomass. This Group reports to the Biomass R&D Board. The Department's Bureau of Indian Affairs provides renewable energy grants to address feedstock issues on Indian lands.

EPA - Role in understanding environmental aspects of biofuels, including full life cycle analysis and R&D on environmentally preferable options; explores systems approach to biofuels with focus on sustainable feedstocks and fuels; ORD supports a Waste to Energy Team Network for converting biomass and wastes to products; developing an informational matrix summarizing biomass conversion technologies, compatible feedstocks and potential products; ORD and EPA Regions support an analysis of trade-offs among different ecosystem services under various biofuels development scenarios. Regional collaboratives conduct some market development programs and various regional programs conduct small-scale demonstrations of bio-waste to energy.

DOT - Participants in Sun Grant Initiative (environmental sustainability, feedstock research, systems analysis); conducts some economic, logistics, and environmental analysis. Conducts demonstrations using biofuels.

DOD – Basic research, demonstration, and validation on feedstock preprocessing for MSW/waste biomass; potential for greater role in large-scale demonstrations.

Table 3. Feedstock Development Activities by Agency

Agency/ Department	FEEDSTOCK PRODUCTION			
	Sustainability	**Forest and Feedstock Management**	**Plant Science, Genomics and Genetically Modified (GM) Feedstocks**	**Regional Inventory**
USDA	Conducts various R&D and conservation programs to help conserve, maintain, and improve natural resources, while maximizing sustainable harvest of all feedstocks	R&D on management practices and systems to expedite the establishment of herbaceous and woody crops, and forest resources	Improve plant material through breeding and biotechnology Develops national and regional plant breeding resources to facilitate and accelerate the commercial adoption of superior genetic resources across a wide array of feedstock crops Uses GM to produce herbaceous energy crops with superior traits for Biofuels (including the National Plant Genome Initiative (DOE/USDA/NSF)	Provide forest and crop databases such as FIA and NRI Multi-state research documenting the bioenergy potential for switchgrass in the Great Plains
DOE – EE-OBP	Biomass Regional Partnerships: focuses on regional R&D needs and sustainable feedstocks	Congressionally-directed work involving hybrid poplar plantation and switchgrass management	Congressionally-directed work to improve hybrid poplar yields, pest resistance, etc.	Biomass Regional Partnerships: more accurate supply cost information
DOE – SC – BER	Feedstock sustainability activities such as the study of microbial communities and plant-microbe associations		Plant science and GM to understand plant structure and metabolic pathways (Genomics GTL, Joint Genome Institute, National Plant Genome Initiative (DOE/USDA/NSF), Bioenergy Research Centers)	
DOE-SC-BES			Basic research on energy transduction systems from photosynthetic capture of solar energy, through charge separation, CO2 fixation and intermediary metabolism, to deposition into energy-rich compounds	
NSF	Basic research to improve sustainability of water and other natural resources		Basic research to improve biofuel feedstocks, including National Plant Genome Initiative (DOE/USDA/NSF)	

Table 3. Feedstock Development Activities by Agency				
DOI	Conducts research and analysis to help conserve, maintain and improve soil and other natural resources (USGS) Administers federal regulations for fish and wildlife conservation (USFWS) Evaluates the environmental impacts of hazardous fuels treatments and other forest management activities. (USFWS, BLM, NPS, BIA)			Provides AS-IA renewable energy grants to address feedstock inventory. Coordinates with USFS and other landowners to identify biomass resources availability across agency boundaries. (BLM)
EPA	Conducts R&D related to sustainable feedstock practices. Conducts regional comparative analysis of ecosystem service trade-offs under different feedstock production scenarios. Developing an informational matrix summarizing biomass conversion technologies, compatible feedstocks and potential products. Regional collaboratives conduct some market development programs and small-scale demonstrations of bio-waste to energy. Developing a Waste-to-Energy Strategy focusing on manures, woody wastes, municipal solid waste, construction & demolition, and biosolids, evaluating reductions in waste, energy use, greenhouse gases.	Conducts lifecycle analysis from production to fuel (as in RFS Regulatory Impact Analysis). Conducts R&D related to water quality issues arising from various pollutant sources, including agricultural practices. Assesses sources, transport, impacts, and mitigative measures. Developing decision waste decision support tools that consider availability, transport, and environmental impacts of conversion.		Expands biomass technology database (feedstocks, conversion, and products) to include GIS data. Analyzes waste characteristics, availability, and economic competitiveness, considering existing waste infrastructures. Comparing use of wastes as feedstock vs. agricultural feedstocks for reductions of energy and water use, and water, air, and greenhouse gas emissions.
DOT	Conducts environmental sustainability and feedstock research through the Sun Grant Initiative Carbon sequestration Nutrient management Soil quality Erosion & soil cover	Cropping systems Crop rotations Alternate crops	Screening and selection of native populations Traditional breeding for increased yield, improved composition and broader adaptation Biotechnology assisted gene markers and modification of selected traits in selected materials	GIS tools to quantify feedstock availability and the impact of climate, weather events and policy decisions of feedstock supply
Agency/	**HARVESTING, COLLECTION, STORAGE, TRANSPORT**		**PREPROCESSING**	

Table 3. Feedstock Development Activities by Agency				
Department	**Yield, Harvesting and Collection**	**Storage and Transport**	**Feedstock Densification, Particle Sizing and Materials Handling**	**Feedstock Flexibility**
USDA	R&D on commercially-viable and sustainable practices for harvesting and handling energy feedstocks, including an integrated feedstock supply system for agricultural residues and forestry biomass	Working to develop an integrated feedstock supply system. Develop technologies for wet harvesting and storage of perennials and agricultural crop waste	Develops commercially-viable and sustainable practices for handling energy crops, including forest residues. . R&D on size reduction and separation processes	Understand plant structural and compositional characteristics
DOE –EE-OBP	Research on feedstock (agricultural residues, herbaceous and short rotation woody crops) preprocessing that includes collection and harvesting, and involves development/validation of technoeconomic models	Research on feedstock (agricultural residues, herbaceous and short rotation woody crops) preprocessing that includes storage and involves development/ validation of technoeconomic models	Research on feedstock (agricultural residues, herbaceous and short rotation woody crops) preprocessing that includes feedstock densification and materials handling, and involves development/validation of technoeconomic models	
DOE –SC-BER				Basic research on feedstocks with similar characteristics (e.g., composition) that support feedstock flexibility
DOE-SC-BES				Fundamental biophysical and biochemical research on cell wall architecture
DOI	Conducts various activities in forest thinnings, including R&D to monitor, manage, and remove thinnings; Partners with others, including the Federal Woody Biomass Utilization Working Group to address biomass utilization issues, including collection issues; Assistant Secretary – Indian Affairs (AS-IA) awards renewable energy grants for biomass collection	AS-IA renewable energy grants address feedstock transport		

Table 3. Feedstock Development Activities by Agency				
EPA	Analyses on availability of various wastes as feedstock and infrastructures for collection	Waste to Energy Team's Network: focuses on technologies for converting biomass and wastes to products; looks at feedstock infrastructures and compatibilities Models energy use, air and Greenhouse emissions under different spatial relationships of feedstock to conversion technologies and users		*"Biomass Conversion: A Matrix of Technologies, Feedstocks, and Products"* helps differentiate applicability of various feedstocks for specific conversion technologies
DOD			Basic R&D and demonstration/validation work on feedstock preprocessing/handling for conversion of MSW/waste biomass to fuels and products	
DOT		Capacity and infrastructure analysis; regulatory oversight of transport systems		
Agency/ Department	**DEMONSTRATION**		**CROSS-CUTTING/OTHER**	
USDA	Demonstration/deployment of small-scale biomass energy systems Demonstrations of sustainable and high-production feedstock systems		Works with DOE on regional partnerships to assess biomass potential across the U.S. Develop economic information systems for various feedstocks	
DOE-EE-OBP	Demonstrations of various hybrid poplar and switchgrass production/collection systems		Technoeconomic analysis and market development for congressionally-directed projects (e.g., cellulosic ethanol industry in Dakotas, hybrid poplar, and switchgrass) Regional Partnerships also address integration of feedstock supply systems and conversion technologies and improved communication with all elements and partners in the feedstock supply chain	
NSF			Basic research across platforms/barrier areas and feedstocks to improve economics (includes SBIR and State programs)	
DOI	Demonstration of woody biomass utilization projects, use of biomass in agency heating systems		Native American energy development activities, such as feasibility studies for using local biomass resources for biopower (for example: one tribe has a 7 MW plant; expanding to 22 MW) Education, outreach, development of policies promoting the use of woody biomass	
EPA	Several demonstrations, including growing oil crops in Hawaii for biodiesel production, and creation of a large-scale biodiesel market based on waste cooking oil Developing inventory of waste-to-energy projects that produce biofuels		Economic analysis of biofuel feedstocks and biofuels using supply curves and related conversion technologies that consider economic (fuels market), environmental, and social impacts (Example: RFS analysis) Market development programs	
DOT			Economic and environmental analyses of alternative fuels and supply chains.	

Table 3. Feedstock Development Activities by Agency		
DOD	Demonstration/validation work on feedstock work on feedstock preprocessing/handling for conversion of MSW/waste biomass to fuels and products.	

Federal Budgets for Feedstock Development

Table 4 is a rough attempt to capture the current budgets for activities supported by the agencies involved with feedstock development. This information is not necessarily up to date or consistent regarding funding year and, as such, needs to be reassessed by an interagency team. Colored shading in cells indicates that funding numbers overlap in those technical areas. Funding numbers are incomplete at this time (na = not available).

Table 4. Budget for Feedstock Infrastructure By Agency ($ million)

Agency/ Department	Production				Harvesting, Collection, Storage & Transport		Preprocessing		Demonstration/ Other	
	Sustainability	Forest and Feedstock Management	Plant Science, Genomics and GM	Regional Inventory	Yield, Harvesting and Collection	Storage and Transport	Feedstock Densification/ Materials Handling	Feedstock Flexibility	Demonstrations	Cross-cutting/Other
USDA (Total)	Na	Na	Na	None	Na	Na	Na	None	Na	None
FS	2.75	1.50	0.50	None	0.50		Na	None	Na	None
CSREES	~0.3	~0.6	5	None	Na	Na	Na	None	Na	None
ARS	0.78	0.91	6.93	None		Na	Na	None	Na	None
NRCS	Na	Na	Na	None	Na	Na	Na	None	Na	None
OCE										
OEPNU	Na	Na	Na	Na	Na	Na	Na	Na	Na	Na
DOE-EE-OBP	3.35 (FY07)	Na[b]	Na[b]		0.037 (FY06) 3.225 (FY07)			None	Na[b]	Na[b]
DOE –SC-BER	Na	None		None	None	None	None	Na	None	None
DOE-SC-BES	None	None	11	None	None	None	None	4	None	None
NSF	None	None	~24 - 27[e] (FY06, FY07)	None	None	None	None	None	None	~11[a] (FY06, FY07)
DOI	None	None	None		208[c] (FY06) 199[c] (FY07) [f] (FY07)		None	None	None	None
EPA	Na	None	None	Na	None	Na	None	None	Na	Na
DOT	~50[d] (FY06 – FY09)	None	None	None	None	~50[d] (FY06 – FY09)	None	None	None	Na
DOD	None	None	None	None	None	None	Na	None	Na	None

a May cover more than feedstock related research

b No funding for earmarks provided – are they working completely off of previous (FY05 and earlier) funds

c Primarily for the National Fire Plan Hazardous Fuel Reduction Program. Biomass portion of this budget is not identified. DOI's BLM estimates expenditures approximating $.290 in FY06 for all biomass projects. Numbers for those associated w/biofuels are not available.

d The Sun Grant Initiative funds are for Biobased Transportation Research and cover various areas including some outside the feedstock group (fuel distribution infrastructure, etc.). Funding is $12.5 MM per year.

e Includes 24-25 for NSF/BIO, 2-3 for NSF/ENG. Does this also include the $30MM over three years for the National Plant Genome Initiative (DOE/NSF/USDA)

f Funding for the entire Bureau of Indian Affairs renewable energy program is FY07 is $1.5 M.

Na not available.

Detailed Recommendations to the Board for **Feedstocks and Feedstocks Infrastructure**

The following recommendations were made to improve coordination as well as expand the current scope of activities in biofuels. These recommendations are not in order of priority nor are they expressed in the context of activities to meet the near-, mid- or long-term goals. An interagency team should evaluate these recommendations for their relevance before moving forward with any implementation, as well as make additional recommendations in the context of activities needed to meet the near-, mid-, or long-term needs as identified in Table 2 of this section.

- **Coordinate feedstock demonstration and validation.** USDA and others should coordinate more closely with DOD and other agencies on feedstock demonstration and validation. As significant land holders, there are opportunities for large scale demonstrations on Federal land which otherwise might not be possible. In addition, potential revenue must be adequate to ensure producer participation in the feedstock production stream.
- **Environmental impacts**. EPA and USDA should develop a comprehensive analysis of the environmental impacts (water, air, soil quality and wildlife habitat) of biofuel production on cropland.
- **Increase EPA participation with Sun Grant Universities and Land Grant Universities**. These broad-based university consortiums would benefit by increasing cooperation on sustainability, air and water quality, and other issues that EPA brings to the table. Cooperation may also include participation in Regional Feedstock Partnerships.
- **Establish protective environmental standards for surface waters** EPA should continue to work with states to set protective numeric water quality standards for nutrients that will serve as a target to measure sustainable crop practices.
- **Coordinate future development of the Regional Inventory with USDA, DOE, DOI and EPA.** There are data and other resources among all three agencies that could contribute to the successful development of the inventory, and should be coordinated to ensure consistency and mitigate duplication of effort.
- **Harvesting and collection coordination.** DOE should coordinate with DOI, USDA and the Forest Service to better understand what technology is available and currently under development. There is potentially an opportunity for coordinated Federal development of advanced feedstock harvesting and collection equipment.
- **USDA and DOE coordination on crop improvement programs.** This includes plant science GM and plant breeding to fill the critical need to enhance national and regional plant breeding resources targeting bioenergy feedstock crops.
- **Explore waste to energy (waste oils, MSW [includes landfill gases], industrial, animal wastes, construction/demolition, yard waste, biosolids).** This is potentially an important aspect of the bioenergy arena that is currently under-emphasized, although

waste was included as a viable resource in the *Billion Ton Study*. Wastes could potentially provide stop-gap resources in times of drought or other supply shortages. Biomass waste resources need to be on the table and explored by all agencies, as the needs and opportunities are unique to each. Additionally, the interagency team focused on feedstocks should identify activities that include manure management, waste to fuels management and woody biomass management.

- **Create focused working groups.** Working groups are needed to develop the best strategies for R&D coordination, resource allocation, dissemination of information, and implementation in the feedstocks area. Utilize existing working groups, such as the Woody Biomass Utilization Group, to prevent duplication of effort.
- **Evaluate feedstock development funding.** The level of funding of current agency activities in Table 4 needs to be further developed to address missing information (such as the level of funding by agency for National Plant Genomics Initiative). This current funding is needed to identify gaps or underfunded areas. Future funding needs to be addressed so that decision-makers are aware of the sizable investments in feedstock development necessary to reach the goals.
- **Coordinate Requests for Proposals** amongst federal agencies to minimize gaps in needed research, development, and deployment of feedstock related activities.
- **Create a detailed agency activity report**. A detailed report on agency activities (beyond the summary tables and matrices provided in this document) is needed to clarify what is currently being done and what needs to be done (gaps in existing feedstock efforts). This would include both scope of effort and funding.
- **Revisit issues including land cover changes, price effects, opportunity costs in feedstock availability, and other sustainability concerns such as carbon sequestration**. The scope of this report does not allow adequate detail of these issues.
- **Create a definition of "Sustainability."** A common definition of sustainability that all can agree on and a set of criteria subject to peer discussion and review is necessary.

References

1. *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*. (April 2005). U.S. Department of Energy and U.S. Department of Agriculture. DOE/GO-102005-2135. http://www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf
2. "2006 Ethanol Production up Nearly 25 Percent Over 2005," Renewable Fuels Association. (March 5, 2007). http://www.ethanolrfa.org/media/press/rfa/view.php?id=964
3. National Biodiesel Board. http://www.nbb.org/pdf_files/fuelfactsheets/Production_Graph_Slide.pdf and http://www.nbb.org

Biochemical Conversion

Technology Status and Challenges

Meeting the President's goals will require a significant increase in ethanol production over today's corn starch-based industry. Put simply, it will require the commercialization of cellulosic ethanol technology in the near term. Currently, this is technically feasible for corn stover (Aden et al. 2003) and possibly poplar (Wooley et al. 1999) using biochemical conversion technologies. The biochemical route involves the breakdown of lignocellulosic biomass into its component sugars using a combination of chemical and biological processes that include pretreatment, enzymatic hydrolysis, and fermentation (see Figure 1). However, the process remains inefficient and is therefore costly to commercialize.

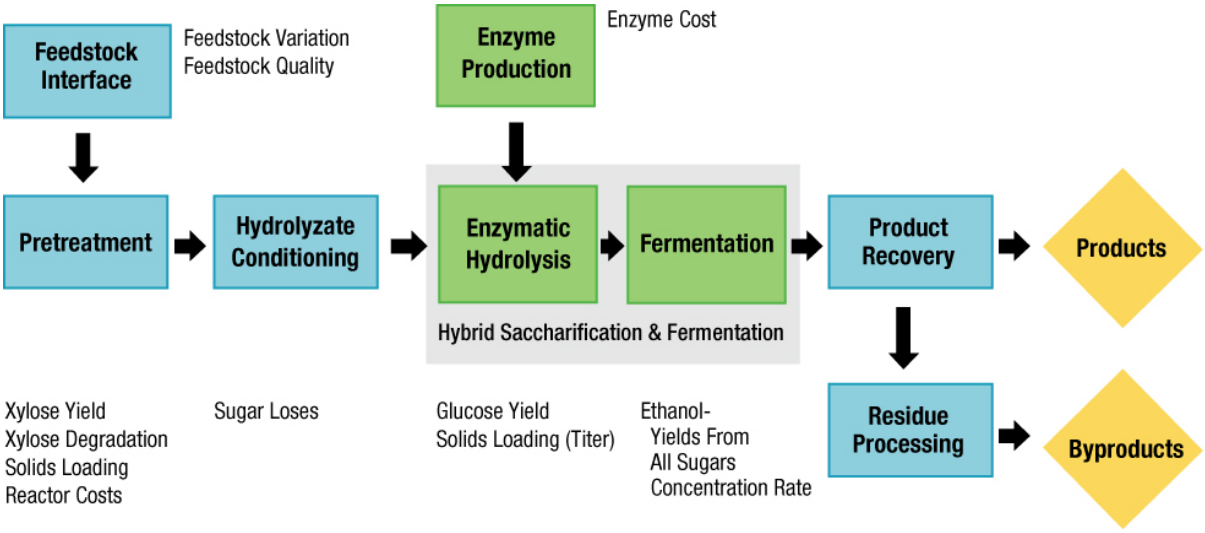


Figure 1. Major research areas and barriers for biochemical ethanol to meet 2012 goal (Thomas Foust, et. al, 2006)

Table 1 explains in more detail the biochemical conversion processing steps and the key barriers that impact cost and performance currently hindering the commercialization of lignocellulosic conversion to biofuels.

Table 1. Biochemical Conversion Elements and Key Barriers

Element	Key Barriers
Feedstock Interface and Preparation	**Key Barriers**
A. Biomass Fractionation Fractionation can be used to increase the value of the individual components in biomass prior to their subsequent conversion into products.	• A1. Lack of a fundamental understanding of the interactions between chemical, biological, solvation (ability to go into solution), and mechanical processes to ultimately allow biomass to be more efficiently fractionated at high yield into high purity components.
B. Biomass Variability The characteristics of biomass can vary widely in terms of physical and chemical composition, cell wall structure, size, shape, moisture content, and bulk density.	• B1. Variations in biomass characteristics can make it difficult (or costly) to supply biorefineries with feedstocks of consistent, acceptable quality year-round, and feedstock variability affects overall conversion rate and product yield of biomass conversion processes.

