Biomass and Biorefinery Systems R&D

Funding Profile by Subprogram

(dollars in thousands)

	FY 2008 Current Appropriation[a]	FY 2009 Original Appropriation	FY 2009 Additional Appropriation	FY 2010 Request
Biomass and Biorefinery Systems R&D				
Feedstock Infrastructure	12,144	15,500	–	27,500
Platforms Research and Development	65,844	53,400	–	59,700
Utilization of Platform Outputs R&D	112,690	148,100	–	147,800
Cellulosic Ethanol Reverse Auction	4,955	0	–	0
Total, Biomass and Biorefinery Systems R&D	195,633	217,000	786,500[b]	235,000

Public Law Authorizations:

P.L. 93-577, "Federal Non-nuclear Energy Research and Development Act" (1974)
P.L. 94-163, "Energy Policy and Conservation Act" (EPCA) (1975)
P.L. 94-385, "Energy Conservation and Production Act" (ECPA) (1976)
P.L. 95-91, "Department of Energy Organization Act" (1977)
P.L. 95-618, "Energy Tax Act" (1978)
P.L. 95-619, "National Energy Conservation Policy Act" (NECPA) (1978)
P.L. 95-620, "Powerplants and Industrial Fuel Use Act" (1978)
P.L. 96-294, "Energy Security Act" (1980)
P.L. 100-12, "National Appliance Energy Conservation Act" (1987)
P.L. 100-615, "Federal Energy Management Improvement Act" (1988)
P.L. 101-218, "Renewable Energy and Energy Efficiency Technology Competitiveness Act" (1989)
P.L. 101-549, "Clean Air Act Amendments" (1990)
P.L. 101-575, "Solar, Wind, Waste, and Geothermal Power Production Incentives Act" (1990)
P.L. 102-486, "Energy Policy Act" (1992)
P.L. 106-224, "Biomass Research and Development Act" (2000)
P.L. 107-171, "Farm Security and Rural Investment Act" (2002)
P.L. 108-148, "Healthy Forest Restoration Act" (2003)
P.L. 109-58, "Energy Policy Act of 2005" (2005)
P.L. 110-140, "Energy Independence and Security Act of 2007" (2007)
P.L. 110-234, "The Food, Conservation, and Energy Act of 2008" (2008)

Mission

The mission of the Biomass Program is to facilitate the development and transformation of domestic, renewable, and abundant biomass resources into cost-competitive, high performance biofuels,

[a] SBIR/STTR funding was transferred to the Science Appropriation in FY 2008, which includes a reduction of $2,275,000 that was transferred to the SBIR program, and $272,000 that was transferred to the STTR program.
[b] An additional $13.5 million in Biomass related projects is included within EERE Facilities and Infrastructure

bioproducts and biopower through targeted research, development and deployment (RD&D) leveraged by public and private partnerships.

Benefits

The Biomass Program's vision is for a viable, sustainable, domestic biomass industry that produces clean, secure, renewable biofuels, biopower, and bioproducts that can: 1) enhance U.S. energy security by reducing dependence on foreign oil, 2) provide environmental benefits including reduced GHG emissions, and 3) create economic opportunities across the nation.

The Biomass Program's groundbreaking RD&D work and support of private sector investment and innovation is critical to achieving the Energy Independence and Security Act of 2007 (EISA 2007) Renewable Fuel Standard (RFS) targets for advanced and cellulosic biofuels. The RFS requires 36 billion gallons per year of the national fuel supply be comprised of renewable fuels by 2022. Of the 36 billion gallon mandate, 21 billion gallons is to be advanced biofuels. Further, of the 21 billion gallons of advanced biofuels, 16 billion gallons must be cellulosic biofuels.

The Biomass Program has developed an approach centered on the integrated biorefinery concept to support meeting the RFS. A biorefinery is a facility analogous to a petroleum refinery, designed to efficiently produce fuels and a variety of co-products such as power, chemicals, and other materials from biomass. Demonstrating and validating the commercial viability of the integrated biorefinery concept requires: sustainably producing, collecting, and transporting large volumes of biomass feedstocks; advancing biomass conversion technologies; and developing an adequate biofuels distribution and end use infrastructure. The R&D platforms will focus on reducing the costs of feedstock and conversion technology options, while operational data from demonstrating integrated biorefineries at various scales will reduce technology risks. Ultimately, this strategy validates the commercial viability of biorefinery concepts by attracting other sources of capital for larger scale production of biofuels to meet the RFS.

Meeting the RFS targets also requires the concerted efforts of Federal and state policy and decision makers; the industrial, agricultural, and environmental communities; and financial sector and business entrepreneurs. Coordination of multidisciplinary scientific and engineering expertise of academia and National Laboratories will be critical to building a strong technology innovation foundation. The Biomass Program is advancing science in these areas through important collaborations with other programs and agencies such as DOE's Office of Science (Bioenergy Centers) and the United States Department of Agriculture (USDA). The Biomass Program is forging new partnerships and strategic alliances to leverage efforts in meeting the technological and economic challenges of establishing integrated biorefineries such as DOE and USDA's Loan Guarantee Offices.

The FY 2010 Budget investments complement Recovery Act funds that accelerate achievement of program goals. To enable decision makers and the public to follow performance and plans, the program will post its progress in these planned activities at: http://www.energy.gov/recovery/index.htm.