C. Biomass Recalcitrance Lignocellulosic biomass feedstocks are naturally resistant to chemical and/or biological degradation.	• C1. Lack of understanding of fundamental roles of biomass structure and composition and the critical physical and chemical properties that determine the susceptibility of cellulosic substrates to hydrolysis. This lack of understanding limits the cost-effectiveness and efficiency of pretreatment processes.
Pretreatment/Preprocessing	**Key Barriers**
D. Pretreatment Chemistry Pretreatment is required to open up the structure of biomass all the way to the plant cell wall scale and increase its susceptibility to subsequent enzymatic hydrolysis by cellulase enzymes.	• D1. Lack of full understanding of the critical physical and chemical properties that determine the susceptibility of cellulosic substrates to hydrolysis and the role that lignin and other products of pretreatment chemistry play in impeding access to cellulose.
E. Pretreatment Costs	• E1. Pretreatment reactors typically require expensive construction materials to resist acid or alkali attack at elevated temperatures or for prolonged times. • E2. Lack of understanding of the impact of reaction configuration and design on thermochemical cellulose prehydrolysis, especially for high-solid loadings.
Processing and Conversion and Product Recovery	**Key Barriers**
Enzymatic Hydrolysis	
F. Cellulase Enzyme Production Cost Cellulase enzymes remain a significant portion of the projected production cost of sugars from cellulosic biomass.	• F1. Lack of cost-effective enzyme production technologies ($/kg enzyme) for saccharification of pretreated biomass
G. Cellulase Enzyme Loading	• G1. Need to identify more efficient enzyme preparations and enzyme hydrolysis regimes that permit lower dosages (kg enzyme/kg substrate) to be used and thereby reduce the cost of enzymatic hydrolysis
H. Enzyme Biochemistry Enzymes that exhibit high thermostability and substantial resistance to sugar end-product inhibition will be essential to fully realize enzyme-based sugar platform technology.	• H1. Need to increase our understanding of the fundamental mechanisms underlying the biochemistry of enzymatic cellulose hydrolysis, including the impact of biomass structure on enzymatic cellulose decrystallization. • H2. Lack of understanding of the role of cellulases and their interaction not only with cellulose but also the process environment, which is necessary to affect further reductions in cellulase cost through improved production.
I. Hemicellulase Preparations for Production of Sugars Pretreatments that do not chemically saccharify xylan related sugars will need to rely on chemical or enzymatic means for converting these polymers to complete saccharification.	• I1. Further work is needed to define the ability of these and ligninases to compensate for declining sugar (and product) yields at lower severity operating conditions. Relating any such affects to changes in cell wall structure would be highly desirable.
Process Integration	
J. Cleanup/Separation Sugar solutions resulting from pretreatment are impure, containing a mixture of sugars and a variety of non-sugar components. The presence of some of the non-sugar components can be inhibitory to microbial fermentation or biocatalysis or can poison chemical catalysts.	• J1. Low cost purification technologies need to be developed that can in activate or remove impurities from hydrolysates. Alternately, further work on stress tolerance can be used to raise the concentration at which inhibition occurs and reduce or perhaps eliminate the need for their removal. • J2. Lack of cost effective methods for providing purified, concentrated and clean sugar feedstocks to biobased product manufacture, as well as allowing for water recycle as appropriate for maintaining plant-wide water balances
K. Biological Process Integration	• K1. Need to characterize the complex interactions that exist between many of the processing steps, identify unrecognized separation requirements, process bottlenecks and knowledge gaps, and generate the integrated performance data necessary to develop predictive mathematical models that can be used to guide process optimization and scale-up.
Conversion	

L. Fermentation	• L1. Significant improvements in currently existing organisms are required to increase the efficiency of the fermentation of sugars to ethanol. The primary improvements are the development of organisms that are capable of utilizing all the sugar components from biomass hydrolysate. Specifically, organisms need to be capable of utilizing 5 carbon sugars, namely xylose and arabinose with a targeted yield of 80-90% utilization of five carbon sugars. Furthermore, development of an organism that is capable of utilizing five carbon sugars, preferably simultaneously with six carbon sugars, derived from hydrolysate is desired. An organism with greater thermotolerance allowing bioreactor operation at temperatures closer to the optimum temperature of the enzymes is also desired.
Product Recovery	
M. Separation Technologies. Enhanced efficiency and heat integration capabilities of separation technologies are desired in order to reduce the energy required to produce fuels from dilute fermentation broths. Improvements in current distillation/adsorption technologies, the development of alternative product recovery technologies, and new hybrid process approaches are needed which encompass a range of biofuel facility capacities.	• M1. Need for integration of cyclic with continuous processes • M2. Alternative separation technologies may only be in R&D phase • M3. Lack of real world and long term demonstrations with emerging separation technologies • M4. Broth from cellulosics may be more dilute in biofuels than grain-based broth.
Process Design	**Key Barriers**
N. Analysis Analysis 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.	• N1. Lack of analysis • N2. Lack of funding • N3. Lack of time

New research investments being made hold significant promise for making biofuel production from lignocellulosic biomass cost effective and commercially viable to meet the 2012 goal. Note that most of the barriers described in Table 1 apply equally to ethanol conversion as well as fermentation to value-added chemicals and bio-butanol. Tapping into the ability to utilize lignocellulosic feedstocks will supplement grain based biofuels and is critical to meeting the BFI volumetric goals.

Table 2 outlines the major activities needed, in the near-, mid-, and long-term, to meet the challenges described in Table 1. Each agency that currently contributes to each activity described in Table 2 is noted after that activity [e.g., ***(USDA, DOE…)***]. The key barriers addressed by each Table 2 activity align with the numbered barriers in Table 1, and are also noted after each activity in Table 2 [e.g., ***(A1, B2…)***]. Table 3 lists specific agency activities based on the information provided by each agency during the November workshop and during the drafting of this document. Table 4 describes each agency's funding that supports its activities. Tables 3 and 4 are not complete or linked with Tables 1 and 2; interagency teams should continue this effort.

Together, these four tables represent the most complete interagency biofuels activity reference to date, and should serve as a guide for future interagency teams. Development of a detailed, shared agency activity database is recommended to further illustrate these collaborations and identify gaps (see *Summary of Overall Recommendations*).

Note: These notations are based on agency input at the time of this document's drafting, and the November workshop proceedings. They do not necessarily reflect established future work plans by these agencies, but rather reflect their current or potential future activities.

Table 2. Key RD&D Activities Needed to Overcome Barriers for Biochemical Conversion			
Biochemical Conversion RD&D Area	**Near Term (0-5 Years)**	**Mid Term (5-10 Years)**	**Long Term (10+ Years)**
Feedstock Interface and Preparation			
Characterize Feedstock Quality		▪ Evaluate ethanol yields. ***(USDA-CSREES) (B1, C1)***	
Pretreatment/Preprocessing			
Pretreatment Chemistry	▪ Increase sugar yields. ***(USDA-CSREES) (D1)*** ▪ Reduce sugar degradation with high solids throughput. ***(USDA-CSREES) (D1)***	▪ Optimize pretreatment and enzyme process variations for conversion of Short Rotation Woody Crops (SRWC) and forest thinning and residues. ***(DOE-EE-OBP, USDA-CSREES) (A1,B1,C1)*** ▪ Continually increase sugar yields and decrease sugars degradation (Ag Residue Pathway). ***(USDA)*** ▪ Increase sugar yields (Herbaceous Energy Crop Pathway). ***(USDA)*** ▪ Reduce sugar degradation with high solids throughput (Herbaceous Energy Crop Pathway). ***(USDA)***	▪ Continually increase xylan yields and decrease sugars degradation (Herbaceous Energy Crop Pathway). ***(USDA)*** ▪ Increase sugar yields (Short Rotation Woody Crops). ***(USDA)*** ▪ Reduce sugar degradation with high solids throughput (Short Rotation Woody Crops). ***(USDA)***
Processing, Conversion and Product Recovery			
Enzymatic Hydrolysis	▪ Increase specific activities. ***(USDA-CSREES) (F1, G1, H1, H2, I1, J1, J2, K1, L1)*** ▪ Reduce product inhibition. ***(USDA-CSREES) (F1, G1, H1, H2, I1, J1, J2, K1, L1)*** ▪ Achieve reduction of sugar losses in conditioning step. ***(USDA-CSREES) (F1, G1, H1, H2, I1, J1, J2, K1, L1)*** ▪ Understand effect of conditioning step on fermentation. ***(USDA-CSREES) (F1, G1, H1, H2, I1, J1, J2, K1, L1)***	▪ Reduce sugar losses in overliming conditioning step (Herbaceous Energy Crop Pathway, and Short Rotation Woody Crops). ▪ Understand effect of conditioning step on fermentation (Herbaceous Energy Crop Pathway, and Short Rotation Woody Crops).	▪ Continue reduction of sugar losses in overliming conditioning step (Ag Residue Pathway, Corn Wet and Dry Grind Milling, and Herbaceous Energy Crop Pathway).
Cellulase Enzyme Production Costs	▪ Understand impacts of pretreatment on enzyme efficacy. ***(USDA-CSREES) (F1, G1, H1, H2, I1, J1, J2, K1, L1)*** ▪ Increase saccharification rate. ***(DOE-SC-BER, USDA-CSREES) (F1, G1, H1, H2, I1, J1, J2, K1, L1)*** ▪ Understand cellulase interaction at the plant cell wall, increase rate, and reduce specific inhibitors. ***(USDA, DOE-SC-BER) (H1, H2)***	▪ Understand cellulase interaction at the plant cell wall, increase rate, and reduce specific inhibitors (Herbaceous Energy Crop Pathway). ***(USDA, DOE-SC-BER) (H1, H2)***	

Table 2. Key RD&D Activities Needed to Overcome Barriers for Biochemical Conversion			
Biochemical Conversion RD&D Area	**Near Term (0-5 Years)**	**Mid Term (5-10 Years)**	**Long Term (10+ Years)**
Saccharification	▪ Demonstrate new enzymes and molecular machines that perform high efficiency digestion, have high yields of fermentable sugars, and are resistant to inhibition by reaction conditions. ***(DOE-SC-BER, USDA-CSREES) (F1, G1, H1, H2, I1, J1, J2, K1, L1)***		▪ Demonstrate new enzymes and molecular machines that perform high efficiency digestion and have high yields of fermentable sugars, and are resistant to inhibition by reaction conditions (Herbaceous Energy Crop Pathway). ***(USDA, DOE-SC-BER)***
Fermentation	▪ Development of improved ethanologen to co-ferment all biomass sugars to ethanol. ***(DOE-SC-BER, USDA-CSREES) (F1, G1, H1, H2, I1, J1, J2, K1, L1)*** ▪ Evaluate viability of syngas fermentation to ethanol (Forest and Pulp and paper Mills). ▪ Development of improved butanologen to tolerate higher concentrations of product ***(EPA-ORD, NSF-MCB[MEWG])(L1)***	▪ Evaluate viability of syngas fermentation to ethanol. (***NSF)***	
Enzymatic Saccharification and Fermentation	▪ Understand lignin redeposition and other process enzyme effects, and reduce process time. ***(DOE-SC-BER) (C1)*** ▪ Develop ethanologen to co-ferment mixed sugars to ethanol. ***(DOE-SC-BER, USDA-CSREES) (F1, G1, H1, H2, I1, J1, J2, K1, L1)***	▪ Understand lignin redeposition and other process enzyme effects, and reduce process time (Herbaceous Energy Crop Pathway). ***(DOE-SC-BER) (C1)*** ▪ Develop ethanologen to co-ferment mixed sugars to ethanol (Herbaceous Energy Crop Pathway). ***(USDA, DOE-SC-BER)(L1)***	
Single Step Processing			▪ Develop commercial organisms for single-step processing that produces competitive ethanol yields. ***(DOE-SC-BER, USDA-CSREES) (F1, G1, H1, H2, I1, J1, J2, K1, L1)***
High Value Co-products	▪ Produce high value chemical and material co-products from biomass sugars. ***(USDA-CSREES)*** ▪ Produce new products from corn DDGs and soymeal derived oils. ***(USDA-CSREES)***	▪ Produce high value chemical and material co-products from biomass sugars (Herbaceous Energy Crop Pathway, and Short Rotation Woody Crops).	

Table 2. Key RD&D Activities Needed to Overcome Barriers for Biochemical Conversion			
Biochemical Conversion RD&D Area	**Near Term (0-5 Years)**	**Mid Term (5-10 Years)**	**Long Term (10+ Years)**
Product Separation Technologies	▪ Develop and demonstrate energy efficient hybrid processes. ***(EPA-ORD) (M2, M3)*** ▪ Demonstrate emerging technologies with actual fermentation broths. ***(EPA-ORD) (M3)*** ▪ Membrane research and module development for liquid biofuels recovery. ***(EPA-ORD, USDA) (M2)***	▪ Demonstrate hybrid processes in biofuel facilities at pilot- scale. ***(EPA-ORD) (M2, M3)*** ▪ Membrane research and module development for gaseous biofuels recovery. ▪ Research into recovery of carbon dioxide from fermentor off-gas. ***(USDA)***	▪ Refine hybrid process design for improved energy efficiency. ▪ Develop and demonstrate carbon dioxide recovery. from fermentor off-gas ▪ Incorporate improved membranes and modules.
Process Design			
Analysis	▪ Evaluate the ability to bring in new forest feedstocks (thinning) into existing facilities for separate processing to sugars. ***(USDA-CSREES)***		
Sugar Extraction	▪ Conduct study on extracting C5/C6 sugars from hemicellulose (upstream of pulp digester) and effect on pulp quality. ***(USDA-CSREES)***		
Demonstration			
Demonstration	▪ Complete integrated pilot scale trials for facilities utilizing Short Rotation Woody Crops feedstocks. ***(USDA, DOE-EE-OBP)***		
Crosscutting			
Measurement methods, standards, and data to support the optimization of bioconversion processes.	▪ Comprehensive databases of thermodynamic and kinetic data that are pertinent to biofuels; Standard Reference Materials and analytical methods needed for the utilization of hemicelluloses. ***(DOC-NIST) (A1, B1, C1, D1, F1, G1, H1, H2, I1, K1, L1)***	▪ Measurement methods, standards, and data to support the optimization of bioconversion processes.	▪ Comprehensive databases of thermodynamic and kinetic data that are pertinent to biofuels; Standard Reference Materials and analytical methods needed for the utilization of hemicelluloses. ***(DOC-NIST) (A1, B1, C1, D1, F1, G1, H1, H2, I1, K1, L1)***
Benchmark IP successes and learn how to manage IP effectively.	▪ This affects all items in Table 1	▪ Benchmark IP successes and learn how to manage IP effectively.	▪ This affects all items in Table 1

Current Federal Efforts in Biochemical Conversion

Five Federal agencies (seven programs) provided an overview of their current involvement in some aspect of biochemical conversion of biomass to biofuels. The illustration of the link between each barrier, activity, and agency is identified in Table 2. The roles and primary

contributions of USDA, DOC, DOE, EPA, and NSF and other Federal agencies involved in biochemical conversion are outlined below in Table 3.

DOE-Office of the Biomass Program (OBP) plays a major role in the biochemical conversion of lignocellulosic material to fuels and products. Conducts research in pretreatment, enzymatic hydrolysis, fermentation, process integration and the demonstration of these technologies.

DOE- Office of Science (SC) - Office of Biological & Environmental Research (BER) supports fundamental research on feedstock genomics, biodegradation of lignocellulose, and bioethanol and biohydrogen production.

DOE-Office of Basic Energy Sciences (BES) supports biophysical and biochemical research on cell wall architecture.

DOE – Hydrogen, Fuel Cells, and Infrastructure Technology Program (HFCIT) supports research on the production of hydrogen utilizing micro-organisms.

NSF- The Engineering (ENG) and Mathematical and Physical Sciences (MPS) Directorates supports basic research on the enzymatic and catalytic conversion of lignocellulosic material to fuels and other chemicals.

USDA - Agricultural Research Service (ARS) plays a major role in facilitating the biochemical conversion of lignocellulosic material. Specifically ARS funds R&D to reduce the pretreatment and enzymatic costs.

USDA –Cooperative State Research, Education and Extension Service (CSREES)-National Research Initiative (NRI) and Small Business Innovation Research (SBIR) Program support competitively funded applied and basic research to economically and efficiently convert lignocellulosic biomass to fuels and value-added industrial biobased products.

USDA - Forest Service (FS) plays a major role in overcoming the recalcitrant nature of cellulose from forest resources. Research is focused on efficient fermentation of five carbon sugars and improving hemicellulose and cellulose separation and extraction.

EPA- NVFEL evaluates environmental and potential market impact of technologies via scenario analysis, conducts technical assessments; and investigations into advanced renewable fuel production technologies which are close to commercialization. EPAct directs and authorizes EPA to create programs designed to assist in the research, demonstration, and production of ethanol from cellulosic biomass and to establish an Advanced Biofuel Technologies Program for production of transportation fuels. Funding authorization is included in EPAct, however there are none appropriated. **Environmental Technology Verification Program (ETVP)** develops testing protocols and verifies the performance of innovative technologies; including technology that is used in biochemical and thermochemical conversion processes. **ORD** will assist regions and states in assessing the environmental impacts of growing, harvesting, transporting a variety of renewable feedstocks coupled with various biofuel technology pathways and sustainable biorefinery production, using research and modeling tools (such as the 9-Region MARKAL model). ORD is actively investigating membrane-based alternatives to distillation systems and molecular sieve dryers for the recovery and dehydration of biofuels from dilute fermentation broths.

DOC-National Institute of Standards and Technology (NIST) supports characterization and standardization of catalyst design, biocatalytic processing and quantization of biochemical properties of biomass feedstocks and their constituents.

Table 3. Biochemical Conversion Activities by Agency

Agency/ Department	FEEDSTOCKS INTERFACE*
	Characterize Feedstock Quality
USDA	Develop models describing the interaction between differences in cell wall structure and subsequent pretreatment and fermentation steps for a range of herbaceous biomass types. Characterize differences in cell wall structure across species and cultivar types.
DOE-SC-BER	Study of lignocellulose degrading microbes and communities Structural characterization of plant cell walls Feedstock genomics
NSF	Basic plant genomics research related to overcoming Utilization recalcitrance.
DOC/NIST	Studies of hydrolysis reactions of polysaccharides Plant genomic research in collaboration with University of Maryland Biotechnology Institute Cell and Tissue metrology Molecular and Structural biology tools to characterize feedstock Measurement standards to characterize feedstock quality
EPA	

Agency/ Department	PRETREATMENT/PREPROCESSING		PROCESSING, CONVERSION AND PRODUCT RECOVERY
	Reduce Pretreatment Costs **Hydrolysate Conditioning**		**Reduce Enzyme Production Costs** **Saccharification** **Fermentation** **Enzymatic Saccharification and Fermentation** **Single Step Processing** **High Value Co-Products**
USDA		Integrate mild preprocessing steps involving biological and/or chemical agents to lower the severity of pretreatment. Evaluate thermally mild alkaline pretreatments for agricultural wastes. Integrate low severity pretreatments with cultivar breeding of herbaceous biomass for enhanced ethanol yields. Develop and refine pretreatment technologies in cooperation with plant production researchers. Integrate biochemical generation of biofuels with existing pulp and paper processing operations.	Identify genes and genetic systems that allow for increased stress tolerance utilizing native S. cerevisiae genes and xeno-genes from environmental samples. Begin to understand the interaction of inhibitors and ethanol tolerance on single cell physiology *of S. cerevisiae.* Developed new or improved biocatalysts capable of co-fermenting glucose and xylose by utilizing *S. cereviciae, Pichia stipitis,* and lactic acid bacteria platform microbes. Research and develop new integrated microbial based bioconversion process for biofuels, including but not limited to, ethanol and butanol.

Table 3. Biochemical Conversion Activities by Agency			
DOE-SC-BER			Study of cellulolytic enzymes and molecular complexes Study of pentose/ hemicellulose utilization Development of novel microbes & molecular systems Study of microbial traits associated with stress tolerance Development of microbes and consortial communities for single-step processing
NSF		Basic research on novel pretreatment approaches.	Conversion of biomass with enzymes, immobilized enzymes, and inorganic catalysts via hydrolysis and gasification
DOC		Measurements and standards to optimize bioconversion methods	Enzyme catalysis measurement and calculation of structure and energetics.
EPA			RD&D in membrane-based pervaporation and vapor permeation technologies as well as distillation-membrane hybrid processes for biofuel recovery and concentration.

Agency/ Department	PROCESS DESIGN Analysis Sugar Extraction	DEMONSTRATION Demonstration
USDA		Demonstration of enzymatic milling as an alternative to traditional wet milling for fractionation of corn kernels prior to fermentation.
DOE-EE-OBP		Demonstration activities are mainly corn based activities but there are several ongoing projects with the national laboratories.
DOC		NIST is not involved directly in demonstration activities for biofuels. However, NIST has ongoing related programs in biocatalysis, biothermodynamics and DNA analysis of grains.

*Note: The activities in "Feedstocks Interface" should be covered in the Feedstocks section. However, this area is where both Feedstocks and Biochemical Conversion "interface." This needs to be resolved by the appropriate interagency team to ensure that the upstream biochemical conversion needs are being considered in feedstock R&D.

Federal Budgets for Biochemical Conversion

Table 4 is a rough attempt to capture the current budgets for activities supported by the agencies involved with biochemical conversion. This information is not necessarily up to date or consistent regarding funding year and, as such, needs to be reassessed by an interagency team. Colored shading in cells indicates that funding numbers overlap in those technical areas. Funding numbers are incomplete at this time.

Table 4. Budget for Biochemical Conversion By Agency ($ million)

Agency/ Department	FEEDSTOCKS		PRETREATMENT/ PREPROCESSING		PROCESSING AND CONVERSION		PROCESS DESIGN		DEMOS
Fiscal Year	2006	2007	2006	2007	2006	2007	2006	2007	
USDA - CSREES	~2.0	~2.3			~5.6 (Pending)	~5.6 (Pending)			
DOE-EE–OBP	~1.0	~1.0	~4.0	~11.0	~9.0	~33.0	~0.4	~1.0	
DOE-EE-HFCIT					0.6	1.5			
DOE-SC–BER									
DOE-SC-BES	4.0	4.0							
NSF	~25.0	~25.0	~0.5	~0.5	~1.5	~2.0	~0.3	~0.5	
DOC									
EPA									

Detailed Recommendations to the Board for **Biochemical Conversion R&D**

The following recommendations were made to improve coordination as well as expand the current scope of activities in biofuels. These recommendations are not in order of priority.

- **Shift emphasis of Metabolic Engineering Working Group.** The USDA, DOE, and NSF should continue to collaborate on the Metabolic Engineering Working Group and shift the emphasis of the group to biofuels and fermentation of five carbon sugars. The near term need is to identify the basic R&D needs to achieve the best commercial organism available with the highest possible ethanol tolerance. This working group will be used as a model to enhance relationships and funding mechanisms between different federal programs.
- **Coordinate agencies to study biomass recalcitrance.** Collaboration between USDA, DOC, NSF, DOE, and EPA should be initiated to study the recalcitrant nature of cellulosic biomass. Several collaboration concepts were suggested, including the development of a working group to jointly solicit and fund basic-to-applied research.

- **Coordinate and integrate economic and environmental analyses:** Economic and environmental considerations may dictate technical and economic viability amongst various biochemical and thermochemical conversion technologies and preference for developing technologies in specific regions.
- **Emphasize value-added coproducts.** The agencies present generally agreed on the continued importance of emphasizing coproducts (i.e., nutraceuticals, biopolymers and biochemicals) in plant design, as profitable manufacturing outputs, taking environmental impacts and permitting issues into account. The opportunity to work with feedstock developers to engineer coproducts into plants was proposed and is directly related with the interface between feedstocks and processing.
- **Hold meeting/create working group for feedstock interface with biochemical processing.** Co-sponsor a meeting on overcoming specific barriers in processing difficulties of varied feedstocks (i.e., Regional Feedstock Partnership). The creation of a working group that focuses on the interface between feedstock and enzymes developed to process the materials was proposed.
- **Share information and data.** The participants of the breakout session recognized the distribution of knowledge gap as an enormous opportunity for collaboration in the future. Databases on both experimental and mathematical modeling as well as actual thermodynamic and kinetic data were suggested. All agencies with data intensive research programs (USDA, NSF, DOE, DOC, etc.) need to share responsibility in facilitating and coordinating development in this area.
- **Discuss EPAct Implementation efforts:** EPAct directs and authorizes EPA to create programs designed to assist in the research, demonstration, and production of ethanol from cellulosic biomass and to establish an Advanced Biofuel Technologies Program for production of transportation fuels. Funding authorization is included in EPAct, however no appropriations have been made. This section of EPAct is similar to the DOE Biomass Program's mission. EPA and DOE should discuss this EPAct authorization so as not to create duplication of federal efforts.
- **Coordinate Federal efforts.** Close interaction, coordination, and cooperation between Federal biomass research programs and specific project groups are necessary to facilitate progress, coordinate planning and communication data. While this has been informally done, a more planned and managed interaction is warranted. Efforts are needed that focus on both improvement and better characterization of current processes and the development, testing and implementation of future conversion processes.
- **Coordinate Requests for Proposals (RFPs).** Coordination of RFPs among federal agencies to minimize gaps in needed research, development, and deployment of biochemical conversion technologies.

Thermochemical Conversion

Technology Status and Challenges

Advantages of Thermochemical Conversion Technologies

- Increases the Btu yield of transportation fuels from biomass
- Potentially more environmentally friendly than other conversion technologies
- Requires lower energy inputs
- Produces multiple fuels
- Uses a variety of feedstocks
- Can be sized to fit application and location – amenable to distributed production
- Clear achievable objectives for plant breeding
- Underlying technologies already at commercial scale for coal

Thermochemical conversion provides an effective approach for producing fuels and chemicals from a wide variety of biomass feedstocks. The process can convert all components of whole biomass, including lignin (a residue of fermentation processes) and spent pulping liquors, to clean intermediates which can be transformed into a variety of fuels and chemicals. The processing technologies can be categorized as gasification, pyrolysis, or carbonization, and catalytic liquefaction. It could also include aqueous phase reforming of bio-derived liquids such as sugars to liquid fuels or hydrogen. Intermediate products include clean synthesis gas (a mixture of primarily hydrogen and carbon monoxide), bio-oil (pyrolysis or hydrothermal), and gases rich in methane or hydrogen. These intermediate products can then be processed to products such as gasoline, diesel, alcohols, ethers, synthetic natural gas, or high-purity hydrogen, or may be used directly for heat and electric power generation.

Thermochemical conversion technologies are important for providing a source of additional value-added fuels, chemicals, and heat and power, thus improving the economics of an integrated biorefinery. These technologies are necessary because there are low carbohydrate or “off spec” feedstocks, lignin rich residues, and other unconverted materials which cannot be effectively converted by biochemical routes. To avoid waste streams and maximize value from processing lignocellulosic feedstocks, thermochemical technologies must be used to produce value-added fuels and chemicals. Additionally, thermochemical conversion technologies offer the potential for more energy efficient biorefineries by allowing integration of high efficiency heat and power production systems, such as combined cycle gas turbines or fuel cells. Thermochemical conversion also provides an opportunity for direct substitution of biomass into the existing petroleum processing infrastructure.

In the gasification process, cleanup and conditioning of the raw gas results in a clean synthesis gas amenable to existing catalytic fuels synthesis processes. When perfected, liquefaction might be employed as a technology that transforms biomass into a bio-oil liquid intermediate which can be transformed into a feedstock amenable to conventional petroleum processing techniques. After liquefaction, this bio-oil can be chemically upgraded to conventional hydrocarbon fuels using existing petroleum refinery technology. It is then possible to access and leverage the extensive infrastructure developed in the petroleum and chemicals industry to produce a wide range of liquid fuels and chemicals. Opportunities for introducing biomass thermochemical intermediates into existing petroleum refineries are being considered by industry.

Thermochemical conversion of biomass to synthesis gas or bio-oils requires technology which is similar to that currently used in the coal and petroleum industries today. However, biomass is

harder to handle and feed than fossil-based feedstocks. The lower bulk density and energy content, and higher volatility of biomass compared to coal are fuel properties affecting the technical and economic feasibility of biomass thermochemical conversion processes. Biomass gasification processes produce synthesis gas (syngas) with potentially higher levels of tars and inorganic contaminants than their fossil counterpart feedstocks. Additionally, the size and scale of current fossil-resource-based thermochemical processing facilities are much larger than that which can be economically applied in a biomass conversion scenario because of the dispersed nature of the feed. The quality of biomass-derived syngas is defined by the processes used to convert the syngas into liquid fuels. In most cases processes for converting syngas into liquid fuel products are commercial or have been demonstrated at the industrial pilot scale. Thus, the syngas quality specifications are reasonably well known. Figure 1 below details the many syngas processing pathways and their associated products.

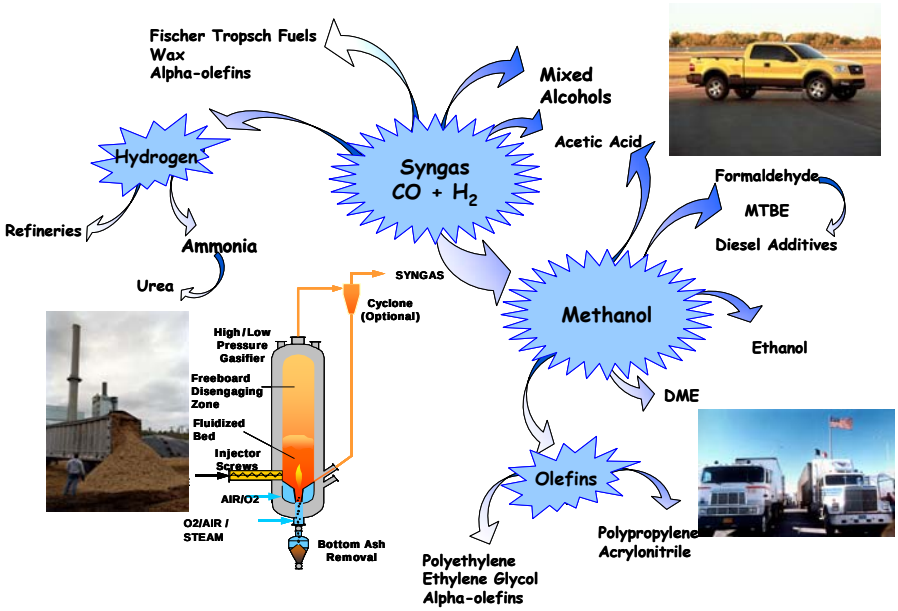


Figure 1: Syngas Pathways and Products

To move beyond corn ethanol, the biomass to biofuels route must increasingly deal with feedstocks that are highly variable in mass and energy density, size, moisture content, and intermittent supply. While most research and development activities focus on biochemical conversion, little or no activity is being undertaken in developing thermochemical technologies which can use multiple feedstocks. While thermochemical conversion has the unique advantage of not being limited in the type of feedstock used in conversion, there are challenges to overcome in using feedstock that is not uniform and reducing the cost of gasification (see Figure 2 and Table 1).

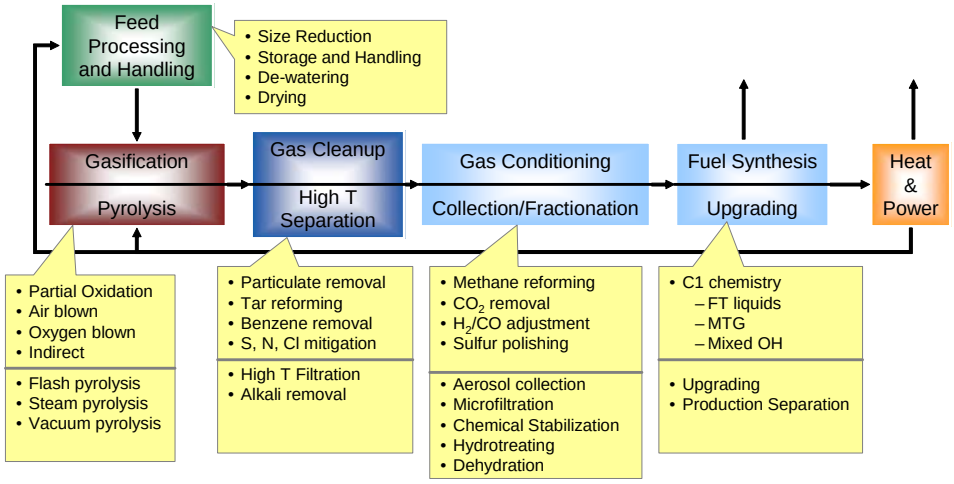


Figure 2: Current and Developing Thermochemical Conversion Technologies

Tables 1 and 2 highlight the key technology barriers and RD&D needs to overcome these barriers.

Table 1. Thermochemical Conversion Elements and Key Barriers

Elements	Key Barriers
A. Feedstock Thermochemical technologies, requires a supply of uniform feedstock and reliable feed preparation, storage, and handling systems	• A1. Lack of technologies to support multiple feedstock utilization • A2. Lack of uniform feedstock
B. Gasification Gasification technologies need to be developed to produce clean syngas for conditioning and upgrading to biofuels (such as Fischer-Tropsch liquids, methane to gasoline (MTG), and mixed alcohols).	• B1. Optimize gas clean-up and conditioning technologies for biomass derived syngas • B2. Research is needed for process intensification to combine steps to reduce capital costs • B3. Conditioning fuel to meet current standards • B4. Need to maximize yield and increase efficiency while ensuring quality and consistency
C. Pyrolysis Producing biofuels (green diesel/gasoline) from pyrolysis of biomass feedstocks to bio-oils and upgrading through hydrotreating/cracking	• C1. Upgrading bio-oil • C2. Biofuel stability issues • C3. Insufficient value/market for co-products/waste (e.g. char)

D. Aqueous Phase Reforming Producing hydrogen and or alkane fuels from biomass-derived liquids through one step low temperature (~250 C) catalyzed reforming. Preferred liquids are water soluble biomass hydrolysates.	• D1. Yields and selectivities to hydrogen or alkanes are not as high as desired especially with less "refined" hydrolysate. Catalyst development is needed. • D2. Hydrolysis of biomass solids does not yield the preferred pure sugar hydrolysate cost effectively. Improved hydrolysis technology would reduce overall cost and yields. • D3. The reactor configuration and design needs to be optimized.
E. Deployment Integrating thermochemical conversion technologies in commercial biorefineries; increasing the total amount of liquid fuels produced thereby increasing the overall marketability of the biorefinery	• E1. Need for additional economic, environmental and technical analyses identifying priorities • E2. Lack of fuel codes and standards • E3. Uncertainty in planning caused by inconsistency among State and Federal permitting regulations, and by potential delays in obtaining permits • E4. Need to integrate thermochemical conversion technologies with existing biorefinery

Table 2 outlines the major activities needed, in the near-, mid-, and long-term, to meet the challenges described in Table 1. Each agency that currently contributes to each activity described in Table 2 is noted after that activity [e.g., ***(USDA, DOE…)***]. The key barriers addressed by each Table 2 activity align with the numbered barriers in Table 1, and are also noted after each activity in Table 2 [e.g., ***(A1, B2…)***]. Table 3 lists specific agency activities based on the information provided by each agency during the November workshop and during the drafting of this document. Table 4 describes each agency's funding that supports its activities. Tables 3 and 4 are not complete or linked with Tables 1 and 2; interagency teams should continue this effort.

Together, these four tables represent the most complete interagency biofuels activity reference to date, and should serve as a guide for future interagency teams. Development of a detailed, shared agency activity database is recommended to further illustrate these collaborations and identify gaps (see *Summary of Overall Recommendations*).

Note: These notations are based on agency input at the time of this document's drafting, and the November workshop proceedings. They do not necessarily reflect established future work plans by these agencies, but rather reflect their current or potential future activities.

Table 2. Key RD&D Activities Needed to Overcome Barriers for Thermochemical			
	Near-term (0-5 years)	**Mid-term (5-10 years)**	**Long-term (10+ years)**
Feedstock	Determine optimum physical and chemical composition of feedstock ***(USDA) (A1, A2)***		
	Adapt current processing technologies to meet the needs of using multiple feedstocks ***(A1, A2)***		
Lignin Utilization	Produce heat and power from biomass or residues ***(A1, B1, B2, E1, E3, E4)***		
		Identify and verify the best end-use and processing of fiber ***(EPA)***	
		Identify and verify the best end-use and processing of lignin into ethanol, mixed alcohols or other products from syngas (Ag Residues; Forest)	Identify and verify the best end-use and processing of lignin into ethanol, mixed alcohols or other products from syngas (Herbaceous; Woody Crops) ***(EPA)***
	Produce high value chemical and material co-products from biomass lignin (Ag Residues, Forest) ***(EPA)***	Produce high value chemical and material co-products from biomass lignin (Herbaceous, Forest) ***(EPA)***	
Selective Thermal Processing		Develop new synthesis technology ***(A1, B1, B3, B4)***	
Pyrolysis		Develop hydrotreating and upgrading for green diesel ◆ Improve efficiency of hydrotreating and upgrading of pyrolysis oils to biofuels ◆ Improve catalyst stability and robustness Improve stability of bio-oil intermediate (pyrolysis oils) (Forest) ***(USDA) (C1, C2)***	Develop hydrotreating and upgrading for green diesel ◆ Improve efficiency of hydrotreating and upgrading of pyrolysis oils to biofuels ◆ Improve catalyst stability and robustness Improve stability of bio-oil intermediate (pyrolysis oils) (Woody Crops) ***(USDA) (C1, C2)***
	Conduct strategic analysis to tie human needs, resource validation, and existing infrastructure ***(EPA) (C3)***		Conduct strategic analysis to tie human needs, resource validation, and existing infrastructure
			Study/develop new chemical transformations to make green diesel (carbon-skeletal rearrangements) ***(C1, C2, E2)***
			Explore routes to process intensification ***(B4)***

Table 2. Key RD&D Activities Needed to Overcome Barriers for Thermochemical			
	Near-term (0-5 years)	**Mid-term (5-10 years)**	**Long-term (10+ years)**
	Conduct bench and pilot scale pyrolysis studies to improve bio-oil quality and net energy. **(*USDA*)**	Development of farm-scale pyrolysis systems. **(*USDA*)**	
	Optimization of technologies for distributed production ***(USDA)***	Optimization of technologies for distributed production ***(USDA)***	
Gasification	Conduct bench and pilot scale thermochemical conversion studies to improve syngas quality (Ag Residues, Forest) ***(USDA,DOE-EE-HFCIT) (B1, B2, B3, B4)***	Conduct bench and pilot scale thermochemical conversion studies to improve syngas quality (Herbaceous) ***(USDA, DOE-EE-HFCIT) (B1, B2, B3, B4)***	
	Produce syngas from biochemical conversion and agricultural residues (Ag Residues, Forest) ***(USDA) (B1, B2, B3, B4)***	Produce syngas from biochemical conversion and agricultural residues (Herbaceous, Forest) ***(USDA) (B1, B2, B3, B4)***	
	Produce syngas from spent pulping liquor, wood residues and other process residues (Forest) ***(B1, B2, B3, B4)***	Produce syngas from spent pulping liquor, wood residues and other process residues (Woody Crops, Forest) ***(B1, B2, B3, B4)***	
	Document correlations between feedstocks and syngas quality (Forest) ***(B3, E2)***	Document correlations between feedstocks and syngas quality (Woody Crops, Forest) ***(B3, E2)***	
	Develop feeder systems for gasification of solid biomass (Forest) ***(B2)***	Develop feeder systems for gasification of solid biomass (Woody Crops, Forest) ***(B2)***	
	Optimize forest resource conversions to syngas (Forest) ***(B2)***	Optimize forest resource conversions to syngas (Woody Crops, Forest) ***(B2)***	
			Optimization of technologies for distributed production
Gas Clean-Up & Conditioning	Achieve continuous tar reforming efficiencies via catalysts (Ag Residues; Forest) ***(EPA) (B1)***	Achieve continuous tar reforming efficiencies via catalysts (Herbaceous; Woody Crops, Forest) ***(EPA) (B1)***	
	Identify syngas contaminants that inhibit catalyst activity ***(B1)***		
		Improve clean-up and conditioning processes targeting identified contaminants ***(B1)***	

Table 2. Key RD&D Activities Needed to Overcome Barriers for Thermochemical			
	Near-term (0-5 years)	**Mid-term (5-10 years)**	**Long-term (10+ years)**
Catalytic Fuel Synthesis	Develop catalyst to achieve higher single pass conversion efficiencies and greater selectivity to ethanol and mixed alcohols (Ag Residues; Forest) ***(D1, D2)***	Develop catalyst to achieve higher single pass conversion efficiencies and greater selectivity to ethanol and mixed alcohols (Herbaceous; Woody Crops; Forest) ***(D1, D2)***	
		Continue improvement to catalyst to achieve higher single pass conversion efficiencies and greater selectivity to ethanol and mixed alcohols (Ag Residues, Forest) ***(D1, D2)***	Continue improvement to catalyst to achieve higher single pass conversion efficiencies and greater selectivity to ethanol and mixed alcohols (Herbaceous, Forest) ***(D1, D2)***
Integration/ Demonstration	Progressively demonstrate (ending at pilot scale in 2012) improved mixed alcohol yields from gasification of lignin-rich biorefinery residues (Ag Residues; Forest) ***(USDA) (E4)***	Progressively demonstrate (ending at pilot scale in 2012) improved mixed alcohol yields from gasification of lignin-rich biorefinery residues (Herbaceous; Woody Crops; Forest) ***(USDA)***	
	Initiate public/private partnerships ***(USDA)***		
Aqueous Phase Reforming	Develop improved catalysts ***(DOE-EE-HFCIT) (D1, D2, D3)***		
	Develop improved hydrolysis step to produce preferred hydrolysate compositions efficiently and cost effectively ***(DOE-EE-HFCIT) (D1, D2, D3)***		
	Develop improved reactor configuration and design ***(DOE-EE-HFCIT) (D1, D2, D3)***		
Deployment		Conduct economic, environmental and technical analyses (on-going) ***(USDA, DOE-EE-OBP, USDA) (E1)***	
		Demonstrate cost/benefits of biorefineries ***(DOE-EE-OBP, USDA) (E1)***	
	Develop and establish regulations/emissions standards including an intra-agency strategy to smooth out facility siting and regulatory approval ***(EPA) (E3)***		

Table 2. Key RD&D Activities Needed to Overcome Barriers for Thermochemical			
	Near-term (0-5 years)	**Mid-term (5-10 years)**	**Long-term (10+ years)**
	Develop and establish fuel codes and standards; develop in concert with other countries ***(EPA) (E2)***		
Note: Some needs identify in the Needs Requirement Document were identical for different pathways but had differing timeframes. The timeframe for those pathways with identical activities are noted under the appropriate timeframe.			

Current Federal Thermochemical Conversion Efforts to Date

Currently, at least seven federal agencies are conducting research, development, and deployment activities in various technical areas of thermochemical conversion. Table 3 summarizes the agency activities in each Thermochemical R&D area.

USDA – Three offices within the USDA conduct activities related to thermochemical conversion. Forest Service (FS) focuses on issues surrounding the conversion of forest resources to biofuels and biopower, and also is collaborating with other federal agencies through a formal inter-agency woody biomass utilization working group. The Cooperative State Research, Education and Extension Service (CSREES) funds basic and applied thermochemical conversion research mainly at the state university and small business level. Agriculture Research Service (ARS) conducts research on developing technologies leading to new and improved biofuels focusing on systems which can be used either on-farm or within a farmer cooperative.

NIST - Supports the missions of other federal agencies through its work in developing standards, measurements and modeling. NIST develops new measurement methods for the determination of thermochemical and thermophysical properties of liquid fuels; models of chemical kinetics and combustion processes; and kinetic and thermodynamic reference data.

DOE - OBP conducts research, testing, integration, and feasibility studies on thermochemical conversion of biomass to provide the technology for advanced and integrated biorefinery systems. The Hydrogen, Fuel Cells and Infrastructure Program conducts research on the production of hydrogen through the gasification of biomass, and the distributed reforming of bio-derived liquids including pyrolysis based bio-oils, ethanol, and sugars.

NSF - Conducts basic research on thermochemical conversion technologies.

EPA – Evaluates technologies (environmental and potential market impact) via scenario analysis, conducts technical assessments; and initiated a general investigation into advance renewable fuel production technologies which are close to commercialization. EPAct set forth several provisions authorizing a variety of tasks related to research, demonstration, and production of ethanol from cellulosic biomass. Specifically, Section 1511 and 1514 authorize EPA to provide grants for renewable fuel production technologies in Reformulated Gasoline Areas, and to establish the Advanced Biofuel Technologies Program, respectively. ORD will assist regions and states in assessing the environmental impacts of growing, harvesting, transporting a variety of renewable feedstocks couples with various biofuel technology pathways and sustainable biorefinery production, using research and modeling tools (such as the 9-Region MARKAL model). Combined Heat and Power program provides technical project assistance for integration of biomass-fueled combined heat and power.

DOD – Program to evaluate the use of gasification technologies as a means of producing energy from solid wastes.

Table 3.Thermochemical Conversion R&D Activities by Federal Agency

Agency	Gasification	Pyrolysis	Gas Clean-up & Conditioning	Integration	Deployment
USDA – FS	• Modeling biomass gasification for energy & syngas • Enhance the steam gasification of char	• Flash pyrolysis of forest biomass in mobile unit • Produce liquid fuels with minimal process H_2O		• Produce liquid fuels with minimal process H2O • Methane feedstock for neutralizing CO2 emissions	• Analyzing value prior to pulping biorefining business case
USDA – CSREES	• Gasification of agricultural residues and wastes • Linking gasification with fermentation to produce ethanol and chemicals	• Improve pyrolysis procedure for treating poultry manure			

USDA – ARS	• Develop a hybrid gasifier system to study various biomass and industrial feedstocks • Manure to energy-biogas • Evaluation of poultry for energy and petrochemical feedstock replacement • On-farm trial evaluating feasibility of on-farm straw gasification • Study evaluating feasibility of wet gasifying animal wastes • First generation conversion system for animal waste management • Determine feasibility of bio-hydrogen generation from animal wastes	• Pyro-oil refining for enhanced-value product development • Pyrolysis char as soil amendment			• Quick QA/QC testing of biodiesel
	• Conversion of biomass to bio-oils by pyrolysis and gaseous fuels by gasification				
DOC – NIST	• Modeling of chemical kinetics and combustion processes; reference data for kinetics and thermodynamics • Measurement methods for the determination of thermochemical (gas phase kinetics, calorific value, distillation curves, etc) and thermophysical properties (fluid density, viscosity, thermal conductivity, speed of sound, etc.) • Combustion modeling • Combustion characteristics • Atomization, combustion and pollutant formation characteristics of liquid fuels				• Standard Reference Materials and analytical measurement methods for chemical characterization of biomass and biofuels blends • Fuel processing and characterization
DOE – OBP	• Hydrothermal gasification • Biomass gasification • Black liquor gasification	• Biomass pyrolysis	• Synthesis gas clean-up and conditioning	• Process integration • Integrated fuel synthesis	• Cost benefit analysis of gasification for fuels • Integrated biorefineries analysis tools

DOE – Hydrogen	• Central biomass gasification for hydrogen production	• Distributed bio-oil reforming for hydrogen production - bio-oil volatilization with low residue and oxidative cracking of bio-oil at < 650 Degree C	• Distributed reforming of bio-derived liquids (e.g. ethanol, bio-oil, sugars) to hydrogen		
EPA	• Central biomass gasification for hydrogen production • Distributed bio-oil reforming - bio-oil volatilization with low residue and oxidative cracking of bio-oil at < 650 Degree C			• EPAct authority and direction for evaluation and integration of cellulosic fuels technology • NVFEL workshop on cellulosic biomass technologies • Support for integration of biomass heat and power technologies	• Integrated systems analysis workgroup • Environmental technology verification • Biomass conversion matrix • Waste to energy team – identifying technical and environmental issues and research needs
NSF	• Basic research to thermally-enhance biomass catalysis	• Basic research on biomass pyrolysis			
DOD	• Assess feasibility of utilizing solid waste biomass material as a feedstock for gasification				

Federal Budgets for Thermochemical Conversion

Table 4 is a rough attempt to capture the current budgets for activities supported by the agencies involved with thermochkemical conversion. This information is not necessarily up to date or consistent regarding funding year and, as such, needs to be reassessed by an interagency team. Colored shading in cells indicates that funding numbers overlap in those technical areas. Funding numbers are incomplete at this time (N/A= not available). Currently, funding is insufficient to overcome identified major R&D technology hurdles.

Table 4. Federal Agencies FY 2007 Budget for Thermochemical Conversion (in millions)

Agency	Non- Biological Sugar Conversion	Gasification	Pyrolysis	Gas Clean-up & Conditioning	Integration	Deployment
USDA –	N/A	Pending	Pending	—	N/A	Pending
USDA – CSREES	N/A	N/A	N/A	—	—	—
USDA –	N/A	Pending	Pending	—	—	Pending
DOC –	N/A	N/A		—	—	—
DOE – EE-OBP	N/A	$2.2	$1.3	$4.4	$0	$.70
DOE – Hydrogen	N/A	1.2	0.3	1.1	—	—
EPA	N/A	N/A	—	—	N/A	N/A
NSF	0.6	0.3	0	—	—	—
DOD	N/A	N/A	—	—	—	—

N/A – budget information was not available

Detailed Recommendations to the Board for **Thermochemical Conversion R&D**

The following recommendations were made to improve coordination as well as expand the current scope of activities in biofuels. These recommendations are not in order of priority.

- **Form interagency team.** Currently, there are myriad agencies conducting R&D in thermochemical technologies. An interagency team should be formed to continue to coordinate agency activities and delineate areas of R&D to avoid duplication. This team should continue to discuss and prioritize efforts to focus R&D on the most promising thermochemical conversion technologies to reach the goals. Ultimately, it is up to the agencies to decide on which technologies to focus their efforts based on their agency's mission and goals. The Biomass R&D Board should serve the role of resolving issues with R&D focus, delineation, and duplication.
- **Coordinate and integrate economic and environmental analyses.** Economic and environmental considerations may dictate technical and economic viability amongst various biochemical and thermochemical conversion technologies and preference for developing technologies in specific regions. These analyses should directly inform agencies' definition of "most promising" technologies in future activities.
- **Develop coordinated biomass technology R&D plans.** Each Federal agency involved in biomass related research should collaborate in this arena.

- **Coordinate Requests for Proposals.** Coordination of RFPs among federal agencies to minimize gaps in needed research, development, and deployment of biochemical conversion technologies.
- **Establish milestones for technology development and decision points**. The lead agency must establish decision point milestones and technology development milestones. A decision body and advisory panel needs to be established that will make technology development decisions, and funding decision.
- **Establish criteria for success.** Criteria that can be used by decision makers to identify "successful" technologies must also be developed, as this will avoid wasted efforts on technologies that are clearly not promising.
- **Develop intra-agency strategy to smooth out facility siting and regulation approval.** This requires DOE and USDA to make a case for EPA prospective action.
- **Conduct periodic collaborative meetings among agencies** conducting biomass R&D activities. Create a website where all agencies can post or announce meetings related to thermochemical process.
- E**nhance stakeholder involvement in activities, foster public-private partnerships**. All agencies should work with universities and private sector, as this will foster research.
- **More pilot scale testing of promising technologies.** Thermochemical conversion technologies must be commercially viable.
- **Develop codes and standards.** The lack of codes and standards will prove to be a barrier to the widespread use of thermochemically produced biofuels. Currently, certification of fuels is the responsibility of state and local governments; where their regulatory or standards related agencies become the de facto agencies for certification. This has resulted in varied standards across the states. Standards ensure a consistent, uniform fuel with which manufacturers can test their equipment to ensure compatibility. Development of codes and standards must be developed in concert with other countries ensuring similar specifications for fuels so as not to be a barrier to trade.

Technology Integration, Deployment, and Permitting for Biorefineries

The breakout session covering this topic did not cover the necessary scope of material for this topic area in the amount of time provided during the workshop. Although agency participants had time to comment and edit the following section, it was recommended that an interagency team should be re-assess and further develop the description and detail for this section, including the information in Tables 1 though 4. The recommendations made by participants in the November workshop and the additional recommendations made during the revision of this section are captured at the end of this section. However, an interagency team should assess their relevance before moving forward.

Technology Status and Challenges

The term *biorefinery* purposely evokes visions of today's petroleum refinery. A biorefinery is a facility that uses biomass to make a slate of fuels and chemicals to maximize the value of the biomass, thereby maximizing the financial return to the investor. The biorefinery concept has already proven successful in the U.S. agricultural, food and forest products processing industries, where such facilities now produce food, feed, fiber, fuels and chemicals.

Large corn wet-milling plants produce fuel grade ethanol as well as enzymes, organic acids, amino acids, food products and animal feed. Corn dry-grind mills produce fuel grade ethanol and animal feed. Pulp and paper mills and forest product mills are other examples of existing biorefineries that produce an array of biobased products and materials. In 2006, the biofuels production in the U.S. was about 5 billion gallons with 4.6 billion gallons of ethanol derived from domestic corn grain and 150 million gallons of biodiesel from soybean oil.

The simple scenario outlined above illustrates the relative magnitude of the 2030 goal. Although these numbers are rough estimates, thinking about the design and construction of about 600 biorefineries with a capital investment of over $150 billion all within 23 years is daunting. It also reinforces the urgency for the Federal government to jump-start biofuels commercialization while at the same time recognizing the potentially enormous role that private investment will play. For these reasons this section of the *Workshop Summary Report* is different than the sections on R&D elements. This section covers the Federal Role in supporting the early stages of technology integration and biorefinery deployment along with the role of private industry and financial community in developing the envisioned biomass industry. It includes issues of permitting, siting, financing, demonstration, and other elements related to deployment.

Integrated biochemical-thermochemical biorefineries capitalize on the process improvements identified in the independent developments of the two technologies. Integrated biorefineries can process feedstocks with both high and low carbohydrate contents -- maximizing feedstock handling efficiencies and heat and power integration. The integration of these technologies will improve the energy efficiency of the overall process, lower costs, and produce more ethanol (or other biofuels) than a standalone biochemical or thermochemical process. Integrated biorefineries also offer opportunities to reduce the environmental impact of biofuels production.[2] Sustainable process integration and intensification will reduce energy and water inputs as well as net solid, liquid, and air emissions. Subsequently, improvements in process efficiency will reduce the land required to produce the required amounts of feedstock. In a sustainable process, biomass will be collected while maintaining environmental quality. In the future, integrated biorefineries

[2] Energy-Water Nexus 2006, Sandia National Laboratory

will produce biofuels and other products with potentially zero liquid discharge, limited air emissions, and the efficient use, recycling, and/or disposal of solids.

Deployment begins with the launch of the first commercial scale biorefinery projects. Reducing the cost of biofuels production technologies from lignocellulosic biomass-to-ethanol has progressed to the point that serious attention must be paid to the deployment of this technology. The challenge will not be in the long term, but will be in building the first or "pioneer" plants that prove the technology by taking higher risks and resolve problems associated with demonstration new technology at a large scale. This also includes improving energy and water efficiencies, and minimizing water, air, and waste discharges. The monetary requirements for deployment will dwarf what has been spent on research and development. The risks are high and the resources are limited. As the Federal government moves forward with supporting biofuels deployment it will be spending larger and larger sums of government funds on research (at national laboratories, universities and in partnership with industry), technology demonstrations, and potentially in various aspects of full scale plants (all in partnership with various industrial companies) they need to make sure the money is spent on the right projects and that the projects are conducted in the best possible manner.

Environmental permitting relies on information from the facility design and permitting activities. Industry representatives believe that the burden of environmental requirements would be eased by greater clarity and consistency of implementation among state and Federal agencies. For the most part, state agencies implement both Federal and state environmental requirements, and thus Federal-state communication will be particularly important in this rapidly changing field. Issues include: plant classification, emission modeling for Particulate Matter (PM) 2.5 and PM 10 with the EPA, the Occupational Safety and Health Administration, and fire codes; rodents, fire, safety and runoff problems with storage; and the noise and smell of operations due to pretreatment chemicals and ethanol distillation.

Figure 1 shows the general steps required to go from the business plan and technical process concepts to a successfully operating biorefinery. The diagram also shows the roles of the industry developer, possible roles for the Government in direct support of specific projects, and more general Government roles in supporting the overall biomass-based industry. The "possible" qualifier on the project-specific Government role is used because, as technologies are successfully proven in the marketplace and the overall maturity if the industry increases, the Government role would be expected to change.

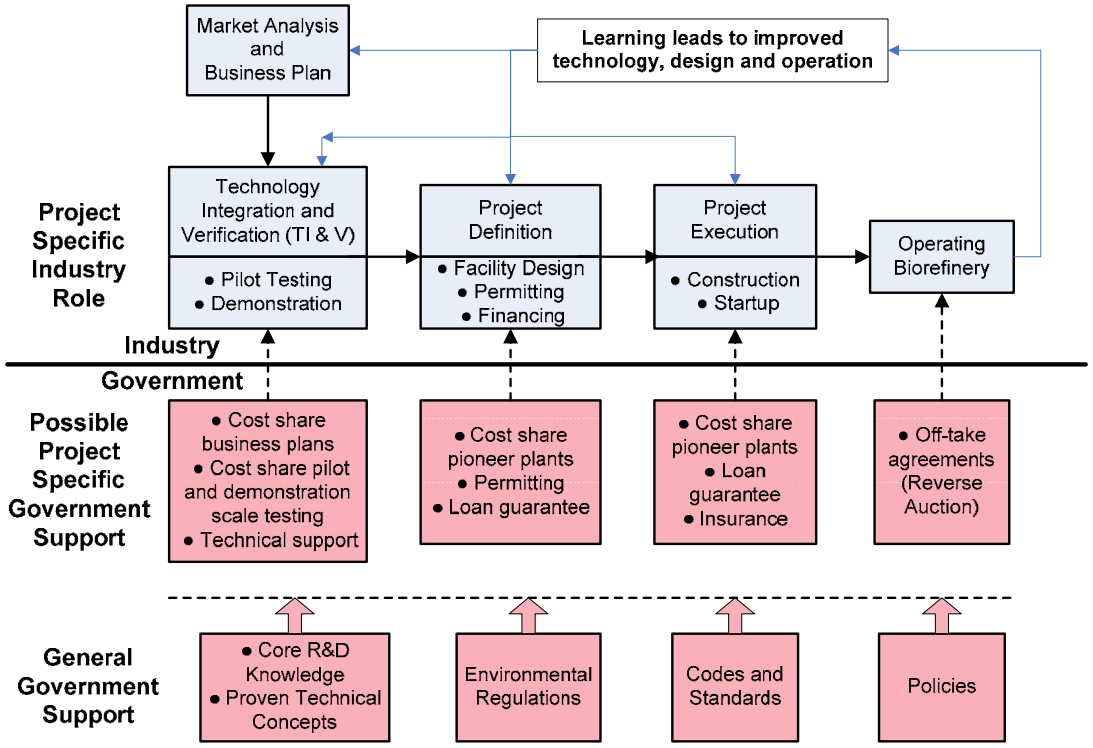


Figure 1: Overview of Steps Required: Business Plan to Operating Biorefinery and Possible Government Support Roles

For any sophisticated conversion process, combining individual unit operations into a complete, integrated, systematic process is a challenge. Technology integration and verification includes the work necessary to prove that both the laboratory data developed for specific processing steps and the mathematical models developed to conceptually integrate the steps describe how the technology really performs, from both technical and economic perspectives. The first step of technology integration is usually a pilot-scale operating unit which aims to prove technical feasibility. The complexity and scope of the pilot testing is directly related to the degree that new feedstocks, new chemical conversion steps, and new equipment are involved. The next and more involved step calls for design and operation of a demonstration-scale facility. At this stage the goal is to prove both technical feasibility and economic viability in a realistic setting and at a large enough scale that there is reasonable confidence that subsequent scale-up to a commercial plant would be straightforward. Once the integrated technology has been verified at the demonstration scale, a business decision can be made to go forward with commercialization and define the biorefinery project. Geographic and market factors will dictate feedstock and conversion technology options and the assumption is that industry will choose the combinations that provide the best economics for their particular set of conditions.

Project Definition includes developing a detailed facility design. This may include two or more phases that are intended to confirm project costs, which help identify and resolve problems early and reduce design costs. Design costs may be 10 percent or more of the total capital costs of the facility. Therefore, if the estimated cost has increased substantially since the previous estimate, the project's feasibility may need to be closely examined. Project definition will sometimes identify new technical uncertainties or issues that have not been resolved by R&D. In these cases, additional R&D may be required before the project definition can continue. Environmental permitting activities usually go on in parallel with the facility design. Once the detailed facility

design is completed it is used as the basis for a definitive project cost estimate required for financing. The target confidence interval for a definitive estimate is generally about 5 percent.

Project Execution includes facility construction and startup. Construction initiation varies from plant to plant and depends on progress in securing construction permits. For pioneer plants, construction may not begin until definitive design is nearly complete. Construction duration depends on the size and complexity of the plant but is generally expected to range between one and three years. As soon as construction is complete, the start-up phase begins. Usually, design errors that were not identified in project definition or detailed engineering will not be identified until startup. One to six months are usually allocated for startup, with pioneer plants being at the longer end of the range. The primary function of startup is to de-bug the plant, as problems, and the resulting delays, in startup are very expensive. Four primary causes of startup problems in pioneer plants are: equipment failures, inadequate equipment, operator error, and improper design. Process failures caused by improper design are generally the most serious: they can result in substantial delays in startup while design changes and additional construction takes place. In some cases, the plant may never achieve its design capacity and suffer severe performance problems that affect profitability if left unresolved. Improper design can often be traced back to incomplete or insufficient technology verification.

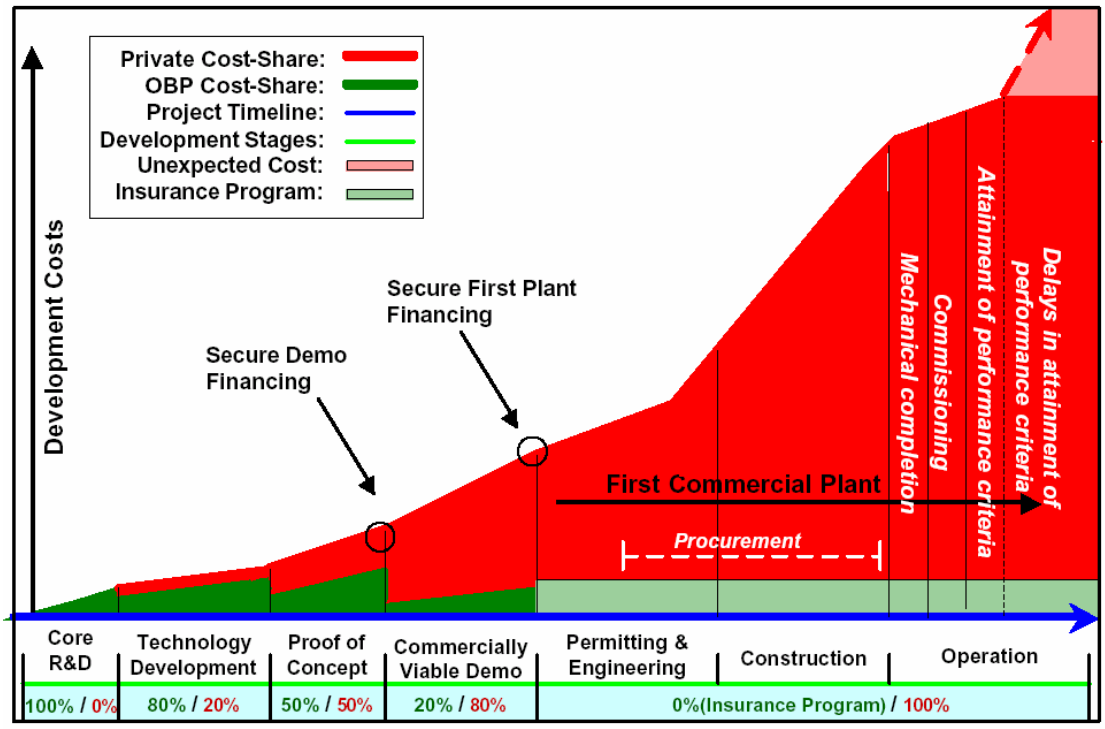


Figure 2: Example of Relative Costs and Possible DOE-EE-OBP Federal Cost Share for Stages of Technology Development through Deployment of Pioneer Commercial Biorefineries

Source: DOE 2004.

Figure 2 is DOE-EE-OBP's graphic of the magnitude of investment that must be made by industry and government to successfully commercialize a new technology. As shown in the figure, industry provides the largest investment in the later stages of development, with

government providing the largest investments at the earliest stages. It should be noted that, although construction costs can be predicted, unexpected costs incurred after the plant is built (e.g., process modifications to achieve design yields, rates, and operating costs) can be considerable and must be borne by operators and investors. Federal government support of the fundamental and applied R&D is appropriate because both carry very high risk, and therefore will not be undertaken by industry alone. Government cost share of pilot-scale, demonstration-scale, and pioneer commercial-scale integrated biorefineries is essential due to the combination of risk for first-of-a-kind facilities and the high capital investment required.

The business decision to commercialize new technology depends on the realistic evaluation of its economic viability in the marketplace. Realism calls for reasonably accurate estimates of the capital investment needed to design and construct a plant that will produce the desired product competitively. Experience in commercializing first-of-a-kind technologies in the energy and chemical process industries has often shown that early cost estimates for technically advanced plants are well below actual costs and performance problems are much more likely for advanced systems than for systems with prior commercial experience. It is necessary to develop and employ strategies to reduce the technical risks associated with commercializing biofuels technologies. At the same time, it is necessary to identify and implement strategies to overcome the remaining non-technical and market barriers. Table 1 lists the key elements and barriers to technology integration, deployment and permitting.

Table 1. Technology Integration, Deployment and Permitting Elements and Key Barriers

Elements	Key Barriers
A. Technology Integration and Verification (Pre-Deployment)	
Primary	
Pilot Scale Projects Proving end-to-end, feed-to-product, process integration is crucial as it impacts both performance and profitability.	• A1. Capital and operating costs of pilot scale facilities are high. • A2. Concepts are novel and the complexity of technical issues associated with integrating several innovative process steps entails considerable additional technical risk. • A3. Research capabilities to resolve technical problems not located with first of a kind facilities.
Demonstration Scale Projects Demonstrating sustained integrated performance that meets technical, environmental and safety requirements at sufficiently large scales is an essential step toward commercialization.	• A4. Capital and operating costs of demonstration scale facilities are very high. • A5. High level of complexity of technical issues associated with fully integrating several innovative process steps and gaining a sufficient depth of understanding to predict economic performance. • A6. Research capabilities to resolve technical problems not located with first of a kind facilities.
Secondary	
Sensors and Controls Effective process control will be needed to maintain plant performance and emissions at target levels with varying load, feedstock and intermediate stream properties, and processing conditions. Development of new sensors and analytical instruments is needed to optimize control systems for biomass processing systems.	• A7. Lack of real-time sensors for measuring feedstock moisture and composition. • A8. Lack of on-line analysis of gas, liquid, solid and multiphase stream compositions for the monitoring of conversion processes such as pretreatment, hydrolysis, liquid conditioning, gasification, gas conditioning, gas purification processes, product synthesis, product recovery. • A9. Lack of process control systems for reactor systems and subsystems (performance, emissions, fuel properties, etc.).

Engineering Design and Modeling Complete understanding of how process chemistry affects reaction engineering, fluid mechanics, phase behavior and heat integration should be incorporated into rigorous engineering models for use in design.	• A10. Current level of understanding of biomass process chemistry is insufficient for developing reliable process models to support efficient process scale-up, optimization and commercialization.
Technical Information and Knowledge Transfer	• A11. Intellectual property concerns will constrain industry learning and rapid improvement.
B. Deployment	
Project-Specific	
Pioneer Biorefineries Once emerging biomass technologies have been developed and tested, they are ready to be commercially deployed.	• B1. Capital costs for commercially viable facilities are relatively high and because the technology is not yet proven, risks are considered high and securing capital is extremely difficult. • B2. In order for private investors to confidently finance biomass technology, it must have been proven and demonstrated to be technically and commercially viable. • B3. The probability of failure is significant in the first biorefineries incorporating a variety of new technologies, unproven in commercial operation. • B4. Achieving design capacity as quickly as possible after start-up is critical to achieving economic viability.
C. Permitting	
Create an information exchange, definitions, database, and published standards used by permitting agencies.	• C1. Inconsistency in or lack of local, state and Federal environmental regulations that constrain biomass development lead to the unwillingness or inability of industry and financial institutions to accept the risks. • C2. Lack of available information about biofuels technologies limits ability of regulators to develop environmental regulations for the new technology. • C3. Long lead time for developing & understanding regulations for new technology. • C4. Transportation Technologies • C5. Consumer misfueling of vehicles (OEM/SAE terminology: "Fuel/Vehicle Interface") • C6. Uniform definitions • C7. Reference Standards • C8. Testing Protocols • C9. Pioneer vs. Retrofit • C10. Modeling • C11. Labeling • C12. Biodiesel Trademark
D. General – Market	
Infrastructure Balance Throughout the Supply Chain Dramatic capital investments are required from feedstock production, through conversion processing and product delivery.	• D1. Uncertainty of a sustainable feedstock supply chain (farm and forest to the biorefinery) and associated risk is a major barrier to procuring capital for start-up biorefineries. • D2. Lack of the biorefinery infrastructure (biorefinery to the pump) to create a demand for biomass energy feedstocks is a barrier to the development and production of bioenergy crops and biorefineries.
Competition with Conventional Transportation Fuels	• D3. Volatility in fuel prices causes uncertainty in the business case for biofuels commercialization.
Human Resources for Bioindustry	• D4. Industry growth rate may be constrained by lack of sufficient scientists, engineers and trades people.
Technical Information and Knowledge Transfer	• D5. Intellectual property concerns will constrain industry learning and rapid improvement. • D6. Information being generated so rapidly it is hard to keep up with. • D7. Determining the quality of information is difficult. • D8. Poor-quality information can result in poor-quality decisions.

Industry and Consumer Acceptance and Awareness. Industry partners and ultimately consumers must believe in the quality and value of biomass-derived products.	• D9. To be successful in the marketplace, biomass-derived products must perform the same or better than existing fossil energy-based products.
E. *General – Government*	
Federal Agency Coordination	• E1. Agencies have different missions, cultures, management processes and strategic approaches. • E2. Information within agencies not currently easy to share across agencies.
Industry Standards and Regulations	• E3. Lack of common language regarding biomass and biofuels leads to confusion. • E4. Lack of local, state, and Federal regulations as well as inconsistency among them increases the perceived risk of biomass development. • E5. Long lead times for regulatory processes can add to the uncertainty inherent in deploying new and rapidly-evolving technologies.
Policies	• E6. Uncertainties in the duration and applicability of policies result in them not having the desired effects.

Table 2 outlines the major activities needed, in the near-, mid-, and long-term, to meet the challenges described in Table 1. Each agency that currently contributes to each activity described in Table 2 is noted after that activity [e.g., ***(USDA, DOE…)***]. The key barriers addressed by each Table 2 activity align with the numbered barriers in Table 1, and are also noted after each activity in Table 2 [e.g., ***(A1, B2…)***]. Table 3 lists specific agency activities based on the information provided by each agency during the November workshop and during the drafting of this document. Table 4 describes each agency's funding that supports its activities. Tables 3 and 4 are not complete or linked with Tables 1 and 2; interagency teams should continue this effort.

Together, these four tables represent the most complete interagency biofuels activity reference to date, and should serve as a guide for future interagency team. Development of a detailed, shared agency activity database is recommended to further illustrate these collaborations and identify gaps (see *Summary of Overall Recommendations*).

Note: Because this topic's breakout session did not cover the necessary material in the amount of time provided during the November workshop, several areas in Table 2 ("Activities Required to Overcome Key Barriers") are absent from this section. It is recommended that Table 2 be created and the information therein used to develop additional recommendations for this interagency team. These notations are based on agency input at the time of this document's drafting, and the November 30x30 workshop proceedings. They do not necessarily reflect established future work plans by these agencies, but rather reflect their current or potential future activities.

Table 2. Activities to Overcome Barriers to Technology Integration, Deployment and Permitting

Elements	Near term (0-5 years)	Mid term (5-10 years)	Long term (10+ years)
Technology Integration and Verification (Pre-Deployment)			
Primary			
Pilot Scale Projects	• Pentose fermentation ***(USDA FS) (A2)*** • Wood cellulose pretreatments ***(USDA FS) (A2)***	• Extraction of compounds from lignin ***(USDA FS) (A2)*** • Fermentation organism development for wood ***(USDA FS) (A2)***	•
Demonstration Scale Projects	• Maximize pre-hydrolysis sugar yields/retain primary product value for wood ***(USDA FS) (A5)***	• Wood pyrolysis methods ***(USDA FS) (A5)*** • Fermentation organism development for wood ***(USDA FS) (A5)***	• Pyrolysis oil refining ***(USDA FS) (A5)***
Secondary			
Sensors and Controls	•	•	•
Engineering Design and Modeling	•	•	•
Technical Information and Knowledge Transfer	•	•	•
Deployment			
Project-Specific			
Pioneer Biorefineries	•	•	•
Permitting			
Create an information exchange, definitions, database, and published standards used by permitting agencies.	•	•	•
General – Market			
Infrastructure Balance Throughout the Supply Chain	• Forest feedstock management systems ***(USDA FS) (D1)***	• Sustainable short rotation woody cropping systems ***(USDA FS) (D1)***	• Improved genetic material and integrated cultural systems for forest trees ***(USDA FS) (D1)***
Competition with Conventional Transportation Fuels	•	•	•
Human Resources for Bioindustry	•	•	•
Technical Information and Knowledge Transfer	•	•	•
Industry and Consumer Acceptance and Awareness.	•	•	•
General – Government			
Federal Agency Coordination	•	•	•
Industry Standards and Regulations	•	•	•
Policies	•	•	•

Table 3 below details each agency's current activities in Technology Integration, Deployment and Permitting.

Table 3. Current Activities by Federal Agencies					
Agency	**Tech Integration & Verification**	**Facility Design**	**Permitting for Plant Design and Siting**	**Financing**	**Deployment**
USDA	Basic and Applied Research	Technical Merit Review Feasibility Study Review		- Direct loans: 0% IR Commercial Technologies: Guaranteed Loans & Grants for Commercial Technologies - Technical Assistance for Feasibility Studies, Marketing and Business Plan - Real Estate M&E Working Capital - Construct facilities - Grant funds for R&D, e.g., Cellulosic ethanol	Loan and Grant Servicing, Performance Evaluation
EPA	- Outreach and Technical assistance on best practices in efficient steam plant design – CHP and alternative fuels - Environmental footprints analysis for proposed Potlatch biorefinery - Environmental Technology Verification Program has verified related commercial energy technologies.		- EPA proposal to make major source size threshold for corn milling plants consistent in Prevention of Significant Deterioration (PSD) attainment areas - Flexible air permits rules proposal - General guidance document to assist with permitting requirements for corn ethanol plants in several Midwestern states		
DOE		Epact 932 Cellulosic biorefinery demonstration projects		Title XVII Loan Guarantees	
DOC/ NIST	Certified Reference Materials – Fuel characterization and verification for chemical composition	- Material reliability for storage containers, pipelines, and end use R&D - Fire suppression characteristics for production, storage, transport, and delivery			

DOI	Grant programs to Bureau of Indian Affairs		NEPA, NSR, General conformity, Clean Water Act, Endangered Species Act	Loan Guarantees to Bureau of Indian Affairs	

Federal Budgets for Technology Integration, Deployment and Permitting

The current budgets for activities supported by the five agencies involved with technology integration, deployment and permitting are were not available for this draft. The detailed recommendations for this section suggest that an interagency team further develop the budget information for this section.

Detailed Recommendations to the Board for **Technology Integration, Deployment, and Permitting**

The following recommendations were made to improve coordination as well as expand the current scope of activities in biofuels. These recommendations are not in order of priority.

- **Reassess the Technology Integration, Deployment, and Permitting** section of this document. The breakout session with this topic did not cover the necessary subject matter during the workshop. There were also issues with understanding what Technology Integration, Deployment, and Permitting entails. Therefore, this entire section should be re-assessed by an interagency team in order to further describe the scope and associated barriers necessary for agencies to then understand and identify activities they are conducting that are relevant to this section. Specifically, Tables 2 and 4 need to be developed to address activities to overcome key barriers and related budgets respectively. The information in these tables should be used to develop additional recommendations on activity gaps and areas requiring better coordination. An interagency team should reassess this topic area before making specific recommendations for Board action.
- **Better coordination in intra-agency and interdepartmental activities.** Funding is needed for the equivalent of two FTEs distributed across the departments and $40k for a contractor to facilitate meetings. This level of funding should continue throughout the course of the program.
- **Coordinate Requests for Proposals**. Coordinate RFPs amongst federal agencies to minimize gaps in needed research, development, and deployment of integrated technologies.
- **Identify Environmental Issues.** Develop a comprehensive approach to identifying environmental issues related to constructing and permitting facilities and explore cross media permitting system.
- **Build flexibility into the permitting process.** Recommended funding for this effort is $10 million over the first five years, then nominal funding as needed, for continuous updating of the process.
- **Better biofuel technology information coordination and dissemination.** Recommended funding for this effort is $20 million over the first four years, then continued funding to monitor technologies and update the information database.
- **Coordinate and integrate techno-economic and environmental analyses for different biofuel production pathways:** As new biofuel technologies are developed, each viable route – from feedstock to production to distribution to end-use in vehicles – should be assessed in terms of its (a) technical feasibility, (b) cost-effectiveness and ability to

compete with other energy technologies in the market, and (c) environmental impact. These analyses would draw from the biofuel technology information database and continued monitoring of emerging biofuel technologies.

- **Biorefinery business planning assistance program.** Recommended funding for this effort is $20 million annually to fund subsidies for developing feasibility plans for building biorefineries.

Biofuels Infrastructure

Description and Status of Technology

The majority of biofuels currently available on the U.S. market is ethanol, with volumes currently exceeding 5.3 billion gallons. However, the market for biodiesel is growing at a rapid pace, with volumes expected to more than double by 2012.

E85 use is currently limited in the U.S. due to a lack of infrastructure to deliver the fuel to large areas of the country and lack of consumer awareness and demand. The bulk of U.S. ethanol conversion plants are heavily concentrated in the Midwest. Most of the nation's approximately 900 E85 refueling stations[3] are also concentrated in the Midwest, primarily in Minnesota. In the Midwest, ethanol is delivered from conversion plants to gasoline terminals by truck. The ethanol is blended with gasoline at the gasoline terminal racks. From the racks, ethanol blends are distributed to individual fueling stations by truck (see Figure 3). Currently, this process is reasonably economical, primarily in the Midwest. However, ethanol is now distributed to many areas across the country. Outside the Midwest, ethanol has to be transported by rail or barge since the long distances make truck transportation cost prohibitive. Barge traffic can move primarily up and down the Mississippi River, which limits its geographical coverage. Rail transportation has potential for congestion and capacity limitation issues, which might limit the potential for distribution in a large-scale ethanol scenario. Pipelines do not currently run along the distribution paths.

Lack of suitable transportation infrastructure to move ethanol beyond the Midwest could inhibit continued growth of the ethanol industry. Blending and distribution of ethanol is currently limited in the U.S. due to a lack of sufficient infrastructure to expand delivery of the fuel across the country.. The expansion of higher blends of ethanol (above 10 volume percent) is further constrained by the lack of consumer awareness and demand and the number of flexible fuel vehicles currently in the fleet. Most of the nation's approximately 900 E85 refueling stations[4] are also concentrated in the Midwest, primarily in Minnesota. Alternatively, the nation could pursue a distributed production model with less transportation required, whereby regionally available feedstocks (including forestry wastes, paper pulp, municipal waste, invasive species, etc.) are converted to ethanol or other biofuels. Systems-level economic and environmental trade-off analyses of these various scenarios need to be performed.

Ethanol and other biofuels (e.g. biodiesel and biodiesel blends) do not currently benefit from the economics of pipeline shipment as do petroleum-based fuels. The primary inhibitors to transporting ethanol and other biofuels through existing pipelines is material compatibility and flow direction. This includes materials of construction and water solubility issues. Throughout the "30x30" workshop, the need for an analysis of pipelines and pipeline alternatives for the transport of ethanol was repeatedly identified. An "outside-the-box" evaluation is needed to find alternatives to pipeline shipment that are economically competitive, as well as identifying regionally available feedstocks that can provide proximal populations with biofuels. Pipelines represent the ultimate sunk cost for infrastructure and are only practical if they start and end in

[3] U.S. Department of Energy, Energy Efficiency & Renewable Energy, "E-85 Fueling Stations in the U.S.," 15 December 2006, <http://www.eere.energy.gov/afdc/infrastructure/e85_stations.cgi> (20 December 2006).
[4] U.S. Department of Energy, Energy Efficiency & Renewable Energy, "E-85 Fueling Stations in the U.S.," 15 December 2006, <http://www.eere.energy.gov/afdc/infrastructure/e85_stations.cgi> (20 December 2006).

places of critical supply and demand. Current petroleum pipelines do not run from the Midwest (production/supplies) to major population (demand) centers around the country.

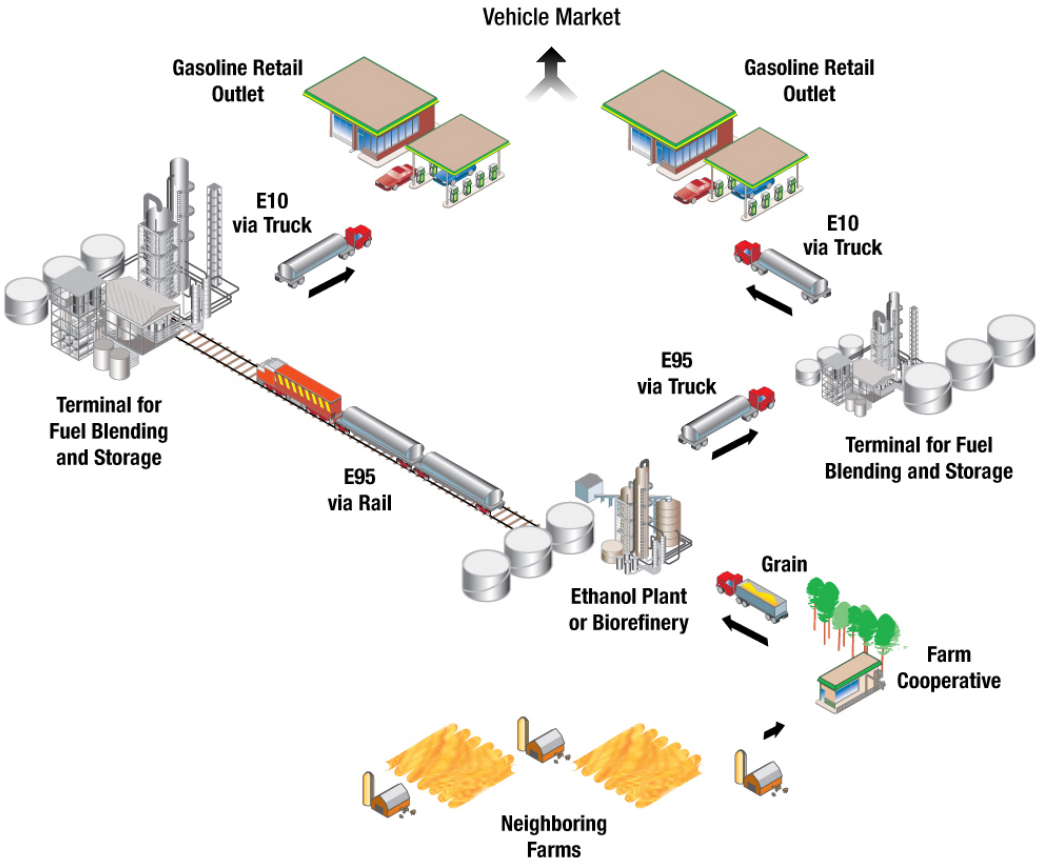


Figure 3. Existing Ethanol Distribution System

Vehicle engine optimization and vehicle fuel quality present additional barriers to biofuels infrastructure. Although some FFVs may predominantly use E85, most FFVs on the road today use less than 4 gallons of E85 per year. The bulk of these vehicles continue to use gasoline. The three domestic auto manufacturers estimated that they would produce one million flexible fuel vehicles (FFVs) in 2006 and would double that number by 2010[1]. However, the FFVs currently being produced are designed to accommodate regular gasoline (typically 87 octane and E85 or blend ratios in between). These FFV engines are not optimized to take advantage of the higher octane value of E85 (which is generally 100 – 105 pump octane). Additionally, ethanol has a lower energy content than gasoline. As a result, the vehicle loses fuel economy due to the lower energy content of E85, and there is an additional efficiency penalty because of the lack of optimization for the higher octane levels.

Another concern is that E85 is much more corrosive to, and aggressive on, storage tank infrastructure. Older existing tanks may not withstand E85. Further, ethanol will act as an extractant, cleaning impurities from the walls of the tank, which will ultimately be pumped into cars. Finally, if any water does find its way into a storage tank, this drives phase separation of petroleum hydrocarbons and the ethanol.

Materials are also an issue at the retail outlets and the dispensing pumps used for petroleum products which, in general, are not designed for storing and dispensing E85 fuel. Pumps designed

and manufactured for dispensing biofuels such as ethanol are available, but they do not carry UL (United Laboratories) certification. However, the Department of Energy and the Environmental Protection Agency are working closely with UL to resolve this issue, and it is not expected to be a long-term obstacle. EPA has recently issued vapor recovery requirements guidance for E85 pumps.

Leaks from underground storage as well as spills of ethanol or blended biofuel products will result in soil and water quality impacts. Various issues require consideration. Field studies have shown that the presence of ethanol may extend benzene plume length and may increase methane formation in soil gas above spills. The behavior of E85, as compared to more typical gas blends should be evaluated. E85 will mix with water and may result in radically different subsurface behavior and in larger contaminated plumes. Ethanol provides an abundance of easily metabolized carbon which can result in the dissolution of naturally-occurring metals such as arsenic and manganese. Past discharges of leaded gasoline may have resulted in lead being sorbed to ferric iron material. This lead can be liberated by releases of ethanol which dissolve the ferric iron material. The water quality impact of other biofuel blends and alcohols, (e.g., butanol, propanol) under consideration for large-scale production, should be examined. A predictive assessment model and supporting data need to be developed. Further, increased water pumping rates due to increasing water demands can exacerbate contamination from leaks or spills. Local and regional predictive models need to be integrated.

Underground storage of ethanol is also an issue and, if not understood and mitigated, could lead to water and soil quality degradation from underground storage tank leakage. The presence of ethanol may make remediation of spills more challenging, as it may extend benzene plume length in underground water. In addition, the presence of ethanol may lead to greater dissolution of metals, such as arsenic, manganese, and lead in ground water. Ethanol spills may result in methane formation in soil gas which, depending on concentrations, could present hazards.

Table 1 below provides a detailed breakdown of the key barriers being faced by the ethanol industry that relate to biofuels infrastructure.

Table 1. Elements and Key Barriers

Biofuels Industry Elements	Key Barriers
A. Distribution (plant to terminal/blender – Wholesale Distribution) Shipment of biofuels needs to be cost competitive with current petroleum products. Materials of construction are compatible with the petroleum and biofuels being distributed.	• A1. Alternatives to shipment by pipeline (such as barge, rail and truck) may not have adequate capacity and/or be as economical • A2. Materials of construction may not be compatible with E85 or other biofuel products • A3. E85 water take-up, not compatible with conventional pipeline transport due to water take-up
B. Terminal infrastructure (blender) Storage capacity for biofuels at the terminals needs to be adequate and materials of construction are compatible with the fuels being stored and blended	• B1. Storage capacity for biofuels at the terminals is not currently adequate in many areas of the country • B2. Materials of construction may not be compatible with E85 or other biofuel products

C. Distribution (blender to fueling station – Retail Distribution) Retail distribution of biofuels needs to be cost competitive with petroleum products and materials of construction are compatible with the fuels being distributed	• C1. Tanker trucks may not be able to switch between biofuels and other products • C2. May not be economically viable to dedicate trucks to biofuel deliveries. • C3. Materials of construction may not be compatible with E85 or other biofuel products
D. Fueling Stations (Retail Sales) Distribution of biofuels refueling stations need to be conveniently located and have achieved critical mass[5] nationwide. Materials of construction must be compatible with the petroleum and biofuels being sold and all equipment is UL certified. The selling price of biofuels needs to be cost competitive with petroleum based fuels.	• D1. Consumers may knowingly or unknowingly fuel (not currently legal) with E-85 in non-FFVs leading to early failures and negative reaction to the fuel • D2. Consumers are not aware of the advantages, disadvantages, availability and proper use of biofuels and E85 may not be priced competitively to compensate for reduced fuel economy • D3. Reluctance by major retail chains to sell E85 or other biofuel products • D4. Materials of construction may not be compatible with E85
E. Vehicle Engine Optimization Cost of vehicle operation varies based on fuel used. The cost of the fuel is not balanced with the vehicle performance using that fuel.	• E1. Consumers may knowingly or unknowingly fuel (not currently legal) with E85 in non-flex-fuel vehicles leading to early failures and negative reaction to the fuel • E2. Consumers are not fully aware of the advantages, disadvantages, availability, or proper use of biofuels
F. Vehicle Fuel Quality (meeting specifications for manufacturers acceptance and warranty) National and international standards for biofuels do not exist and therefore no standards are generally accepted by manufacturers, distributors, and regulators.	• F1. Standards and quality assurance of the standards for biofuels are not currently adequate
G. Vehicle Production and Deployment Adequate numbers of FFVs are not being produced and materials of construction are not compatible with petroleum and biofuels.	• G1. Adequate number of FFVs are not being produced to significantly increase E85 use
H. Crosscutting Consumers are not educated on the benefits of biofuels and do not understand price and performance of biofuels and petroleum based fuels	• H1. Materials of construction for distribution of petroleum products may not be compatible with biofuels • H2. The distribution of biofuels may not be in balance with the FFVs that will use the fuel • H3. Consumers may not be aware of performance advantages or disadvantages of biofuels • H4. Consumers may not be aware of energy security issues of petroleum-based fuels and biofuels

Within the infrastructure area of distribution (plant to terminal/blender – wholesale distribution), near-term, high-priority technology/activity gaps include the test and evaluation of E85 pipeline and storage technical issues and use of existing fuels infrastructure more effectively.
Two additional priority gaps identified were considered *crosscutting* since they applied to many or most of the infrastructure areas. These two gaps were 1) determine if petroleum test methods/standards are appropriate for biofuels and 2) develop a distributed biofuels infrastructure model that does not rely on existing pipelines.

Table 2 outlines the major activities needed, in the near-, mid-, and long-term, to meet the challenges described in Table 1. Each agency that currently contributes to each activity described in Table 2 is noted after that activity [e.g., ***(USDA, DOE…)***]. The key barriers addressed by each Table 2 activity align with the numbered barriers in Table 1, and are also noted after each activity

[5] During the November workshop, industry representatives and stakeholders estimated that "critical mass" would be approximately 62,000 retail stations.

in Table 2 [e.g., ***(A1, B2…)***]. Table 3 lists specific agency activities based on the information provided by each agency during the November workshop and during the drafting of this document. Table 4 describes each agency's funding that supports its activities. Tables 3 and 4 are not complete or linked with Tables 1 and 2; interagency teams should continue this effort.

Together, these four tables represent the most complete interagency biofuels activity reference to date, and should serve as a guide for future interagency team. Development of a detailed, shared agency activity database is recommended to further illustrate these collaborations and identify gaps (see *Summary of Overall Recommendations*).

Note: These notations are based on agency input at the time of this document's drafting, and the November 30x30 workshop proceedings. They do not necessarily reflect established future work plans by these agencies, but rather reflect their current or potential future activities.

Table 2. Key RD&D Activities Needed to Overcome Barriers to Biofuels Infrastructure

Infrastructure Area	Near term (0-5 years)	Mid term (5-10 years)	Long term (10+ years)
Distribution (plant to terminal/blender – Wholesale Distribution)	• Test and evaluate E85 pipeline and storage technical issues ***(NIST, DOT-OPS, DOE-EE-OBP)(A2, A3, B2)*** • Use existing fuels infrastructure more effectively • Investigate increasing throughput of existing rail and barge systems ***(DOT)*** • Investigate back haul potential to eliminate deadheading • Start outlining where additional rail capacity will be needed (particularly short rail) and map where biofuels will be produced ***(DOT)*** • Select target priority markets for focused expansion of infrastructure • Develop containment and recovery tools for E85 discharges/spills ***(EPA) (A2)***	• Research ability to use existing pipelines and/or identify materials for new biofuels pipelines • Expand rail and barge capacity to accommodate larger amount of biofuels in the transportation system	• Determine the need to develop dedicated transportation network for biobased fuels • Build dedicated pipelines and/or rail and barge networks • Evaluate if existing transportation model is satisfactory and will meet President's goals
Terminal Infrastructure (blender)	• Build storage capacity to accommodate increasing ethanol usage – continue through the long term • Evaluate need for capital investment in tanks, pumps, etc		
Distribution (blender to fueling station – Retail Distribution)	• Evaluate need for capital investment in tanker trucks; may need dedicated spaces/units for E85		

Table 2. Key RD&D Activities Needed to Overcome Barriers to Biofuels Infrastructure			
Infrastructure Area	**Near term (0-5 years)**	**Mid term (5-10 years)**	**Long term (10+ years)**
Fueling Stations (Retail Sales)	• Conduct *Multi-modal Transport Study* – a joint public-private study involving government, the fuels and automotive industries, and industries which comprise the supporting infrastructures (i.e., regional, corridor, national, fleets); develop Government Plan ***(NSF, DOT)*** • Enhance efforts of *Multi-modal Transport Study* partners to meet E85 goals in target regions through infrastructure development • Resolve E85 pump issues –, UL listing ***(EPA) (D4)*** • Establish liquid biofuel weights and measures calibration methodology (metering, weighing) ***(NIST)(D3, F1)*** • Develop materials that allow biofuels to meet EPA standards • Design system to eliminate misfueling issues (for non-E85 vehicles) ***(EPA, DOE-EE-OBP) (D1)*** • Field studies and predictive model to assess fate and transport of various biofuels and fuel blends to mitigate potential contamination. ***(EPA) (D4)*** • Material science research to enhance safe storage, transport, and use of new fuels. ***(EPA) (D4)*** • Impacts of upcoming biofuels, and fuel blends on soil and water quality ***(EPA) (D4)***	• Facilitate capital investment for new tanks at existing fuel stations (implementing the transport study) • Implement consumer education program ***(FCVT)***	• Expand network of E85 fueling stations based on the transport plan ***(FCVT)***
Vehicle Engine Optimization	• Optimize engines for a broader range of specified mixtures of petroleum and biofuels ***(FCVT)*** o Fuel efficiency, evaporative emissions, pollutant emissions, etc. o Reduce FFV fuel economy penalty • Materials issues related other automotive parts (fuel lines, etc.) ***(NIST)*** • Determine number of FFVs needed to meet volumetric targets and implement plans.	• Meet current EPA standards • Work with EPA to develop an emissions profile specific to biofuel blends and develop appropriate emission control systems	

Table 2. Key RD&D Activities Needed to Overcome Barriers to Biofuels Infrastructure			
Infrastructure Area	**Near term (0-5 years)**	**Mid term (5-10 years)**	**Long term (10+ years)**
Vehicle Fuel Quality (meeting specifications for manufacturers acceptance and warranty)	• Conduct R&D to define (or redefine) test methods quantifying impurities at very low levels ***(NIST) (F1)*** • Review and refine ASTM standards for all biofuels to ensure fuel quality, vehicle compatibility and maintenance of emissions and vehicle performance requirements ***(EPA) (F1)*** • Participate in defining and developing international standards for all alternative fuels ***(NIST) (F1)*** • Establish Standard Reference Materials to demonstrate compliance with regulations for biofuels ***(NIST) (F1)*** • Establish enforceable fuel quality specifications ***(EPA, NIST) (F1)*** • Promote and enhance testing and sharing emissions and fuel economy data/results ***(EPA, NIST) (F1)***	• Facilitate the development of internationally-accepted documentary and measurement standards	
Vehicle Production and Deployment	• Accelerate biofuel/vehicle certification actions ***(EPA) (F1)*** • Expand procurement of B20 and E85 ***(DOD)*** • Ensure that sufficient FFVs are produced and sold in the targeted markets	• Achieve deployment of optimized E85 vehicles	• Implement plan that calls for 85% of vehicles manufactured to be engine optimized (E85) FFVs

Table 2. Key RD&D Activities Needed to Overcome Barriers to Biofuels Infrastructure			
Infrastructure Area	**Near term (0-5 years)**	**Mid term (5-10 years)**	**Long term (10+ years)**
Crosscutting	• Determine compatibility of biofuels with current material of construction used in existing fuel infrastructure including metals, plastics, rubber, others (Materials science research, not just evaluation of steel.) ***(EPA) (H1)*** • Define specifications for universal (100% compatible) materials with current petroleum and biofuels and work towards driving costs down ***(NIST)(A2, B2, C3, D4, H1)*** • Evaluate biobutanol for its infrastructure needs • Initiate public education/outreach to get people to use biofuels based on price and performance ***(FCVT)*** • Evaluate ethanol import potential opportunities • Coordinate and integrate economic and environmental analysis ***(EPA) (H4)*** • Determine if petroleum test methods/standards are appropriate for biofuels (if not, develop appropriate standards) ***(NIST)(F1)*** • Develop appropriate test methods for biofuel quality assurance ***(NIST) (F1)*** • Develop specifications for metering biofuels from manufacturer to retail ***(NIST) (F1)*** • Develop a distributed biofuels infrastructure model that does not rely on pipelines • Develop and use supply chain analysis to optimize movement of ethanol from plant to terminal to service stations (E85 specific)	• Continue public education/ outreach in getting people to use biofuels based on price and performance (environmental?, other?) • Implement use of selected universal material • Determine and balance critical mass of FFVs with supply of biofuels • Establish a process for siting of tanks and pipelines (Land right of way and permits)	

Current Federal Efforts in Biofuels Infrastructure

Six Federal agencies are currently involved in some aspect of biofuels infrastructure for the biofuels industry. The illustration of the link between each barrier, activity, and agency is identified in Table 2. Highlights of the activities currently being conducted by Federal agencies are summarized in Table 3. Below is a summary of each agency role in biofuels infrastructure.

DOD –Since FY 2002, DOD has spent $75M to $80M in the process of developing biofuels (B20 blend biodiesel and E85 fuel ethanol) for government activities to comply with 1992 EPAct and EO 13149. This includes the purchase of FFVs and biofuels and conducting demonstrations and deployment of biofuels in non-tactical vehicles. DOD is also performing biodiesel emissions

testing on fleet vehicles, studying biodiesel usage and stability for tactical vehicles, and developing specifications and test methods to assure biofuel quality.

EPA - EPA is currently responsible for on activities related to biofuels engine optimization and certification. EPA's National Vehicle and Fuel Emissions Laboratory assists in determining emissions impacts of biofuels (vehicle engine testing, statistical analysis, emission inventory, air quality analysis) and certification of alternative fuel vehicles produced by original equipment manufacturers and alternative fuel system/component manufacturers and converters. EPA conducts Energy Policy Act fuel studies on ethanol and sets and enforces standards for biofuels. EPA is establishing the definition of certification fuels; however, this activity is considered underfunded. Two additional areas of EPA activity include the issuance of guidance allowing states to remove Stage II requirements for E85 pumps (EPA/OAR) and the Smart Way Transport Partnership Grow and Go program and the National Clean Diesel Campaign, including Regional Collaboratives (Northeast Diesel Collaborative, Southeast Diesel Collaborative, Midwest Clean Diesel Initiative, Blue Skyways Collaborative, and West Coast Collaborative), which work to bring greater access to biodiesel and E85 along key transportation corridors. EPA also conducts field research and develops conceptual and predictive models to understand the impact of fuel spills, including the impact of ethanol on petroleum hydrocarbon plumes in ground water. Conducts research on the fate and transport (i.e., the fate and transport of chemical constituents once they are released into the environment) , active and passive treatment techniques, and the assimilative capacity of the environment to attenuate these fuel constituents and their by-products.

DOC - NIST - Performs research and development on materials reliability for storage containers, pipelines and end use fuel delivery systems; however, this activity has not included materials compatibility research for biofuels with high alcohol content. NIST has developed legal metrology specifications, tolerances and methods of sale for use in the commercial distribution of petroleum-based fuels. NIST also provides underpinning Standard Reference Materials and Data, as well as providing measurement traceability through calibrations. However, this metrology infrastructure has not yet been fully extended to E85 and other biofuels. NIST has also developed life cycle analysis software (Building for Environmental and Economic Sustainability, BEES) that is required by federal rule for use in measuring the environmental and economic impacts of biobased product production, use, and disposal. BEES could be applied to measure and reduce the life cycle impact of biofuel production and to optimize biorefinery design. NIST is currently strengthening its BEES Land Use and Water Use metrics to better evaluate Land Sustainability.

USDA - A related activity at the U.S. Department of Agriculture (USDA) is the development of economic analyses to estimate net positive externalities of biofuels. These analyses require improved coordination across Federal agencies.

DOT - Ensures safe and efficient distribution of the fuels. This includes regulations, transportation/distributions systems development, consumer/end-use issues studies, education and outreach, economic and environmental assessment, quality assurance, supply chain analysis, and data and information dissemination to transit agencies and end-users.

DOE - Biofuels infrastructure activities are managed by the Energy Efficiency and Renewable Energy's FreedomCAR and Vehicle Technologies (FCVT) Program and Office of Biomass Program (OBP). FCVT is responsible for the improvement of vehicle and engine efficiency and the establishment of fuel requirements to attain efficiency targets. OBP is responsible for the development of cost-effective technologies for storage and deployment of the fuels. DOE activities in engine optimization, expansion of retail outlets, availability of FFVs and

development of fuel requirements for engine efficiency were identified as areas requiring better coordination across Federal agencies. The DOE OBP infrastructure analysis of pipelines was identified as a gap. DOE's current funding for infrastructure-related activities exceeds $15M/year.

Table 3 described the activities by agency supporting biofuels infrastructure.

Table 3. Biofuels Infrastructure Activities by Agency

Agency/Area	Distribution (plant to terminal) - Terminal Infrastructure - Distribution (Blender to Fueling Station)	Fueling Stations (Retail Outlets)	Vehicle Engine Optimization	Vehicle Fuel Quality	Vehicle Production and Deployment	Crosscutting
DOD	Development of biofuels: B20 blend biodiesel and E85 fuel ethanol for government activities to comply with 1992 EPAct and EO 13149		Biodiesel emissions testing (Fleet vehicles)	Biodiesel usage and stability for tactical vehicles	Purchase of FFVs and biofuels for testing as per Executive Order	
				Development and adoption of specifications and test methods; product and quality assurance		
EPA	Infrastructure analysis on RFS rule and other fuel rules affecting past and future biofuel and alternative fuels production and distribution	Issued guidance (Dec. 12. 2006) allowing states to remove Stage II requirements for E85 pumps if specific conditions are met (EPA/OAR)	Development of emissions profiles for specific biofuels and biofuel blends.	Registration of fuels and fuel additives	Certification of alternative fuel vehicles produced by original equipment manufacturers and alternative fuel system manufacturers and converters	EPA and DOE conducting (EPAct S.1509) fuel system requirements harmonization study
		Smart Way and National Clean Diesel Campaign: Works to bring greater access to biodiesel and E85 along key transportation corridors	Determination of appropriate regulator and non-regulatory actions to address biodiesel quality concerns	Definition of certification fuels		EPA studies under S. 1506 - Assure anti-backsliding and emissions modeling. - Report to Congress on effects of ethanol content in gasoline on permeation.

Table 3. Biofuels Infrastructure Activities by Agency						
Agency/Area	**Distribution (plant to terminal) - Terminal Infrastructure - Distribution (Blender to Fueling Station)**	**Fueling Stations (Retail Outlets)**	**Vehicle Engine Optimization**	**Vehicle Fuel Quality**	**Vehicle Production and Deployment**	**Crosscutting**
		Conducting research examining the fate and transport of chemical constituents once they are released into the environment, natural attenuation, and active treatment of various oxygenates	SmartWay Transport Partnership: A voluntary partnership between various freight industry sectors and EPA that establishes incentives for fuel efficiency improvements and greenhouse gas emissions reductions and environmental benefits of renewable fuels.	Develop guidance on requirements for biodiesel and biodiesel blends		
		Developing conceptual and predictive models to understand the impact of fuel spills	Development of methodologies to quantify car emissions under various driving conditions			
		Conducting laboratory and field studies to examine the impact of oxygenates on ground water	Determinations of emissions impacts of ethanol (vehicle engine testing, statistical analysis, emission inventory, air quality analysis)			
		Researching use of ex-situ bioreactors for treating contaminated ground water				

Table 3. Biofuels Infrastructure Activities by Agency						
Agency/Area	**Distribution (plant to terminal) - Terminal Infrastructure - Distribution (Blender to Fueling Station)**	**Fueling Stations (Retail Outlets)**	**Vehicle Engine Optimization**	**Vehicle Fuel Quality**	**Vehicle Production and Deployment**	**Crosscutting**
DOE – EE-OBP	Infrastructure analysis of pipeline Analysis of water requirement for feedstocks and conversion facilities		Ethanol optimized vehicle testing			
DOE –EE-FCVT		Enhancement and expansion of alternative fuels infrastructure through Clean Cities grants	Advanced engine development and alternative fuel engine optimization	Research of fuel quality requirements for engine optimization	Flex-fuel vehicle availability and Federal fleet requirements tracking and reporting	Local coordination of education, outreach and technical assistance via 90 Clean Cities coalitions
						Maintenance of the Alternative Fuels Data Center
						In coordination with EPA, maintenance of fueleconomy.gov
DOC/NIST	Research and development on materials reliability for storage containers, pipelines and end use fuel delivery systems Development of legal metrology requirements and measurement standards for bio-based liquid fuel transport and blending	Development of legal metrology requirements and measurement standards for bio-based liquid fuel delivery and use		Biofuels characterization and verification for chemical composition for quality control and trade issues (NIST has capabilities for this work but is working in other application areas.)		Life cycle analysis of reduced impact of biofuel production and optimization of biorefinery design
	Development of fire suppression characteristics for production, storage, transport and delivery systems for biofuels	Development of legal metrology; specifications, tolerances and other technical requirements for weighing and measuring devices requirements		Development of legal metrology specifications for fuel quality		Development of methods of sale and specifications for metering/measuring from manufacturer to consumer

Table 3. Biofuels Infrastructure Activities by Agency						
Agency/Area	**Distribution (plant to terminal) - Terminal Infrastructure - Distribution (Blender to Fueling Station)**	**Fueling Stations (Retail Outlets)**	**Vehicle Engine Optimization**	**Vehicle Fuel Quality**	**Vehicle Production and Deployment**	**Crosscutting**
USDA						Development of economic analysis to estimate net positive externalities of biofuels
NSF						Cross-cutting system-wide analysis, applying Industrial Ecology tools, including Materials Flow Analysis (MFA) and statistically enhanced Life Cycle Assessment (LCA), as well as Operations Research (OR) supply chain analysis.
DOT	Safety regulations for biofuels transportation Biofuels transportation demand as part of multimodal freight/infrastructure assessments					Operations and supply chain analysis, infrastructure, transport and logistics interface with feedstocks, production, and end use.

Table 4 is a rough attempt to capture the current budgets for activities supported by the agencies involved with biofuels infrastructure. This information is not necessarily up to date or consistent regarding funding year and, as such, needs to be reassessed by an interagency team. Colored shading in cells indicates that funding numbers overlap in those technical areas. Funding numbers are incomplete at this time.

Table 4. Budget for Biofuels Infrastructure Development (by Agency in order to implement current activities that address key barriers)

Agency/Area	Distribution (plant to terminal) - Terminal Infrastructure - Distribution (Blender to Fueling Station)	Fueling Stations (Retail Outlets)	Vehicle Engine Optimization	Vehicle Fuel Quality	Vehicle Production and Deployment	Crosscutting
DOD	$75 - $80 M		$50K			
EPA	$70K		$5M			$1.5M*
DOE-EE-OBP	$220K		$580K			
DOE –EE-FCVT		$3.2M	$8.8M			$3.5M
DOC/NIST	$1.5M[a]					
USDA						
NSF						~$1M

[a]NIST plans to address biofuels infrastructure needs that encompass development of the legal metrology to permit the transition to liquid bio-based fuels as a national and international commodity, with an estimated $1.5M per year needed to establish this program.
*RFS Implementation – President's request is $9M for EPAct related analysis on technical issues pertaining to biofuels.

Detailed Recommendations to the Board for **Biofuels Infrastructure**

The following recommendations were made to improve coordination as well as expand the current scope of activities in biofuels. These recommendations are not in order of priority, and time and dollar figures are estimates only.

- **A general rethinking of biofuels infrastructure**: EPA, DOT, DOE, and NIST should determine if the existing supporting biofuels infrastructure should be or can be the same for biofuels as it is for petroleum. Essentially, it needs to be determined at what capacity the existing infrastructure could be used to support the expansion of biofuels distribution. Further, identification of additional infrastructure needs is required. It is anticipated that the Federal agencies will catalyze industry and trade associations into broader action. The duration of this effort would be up to 3 Years at a cost of $1M.
- **Develop fuel quality standards**: Standards for biofuels have not been adequately developed. It was recommended that EPA's OAR (lead) develop standards for assurance of fuel quality delivered to the end-user. NIST, DOD, and DOE would participate in this

action, which also requires the involvement of standards development organizations. The duration of this effort would be 5 to 10 years at a cost of $2M/year.

- **Coordinate and integrate economic and environmental analyses:** Economic and environmental considerations may drive the biofuels infrastructure to be significantly different than the existing petroleum infrastructure. It was recommended that all agencies be involved in the coordination and integration of economic and environmental analysis. EPA should lead the environmental analysis with the USDA and DOE co-leading the economic analysis. Duration of this effort would be 5 Years at a cost of $30M to $50M.
- **Test other bio-based products:** In addition to assuring the quality of the fuel delivered, there is a need for testing of other bio-based products (bio-refinery co-products) relative to infrastructure. Agencies involved in this action include FDA, USDA, NIST, DOE, EPA, DOT, and DOD, with the lead being determined by the co-product being evaluated. It was noted that some products will be industry driven. The duration of this effort would be 3 years at a cost of $1.5M/product.
- **Define certification fuels**: To consistently and accurately certify vehicles and engines to meet EPA's emission standards, uniform fuel specifications are established. As new fuels and/or new fuel blends penetrate the market, further evaluation of certification fuels will be necessary. It was recommended that EPA's OAR (lead) evaluate and determine if existing certification fuels are sufficient and/or if based on new fuel types and new fuel blends require establishing new or additional certification fuel standards. NIST and DOE should participate in this process. The duration of this effort would be 2 years/fuel at a cost of $2M/fuel.
- **Evaluate vehicle certification test procedures**: Determine if existing vehicle and engine emissions certification test procedures are appropriate for vehicles and engines that will be using biofuels or base fuels blended with new biofuels or higher blends of biofuels than currently seen in the market. It was recommended that EPA'S OAR (lead) evaluate vehicle certification test procedures. DOE would also participate in this action. The duration of this effort would be 2 years at a cost of $1M/vehicle-fuel combination.
- **Revaluate procedures for late model vehicle emissions testing:** Questions/concerns arise relative to the state/local inspection and maintenance emissions testing of in-use vehicles. It was recommended that EPA's OAR (lead) revaluate in-use test procedures and, if appropriate, establish new protocols and standards. NIST would support the development of end-use test standards. The duration of this effort would be 2 to 5 years at a cost of $25M.
- **Assess safety of pipeline spills:** It currently is not known whether the pipeline shipment of ethanol would be under the jurisdiction of DOT or not. It was recommended that DOT (lead) assess safety of pipeline spills, with support from EPA. Duration and cost were not estimated at the workshop.
- **Convene the states to develop models/legal/policy for siting biofuels infrastructure**: A best practices study for the siting of biofuels infrastructure was recommended. DOE and USDA should co-lead an effort to convene the states to develop models/legal/policy for siting biofuels infrastructure. EPA would also participate in this action. The duration of this effort would be 2 years at a cost of $500K.
- **Establish optimal siting criteria**: A related issue was establishing siting criteria for biofuels infrastructure. It was recommended that USDA (lead) establish optimal siting criteria. EPA and DOE are additional Federal participants in this action, which will also require coordination with NASEO, NCSC, and other state organizations. The duration of this effort would be 3 to 5 years at a cost of $10M/year.
- **Recommendations related to testing and evaluating biofuels pipeline issues:**

- **Evaluate ethanol-petroleum interface management:** DOT should lead the effort to determine how best to manage the ethanol-petroleum interface. NIST and DOE would also participate in this action. Duration of this effort would be up to one year at a cost of $1M.
- **Focus on materials compatibility:** Materials compatibility is a major barrier to the use of the existing petroleum infrastructure for the transportation of ethanol. It was recommended that NIST (lead) determine the impact of ethanol on existing pipeline and storage tank materials (data gathering task) (includes moisture impacts). Supporting agencies include DOT and EPA/ORD. Duration of this effort would be 3 years at a cost of $5M.
- **Investigate use of advanced coatings for pipelines**: An additional materials issue is that of the pipeline materials compatibility with ethanol and potentially other biofuels. It was recommended that NIST (lead) and DOE (co-lead) investigate use of advanced coatings for pipelines. The implications of this research and development are far reaching and DOT, DOI, DOD, USDA, and EPA need to be involved. Duration of this effort would be 5 to 7 years at a cost of $50M.
- **Specify universal material(s):** Completion of materials research and development must be followed by deployment. NIST (lead) should specify universal material(s) for use in biofuel/petroleum infrastructure. The development and implementation of these specifications will be performed in coordination with DOE, DOT, DOI, DOD, USDA, and EPA. Duration of this effort would be 5 to 10 years at a cost of $10M.
- **Develop advanced measurement techniques, implemented with standards development organizations:** If ethanol and petroleum are to be transported in the same pipelines, there needs to be assurance that the quality of the fuel is not degraded by the transportation process. It was recommended that DOE (lead) the development of advanced measurement techniques to be implemented with standards development organizations in order to enable determination of fuel quality. EPA and USDA would co-lead this action and all agencies would be involved. To effectively perform this action, early stakeholder support and agency buy-in is required. The duration of this effort would be up to 3 years at a cost of $30M to $50M.

Communication, Education, and Outreach

Status of Activities and Challenges

Many federal agencies are actively, and successfully, providing one or more aspects of a communications campaign, to audiences appropriate to their goals. The numerous programs underway have significant commonalities that lend themselves to interagency partnerships that would maximize resources and reach wider audiences, including professionals, permit writers, facility designers, and others. Partnerships or coordination would also increase the accuracy, consistency, and comprehensiveness of messages across the full spectrum of technical, social, and economic aspects of biofuels. Further, no one agency has the funding available to achieve all of the goals essential to efficient market transformation for biofuels.

The key challenges identified in Table 1 show common themes across all three areas of communications, education and outreach. The activities described in Table 2 in many cases can have near-term impacts that will dramatically affect efforts to meet market goals for 2030.

Table 1. Communications, Education, and Outreach Elements and Key Barriers

Elements	Key Barriers
A. Communications – General and targeted messaging collaterally created and disseminated for the purpose of informing a variety of stakeholders about all aspects of biofuels with the intention to change attitudes and behavior relevant to biofuels.	• A1. Lack of coordination across agencies and within agencies • A2. Limited ability to reach the widest possible audience • A3. Lack of consensus on priority stakeholders needing information (e.g., permit writers, facility designers, etc.) • A4. Limited understanding of most aspects of biofuels technologies by the general public
B. Education – Information and curriculum on biofuels currently provided in a general way to K-12, undergraduate and graduate students, and technical information for permit writers and facility designers	• B1. Lack of coordination across technologies, agencies and within agencies • B2. Need to understand and further develop biomass/fuel curriculum and educational materials for engineering and operations • B3. Need to maximize reach to research and educational institutions
C. Outreach – Developing partnerships between and among stakeholders to standardize messaging, provide services, incentives and tools to engage them in transforming the biofuels market.	• C1. Lack of coordination across technologies, agencies and within agencies • C2. Need to identify the right stakeholders • C3. Need to formalize working relationships and coordinating benefits, incentives, etc. • C4. Need for improved information, coordination and technical support

Table 2 outlines the major activities needed, in the near-, mid-, and long-term, to meet the challenges described in Table 1. Each agency that currently contributes to each activity described in Table 2 is noted after that activity [e.g., ***(USDA, DOE…)***]. The key barriers addressed by each Table 2 activity align with the numbered barriers in Table 1, and are also noted after each activity in Table 2 [e.g., ***(A1, B2…)***]. Table 3 lists specific agency activities based on the information provided by each agency during the November workshop and during the drafting of this document. Table 4 describes each agency's funding that supports its activities. Tables 3 and 4 are not complete or linked with Tables 1 and 2; interagency teams should continue this effort.

Together, these four tables represent the most complete interagency biofuels activity reference to date, and should serve as a guide for future interagency team. Development of a detailed, shared agency activity database is recommended to further illustrate these collaborations and identify gaps (see *Summary of Overall Recommendations*).

Note: These notations are based on agency input at the time of this document's drafting, and the November 30x30 workshop proceedings. They do not necessarily reflect established future work plans by these agencies, but rather reflect their current or potential future activities.

Table 2. Activities Needed to Overcome Barriers to Communications, Education and Outreach for Biofuels

Infrastructure Areas	Near Term (0-5 Years)	Mid (5-10 Years)	Long Term (10+ years)
Feedstock Production	Educate farmers and forest and other land managers and owners on regionally viable feedstocks, harvesting equipment, storage practices. ***(USDA, DOI, EPA)(A1, A4, B1, B2, C4)***	Continue educating feedstock providers on new practices and equipment. ***(A1, A4, B1, B2)***	Develop certification standards for feedstock providers and continue training, education, and information exchange on innovations.
Biofuels Production	Develop education curriculum and training standards for essential workforce to support biofuels ***(NSF, EPA, USDA, DOI) (A1, B2, B3)***	Institutionalize education and training in biorefinery design and operations at colleges ***(NSF)*** (B2,B3)	Institutionalize training in biorefinery operations in the military, high school technology, and other training organizations (***NSF) (B2,B3)***
Biofuels Distribution	- Partner with fuels distributors to determine systemic changes necessary to current fuels distribution systems to accommodate biofuels ***(EPA, DOT) (A1, B1, C2)***		
Biofuels End-Use	- Expand EPA's voluntary national campaigns and develop federal partnerships to reach additional market change masters ***(EPA) (A1, A4)*** - Develop additional and update existing maps and information on locations of biofuel stations for consumers -Outreach to community leaders and first responders on biofuels transport, storage and use ***(DOT)***		

Cross-cutting	- Establish a formal subcommittee for biofuels communications, education and outreach to foster partnerships across Federal agencies to maximize resources ***(EPA, DOI) (A1, A3, A4, B1, C1, C3)*** - Develop a clearinghouse for biofuels information that presents a common face for Biofuels facts and figures, and links federal information resources for ease of access ***(EPA, DOI) (A1, A4)*** - Develop a Project Deployment Primer to assist technology developers in overcoming many of the logistical barriers encountered during the deployment process ***(DOI) (B2)*** -Work with other established federal biomass groups, such as the Woody Biomass Utilization Group to establish standard messaging and disseminate information. ***(EPA, DOI) (A1, B1, C1)*** - Developing labeling schemes that respond to public interest about environmental aspects of biofuels ***(EPA) (A2, A4)*** -Monitor public perception about biofuels and feedback to R&D		

Current Federal Efforts in Communications, Education and Outreach

Six agencies reported their communications campaigns and/or education programs. The USDA has a significant educational program across all audiences and has leveraged their field and extension offices to provide state-level support. The illustration of the link between each barrier, activity, and agency is identified in Table 2. Highlights of the activities currently being conducted by Federal agencies are summarized in Table 3. Below is a summary of each agency role in communications, education and outreach.

EPA - EPA develops voluntary partnerships (Smart Way Transport Partnership Grow and Go Program) with key stakeholder groups that are essential to biofuels adoption and market transformation. The Agency also works closely with both public and private stakeholders in the biofuels and related sectors as it develops regulations, policy and guidance pertaining to fuels and vehicles. ORD supports a Waste to Energy Team Network that focuses on converting biomass and wastes to products and is currently developing an informational matrix summarizing biomass conversion technologies, compatible feedstocks and potential products. ORD will assist regions and states in assessing the environmental impacts of growing, harvesting, transporting a variety of

renewable feedstocks couples with various biofuel technology pathways and sustainable biorefinery production, using research and modeling tools (such as the 9-Region MARKAL model).

DOE - Education and information on the research & development activities and advancements within the biofuels industry.

DOC - Fostering international markets for US biofuels technologies and educating industry to the economic benefits domestically of a biofuels market.

DOI - Role in communicating forestry recovery methods and land management to relevant stakeholders. Agencies within DOI have a full range of communications, education and outreach programs to address biomass issues. DOI works with partners to promote the utilization of woody biomass removed from DOI-managed lands in the course of preventing wildfires and improving forest health. The Department has an agreement with the National Association of Conservation Districts to educate the public about the benefits of woody biomass utilization. DOI co-chairs the federal Woody Biomass Utilization Group chartered to promote interagency collaboration in promoting the use of woody biomass. USDA, DOE, EPA and other federal agencies participate in this Group. The Group addresses policy barriers to biomass utilization and has a biomass website that provides links for persons interested in biomass projects.

NSF - Developing the next generation of scientists and engineers to further biofuels research and development.

USDA -Full range of communications, education and outreach activities to: facilitate woody biomass utilization; biodiesel agricultural and ethanol forest biomass production and use; and to respond to community and regional interests, and increase markets for biomass.

DOT - Role in education and outreach to transit systems across the country in the incorporation of biodiesel in their fleets. Continued existing activities and inclusion in the Emergency Response guide and other training, education for first responders and local and state code officials. Continued outreach through the DOT Center for Climate Change and Environmental forecasting on the role of biofuels in reducing the impact of transportation on climate change.

Table 3. Communications, Education and Outreach Activities by Agency

Agency/Area	Cross-Cutting	Feedstock Production	Biofuels End-Use
Interagency	Consortia/ Federal Woody Biomass Utilization Working Group Federal Task Force on Woody Biomass Utilization; demonstration of woody biomass heating systems; education, outreach, policies (MOU on Policy Principles for Woody Biomass)		

EPA	- Communication to biofuel related sectors on regulations, policy, and guidance pertaining to production, use, and requirements pertinent to public and private stakeholders. - Biomass conversion technology matrix, depicting feedstock and conversion technology compatibilities, and energy end products - CHP Partnership provides outreach to biorefinery developers and investors on implementing heat and power systems. - Develops voluntary partnerships with key stakeholder groups that are essential to biofuels adoption and market transformation. - Communicates environmental and human health risks associated with biofuels production and use - Models various scenarios of production and use and assesses environmental impacts of different biofuel technology pathways. - ORD will assist regions and states in assessing the environmental impacts of growing, harvesting, transporting a variety of renewable feedstocks couples with various biofuel technology pathways and sustainable biorefinery production, using research and modeling tools (such as the 9-Region MARKAL model)		National Campaigns: Clean Diesel: Public Partnerships to bring greater access to biodiesel and E85 along key transportation corridors - SmartWay Transport Partnership between various freight industry sectors that establishes incentives for fuel efficiency improvements and greenhouse gas emissions reductions
DOE	General information and educational materials in a variety of media targeted to the various stakeholder audiences	Educate Research Institute capability to address biofuels R&D needs	Consumer information & education, technical assistance for early adopters
DOC	- Webinar Series: To educate DOC specialists on U.S. biofuel industry and related infrastructure, and to identify differences in biofuels developments in other countries; and to provide U.S. biofuels industry with data on commercial opportunities for biofuels-related infrastructure development overseas (Tent. Summer/Fall 2007) - Economic Impact Analysis for national and federal decision-makers		
DOI	- Outreach and communication through the Conservation Districts and general public -Outreach through Woody BUG activities	- Research-studies on how to assess biomass supplies in the local area impacts on rural areas - DOI-US Forest Service-cooperative agreement to inform landowners how to manage land and resources	
NSF	- Advance understanding of the underpinnings of bioproduct production and policy implications - K-12 curriculum, informal education for school age and adult audiences		

DOT	-Inclusion in the Emergency Response guide and other training, education for first responders and local and state code officials. -Outreach through the DOT Center for Climate Change and Environmental forecasting on the role of biofuels in reducing the impact of transportation on climate change.		-Education and outreach to transit systems across the country in the incorporation of biodiesel in their fleets -Integration and demonstration of biodiesel use in transit fleet
USDA	- Consumer Education: tools for K-12, public discussion of bioenergy from forests - Expand field employee's understanding of biomass utilization tools and procedures - Cost- and scale-effective options for community-based bioenergy systems - Biomass public outreach campaign for all audiences - Investment and business development - Educating next generation of scientists including biorefinery - Educate farmers about switching practices		

Federal Budgets Communications, Education and Outreach by Agency

Budgets for communication, education, and outreach activities for biofuels are shown in Table 4 by agency. Unavailable funding information is annotated as not available (NA). The funding identified is the agencies portion only and does not include partnerships of any nature. It is also unclear in many areas which dollars are exclusively identified with communications, education and outreach versus development of future scientists or other mixed purpose. Mixed funding likelihood is identified with an asterisk.

Funding is in million dollar ($M) increments on a per annum basis unless otherwise indicated.

Table 4. Budget for Communications, Education and Outreach by Agency

Agency/Area	Cross-Cutting ($M)	Feed Stock Production ($M)	Biofuels End-Use ($M)
EPA	NA	NA	NA
DOE	NA	NA	NA
DOC	NA	NA	NA
DOI	NA	NA	NA
NSF	$5*	NA	NA
USDA	$9*		$1.4

Detailed Recommendations to the Board for **Communication, Education and Outreach**

The following recommendations were made to improve coordination as well as expand the current scope of activities in biofuels. These recommendations are not in order of priority.

- **Establish a Communication, Education and Outreach Subcommittee.** This subcommittee, under the auspices of the Board, should coordinate biofuels communication, education, and outreach activities across agencies and utilize existing interagency groups, as appropriate. This will provide coordination currently lacking to maximize resources that could accelerate the fuels market transformation.
- **Increase funding.** Leverage funding by coordinating delivery mechanisms such as conferences, meetings, training videos, teleconferences, etc.

- **Create a central biofuels information resource**. Develop a clearinghouse for biofuels information that presents a common face for biofuels facts and figures, links federal information resources for ease of access, and serves as a repository for information and tools for all stakeholders. This resource should go beyond the EERE Info Resources web site (http://www1.eere.energy.gov/biomass/information_resources.html).
- **Continue and enhance stakeholder programs.** Further develop partnerships with the stakeholder community similar to the Environmental Protection Agencies Smart Way Transport Partnership and Clean Diesel Fuel Campaign and ENERGY STAR® program models.
- **Develop common language for biofuel technology.** Recommended funding for this effort is $2 million in the first 18 months, then nominal funding to update the standard and definitions and to promulgate them.
- **Identify necessary education and training.** Identify information, education, and training that will be needed by permit writers, planners, and other decision-makers of biofuels development projects and spearhead coordinating this information to these stakeholders.

Conclusions and Next Steps

This *Workshop Summary Report* for the Biomass Research and Development Board is a first attempt to capture, by biofuel topic areas, the barriers, activities for overcoming those barriers in a timeline, identification of agency roles and activities, and agency funding. This report also includes recommendations that collectively provide the framework for the Board to better coordinate biofuels activities within and among key Federal agencies to meet the President's goals and to align related agency goals.

Next Steps:

- The Board should discuss for approval some or all of the key recommendations in *Summary of Overall Recommendations*. Most notably, the Board should review the recommendation for interagency teams and establish a framework and select team members. (See Appendix A for a list of the interagency teams suggested by each agency during the drafting of this report and a summary of their proposed activities.) Included in interagency team tasks should be (a) continue to build upon the information in this *Workshop Summary Report* to develop a *National Biofuels Action Plan* and (b) implementing coordination activities and making new recommendations.
- An outline of a *National Biofuels Action Plan* should be developed by the interagency teams. A method such as a workshop, similar to the November 2006 workshop, could be organized by either DOE and/or USDA, and should cover the following:
    - Brief the interagency teams on their duties,
    - Review the results of the *Workshop Report*,
    - Discuss and agree upon an *Action Plan* outline,
    - Decide upon an interagency team meeting schedule to develop the *Action Plan*,
    - Decide on a method, such as a database, to maintain records of the barriers, activities, and funding by agency for each biofuel area that will be used to develp a comprehensive *Action Plan*.

Recent acceleration of Federal biofuels goals has increased the emphasis on the need to align and coordinate Federal, State, and even local efforts to maximize government resources and knowledge. This report is the first attempt to coordinate this process, and suggests a blueprint for Board actions, interagency team activities, and future Federal biofuels activity. By working together and leveraging resources, the Federal government can achieve the President's biofuels related goals announced in the Advanced Energy Initiative and in the "20 in 10" and also supports DOE's Biofuels Initiative goals (aka "30 x 30").

Appendix A: Summary and Matrix of Interagency Teams

Summary of Proposed Interagency Team Activities

The Biomass R&D Act of 2000, as amended by EPACT 2005, established a Biomass R&D Board to coordinate programs within and among departments and agencies of the Federal Government for the purpose of promoting the use of biobased fuels and products. The Board has been active since 2000, meeting biannually. In response to the President's increased emphasis on renewable and alternative fuels, the Board is elevating the level of its members and increasing the number of members and the frequency of meetings. Additionally, the Board is considering the use of an Executive Steering Committee to assist in the planning of Board activities and Interagency Teams to coordinate the implementation of Federal activities that support the President's goals to reduce gasoline usage in the United States by 20 percent in the next 10 years (2017) and make cellulosic ethanol cost competitive by 2012.

The Executive Steering Committee is comprised of co-chairs' Deputies and key biomass staff from USDA and DOE. This Committee will coordinate planning for the Board meetings including the development of briefing materials and agendas.

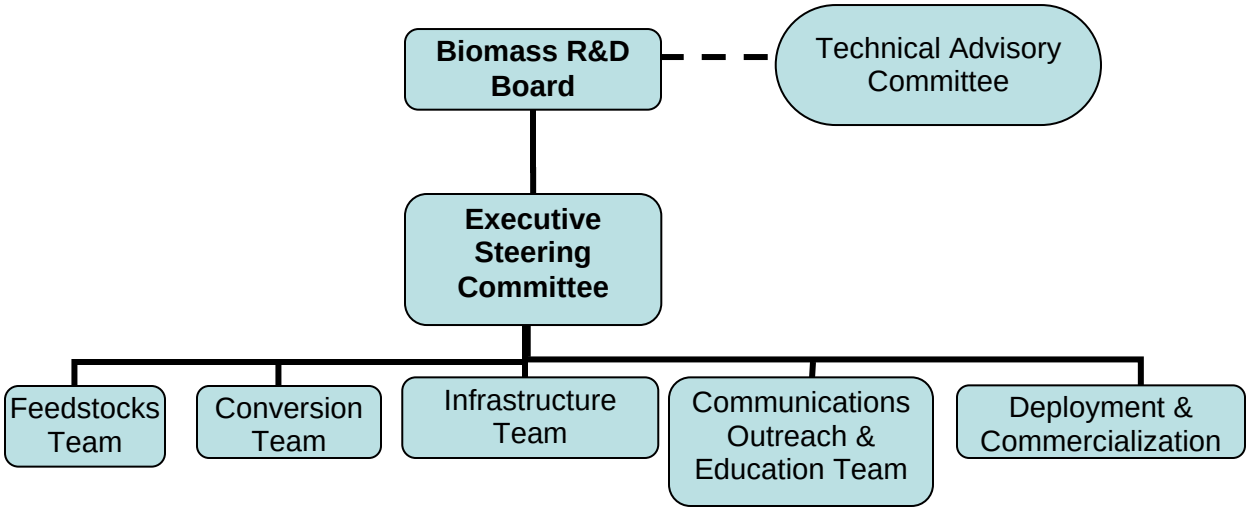
The Interagency Teams would be responsible for the following:

- Develop corresponding section of National Biofuels Action Plan (Action Plan) that builds upon the report from the federal agency workshop held in November 2006.
- Implement the recommendations from the Board and the workshop report.
- Evaluate the progress of federal activities toward implementing the Action Plan.
- Report progress to the Board.
- Develop additional recommendations to improve the coordination of federal agency biofuels activities and budget requests to the Board.

The first task of the teams will be to develop a comprehensive Action Plan for meeting the President's goals for biofuels. The Action Plan will include:

- A schedule and timeline that supports the goals, objectives and targets, and includes key milestones and decision points.
- Current federal activities and associated funding.
- Opportunities for interagency collaboration and partnership building.

The effort of the teams will support collaboration and leveraging throughout government agencies to reduce duplication of effort. The structure is represented below.



The areas and activities covered by each team are described below. Each agency's mission, stakeholder networks, key strengths and capabilities will determine their respective roles on the teams.

Feedstocks Team

- The focus of this team will be on the production, harvesting, collection, storage, transportation and preprocessing stages of the biomass lifecycle. Activities include land sustainability studies, basic and applied plant science, yield improvement, harvesting, material handing and feedstock transportation.

Proposed Leads: USDA– Chair; DOE, DOI – Co-Chairs
Proposed Members: EPA; NSF; DOT; DOD

Conversion (Biochemical & Thermochemical) Team

- The focus of this team will be on reducing the economic and technical barriers for converting lignocellulosic biomass to dilute sugars (from biochemical conversion) or synthesis gas (from thermochemical conversion) and further processing those to liquid biofuels. Activities include, basic and applied research and environmental and economic analysis with the goal to develop next-generation, cellulosic ethanol technologies for a wide range of feedstocks. Biochemical conversion topics include pretreatment, saccharification and fermentation. Thermochemical conversion topics include gasification and pyrolysis oil technology development with further synthesis to biofuels.

Proposed Leads: DOE – Chair, USDA – Co-Chair
Proposed Members: EPA, NSF, DOD, DOC

Infrastructure Team

- Biofuels infrastructure includes the technologies and facilities in the plant-to-pump phase of biofuels development (i.e., storage, transport, pipelines, terminals, retail outlets, vehicles). The scope will include identifying regulatory and policy barriers to biofuels infrastructure deployment, developing strategies for barrier removal, and building partnerships. Activities include standards development, health and safety assessments and environmental and economic analysis.

Proposed Leads: DOT – Chair, EPA, DOE – Co-Chairs
Proposed Members: DOD, DOC

Communication, Education, & Outreach Team

- The federal government needs to increase public awareness of biofuels to facilitate their use and the advancement of biofuels technologies. The focus of this team will be informing and educating the public on biofuels in order to stimulate demand for biofuels. Scope will include developing communication plans and educational materials and programs for skilled laborers and implementing outreach activities. Priorities may include educating safety and code officials, potential end-users, local communities, students and teachers, and industry stakeholders (from feedstocks to retail and automotives).

Proposed Leads: USDA– Chair, DOE, EPA – Co-Chairs
Proposed Members: DOI, EPA, NSF, DOT, OFEE, DOC

Deployment & Commercialization Team

The Deployment & Commercialization Team will focus on the review of current and future program policies and activities that would promote the successful integration and operation of advanced biomass technologies. The scope includes deploying technologies beyond R&D into successfully operating biorefineries. This includes defining government and industries roles during the deployment and commercialization phase. As technologies are successfully proven in the marketplace and the industry matures, the government role would lessen. The scope of this team also includes identifying regulatory and policy barriers, and strategies for their removal. This involves the development of biofuel codes, standards, regulations, policy incentives and loan guarantees in collaboration with key stakeholders. This team will need to coordinate with other interagency teams.

Proposed Leads: USDA – Chair, DOE – Co-Chair
Proposed Members: DOI, EPA, DOD, Treasury

Matrix of Interagency Team Participants

Agencies	Feedstocks	Conversion (Biochemical & Thermochemical)	Infrastructure	Communication, Education, & Outreach	Deployment & Commercialization
Department of Energy	Co-Chair	Chair	Co-chair	Co-chair	Co-Chair
Department of Agriculture	Chair	Co-Chair	Member	Chair	Chair
Department of Interior	Co-Chair			Member	Member
Environmental Protection Agency	Member	Member	Co-Chair	Co-chair	Member
National Science Foundation	Member	Member		Member	
Department of Transportation	Member		Chair	Member	
Office of Science and Technology Policy					
Office of the Federal Environmental Executive				Member	
Department of Defense	Member	Member	Member		Member
Department of Commerce		Member	Member	Member	
Department of Treasury					Member

Table 1. Interagency Teams with Recommended Agency Participants

Table 2. Interagency Feedstock Team - Potential Participants

Name	Agency
Chair	USDA
Michael Viola, Co-chair	DOE - BER
Eric Rohlfing, Co-chair	DOE - BES
Co-chair	DOI
John Ferrell	DOE - OBP
Richard V. Greene	DOE - SC - BES
Sharlene Weatherwax	DOE - SC - BER
John Stewart	DOI - Biomass & Forest Health Program
Gregg Nelson	DOI - BLM
Eric S. Peterson	NSF
William Chernicoff	DOT - RITA
Donna Perla	EPA - ORD
Karen Flournoy	EPA - Region 7
Vince Camobreco	EPA - OAR/ OTAQ
Teresa McKeivier	USDA - Foreign Agricultural Service
Olin Anderson	USDA - ARS
Wally Wilhelm	USDA - ARS
Hans Jung	USDA - ARS
Rob Mitchell	USDA - ARS
Ed Richard	USDA - ARS
Christian Tobias	USDA - ARS
Bill Goldner	USDA - CSREES
Erik Dohlman	USDA - ERS
Don Riemenschneider	USDA - FS
Bob Rummer	USDA - FS
Bryce Stokes	USDA - FS
Mark Peters	USDA - NRCS
Bill Lazarus	USDA - OCE
Irene Xiarchos	USDA - OCE
Lisa Siesennop	USDA - Rural Dev.

Table 3. Interagency Conversion R&D Team - Potential Participants

Name	Agency	Conversion Focus Area
John Ferrell, Chair	DOE - OBP	
Co-chair	USDA	
Bob Goldberg	DOC - NIST	Biochemical
Gene L. Fabian	DOD - Army	Biochemical
Joseph Graber	DOE - BER	Biochemical
Richard Greene	DOE - BES	Biochemical
Amy Miranda	DOE - OBP	Biochemical
Mark Segal	EPA OPPTS	Biochemical
Leland Vane	EPA ORD	Biochemical
Paul Argyropoulos	EPA - OAR / OTAQ	Biochemical
Linda A. Benjamin	HHS - FDA	Biochemical
Tingyu Li	NSF	Biochemical
Bruce Dien	USDA -ARS	Biochemical
Alan Rudie	USDA - FS	Biochemical
Hratch G. Semerjian	DOC - NIST	Thermochemical
Gary Grimm	DOD - Army	Thermochemical
Paul Grabowski	DOE - OBP	Thermochemical
Mark Paster	DOE - Hydrogen	Thermochemical
Frank Princiotta	EPA - APPCD	Thermochemical
Nick Hutson	EPA	Thermochemical
Larry Gonzalez	EPA	Thermochemical
Rick Brandes	EPA - OSW	Thermochemical
Kim Crossman	EPA - OAR/OAP/CPPD	Thermochemical
Paul Argyropoulos	EPA - OAR/OTAQ	Thermochemical
Nick Hutson	EPA	Thermochemical
Larry Gonzalez	EPA	Thermochemical
Rick Brandes	EPA - OSW	Thermochemical
Pat Phelan	NSF	Thermochemical
Robert Fireovid	USDA - ARS	Thermochemical
John Zerbe	USDA - FS	Thermochemical

Table 4. Interagency Biofuels Infrastructure Team - Potential Participants

Name	Agency
Chair	DOT
Ed Wall, Co-chair	DOE - FCVT
Co-chair	EPA
Ellyn Beary	DOC - NIST
William Bolt	DOD - Army
Lindsey Hicks	DOD - Army
Jason Jack	DOD - Army
Marcy Rood	DOE - Clean Cities
Dennis Smith	DOE - FCVT
Kevin Stork	DOE - FCVT
Zia Haq	DOE - OBP
Joy Kandar	DOT
Karl Simon	EPA - OAR/OTAQ
Mark A. Smith	EPA - Region 7
Dana Arnold	OFEE

Table 5. Interagency Comm., Educ., & Outreach Team – Potential Participant List

Name	Agency
Chair	USDA
Amy Chiang*, Co-chair	DOE - EE
Co-Chair	EPA
Stefan Osborne	DOC - ITA Office of Competition and Economic Analysis
Joan Glickman	DOE - Biomass Program
Dennis Smith	DOE - FCVT
Brenda Aird	DOI - BLM
Roy Chen	DOT - FTA
Brenda Groskinsky	EPA - Region 7
Rebecca White	EPA - OAR/OTAQ
Lenore Clesceri	NSF
Bruce Hamilton	NSF
Tony Ashby	USDA
Jim Brownlee	USDA - Office of Communications
Ron Buckhalt	USDA - ARS
Philip Jarrell	USDA
David Lewis	USDA - RD, Business and Industry Division
Wayne Maloney	USDA - Rural Development
Marcia Patton-Mallory	USDA - FS
Steve Yaddof	USDA - FS
Daniel Cassidy	USDA - CSREES

***** starts May 1, 2007

Table 6. Interagency Commercialization and Deployment Team – Potential Participants*

Name	Agency
Chair	USDA
Jacques Beaudry-Losique, Co-chair	DOE - OBP
Michael Karwatka	DOD - Army
Cindy Riley	DOE - OBP
Larry Russo	DOE - OBP
John C. Houghton	DOE - SC - BER
Peter Teensma	DOI - BLM
Mark A. Smith	EPA - Region 7
Brian Shrager	EPA - OAR / OAQPS
Jaime Pagan	EPA - OAR / OAQPS
Kim Crossman	EPA - OAR/OAP
Teresa Harten	EPA - ORD
Donna Perla	EPA - ORD
David Widawsky	EPA - OPEI
Teresa Harten	EPA - ORD
Kim Crossman	EPA - OAR/OAP
Joseph S. Badin	USDA - RD, Electricity Program
Harry Baumes	USDA - OEPNU
Joseph Ben-Isreal	USDA - RD, Specialty Lenders Division
Richard J. Brenner	USDA -ARS, OTT
Marilyn Buford	USDA - FS
William C Smith	USDA
Omar Mendoza	USAF - AFRL/MLSC
Thomas Naguy	USAF - AFRL/MLSC

*May want to include representatives knowledgeable of loan guarantee programs, 932 and 10% validation projects, and Reverse Auctions from these agencies