Climate Change

The Biomass Program's research, development, demonstration and deployment activities all support the achievement of a national reduction in GHG emissions. Biofuels have great potential for displacing petroleum-based liquid transportation fuels, lowering the amount of carbon introduced into the Earth's atmosphere. For example, Argonne National Laboratory estimates that biofuels have the potential to reduce GHG emissions by more than 80 percent when compared to gasoline on a life cycle basis, though subsequent studies suggest that emissions reductions may not be as great when the GHG impacts of

changes in land-use associated with increased biofuels production are included.[a] The Biomass Program's current activities directly support meeting the goals of EISA 2007. It is estimated that the program's activities will enable the law to reduce total CO_2 emissions by well over 300 million metric tons by 2030. The program's non-EISA 2007 related activities are expected to result in an additional cumulative CO_2 emissions reduction of 49 million metric tons.

Energy Security

The displacement of fossil fuels from foreign sources with sustainably produced advanced domestic biofuels will enhance energy security. At the same time, new markets will be created to produce sustainable feedstocks and biofuels. Production distribution infrastructure and related goods and services throughout the supply chain will create new green jobs. The increased production of biofuels has the potential to help reshape our markets, reinvigorate rural economies, and support a sustainable new generation of transportation technologies critical for reducing our carbon emissions and ensuring America's future prosperity and security in the global community. The Biomass Program's current activities directly support meeting the goals of EISA 2007. It is estimated that the program's activities will enable the law to reduce oil imports by well over 700 million barrels by 2030. The program's non-EISA 2007 related activities are expected to result in a cumulative reduction of 200 million barrels of oil imports.

Economic Impact

The Biomass Program pursues its mission through the set of integrated activities proposed in this budget that are designed to increase the use of domestic renewable resources. Improvements are expected to continue to provide concomitant economic, environmental and security benefits. The most significant benefits are expected to be a reduction of oil imports and in reduction of CO_2 emissions.

The benefits tables following this section show the estimated benefits from 2015 through 2050 that would result from realization of the program's goals. These benefits are achieved by targeted Federal investments in technology research and development through industrial partnerships with auto manufacturers, commercial vehicle manufacturers, equipment suppliers, fuel and energy companies, other Federal agencies, State government agencies, universities, National Laboratories, and other stakeholders. These partnerships facilitate the technical coordination of activities and attract cost sharing to provide leveraged benefits.

The benefits table also reflects the increasing market share of advanced-technology biofuels over time as their projected incremental cost relative to conventional biofuels declines, and as their efficiency relative to conventional biofuels increases. The expected benefits reflect solely the achievement of the program's goals. Not included are any policies, regulatory mechanisms, or other incentives not already in existence that might be expected to support or accelerate the achievement of the program goals. In addition, some technologies show diminishing annual benefits by 2050 due to the assumption built into the analysis that industry progress, as reflected in the baseline, will eventually catch up with the more accelerated progress associated with EERE program success.

The program goal case is modeled along with a "baseline" case in which no DOE R&D exists. The baseline case is intended to represent the future without the effect of the Biomass Program, and is identical for all DOE applied energy R&D programs, thereby ensuring that all program benefits are

[a] Wang et al. "Life-cycle energy and greenhouse gas emission impacts of different corn ethanol plant types." *Environmental Research Letters* 2 (2007) 024001 (13pp)

estimated using the same assumptions for external factors such as economic growth, energy prices, and levels of energy demand. The expected outcome benefits are calculated using the same fundamental methodology across EERE and across all of DOE's applied energy R&D programs, and the metrics by which expected outcome benefits are measured are identical. This standardization of method and metrics has been undertaken as part of DOE's efforts to make all program stated benefits comparable.

Prospective benefits are calculated as the arithmetic difference between the baseline case and the program goal case, and the resulting economic, environmental and security benefits attributed to the program's activities. This approach of calculating the benefits as an incremental improvement to the baseline helps ensure that improvements in biomass technologies that would occur in the absence of the program are not counted as part of the program's benefits. In addition to technology and process advances due to the program's activities, energy market policies, such as state and federal tax policies, facilitate the development and deployment of clean energy technologies. The expected impacts of current legislated policies in the baseline case are included so that the expected benefits calculated reflect as much as possible the effects of activities funded by the program.

The Biomass and Biorefinery Systems R&D Program's expected impact on oil import reductions is less than in prior years, primarily because of the inclusion of the EISA 2007 National Renewable Fuels Standard (RFS) in the baseline. Much of the increased production of cellulosic ethanol conversion technology that in prior years has been attributed to the program's activities is now assumed to occur as a result of the RFS mandate, as opposed to the program's R&D activities. The program's benefits are also impacted by the inclusion of the EISA 2007 Corporate Average Fuel Economy (CAFE) mandate in the baseline, which serves to reduce the demand for oil and biofuels in the light duty vehicle segment of the transportation fuels market. While the program's energy security benefits may be smaller this year due to the inclusion of EISA's RFS mandate in the benefits analysis methodology, achieving the aggressive RFS target with minimum adverse impact to the U.S. economy will depend on successful current and future program R&D activities.

While the EISA 2007 national RFS mandates that 36 billion gallons of cellulosic ethanol production be achieved by 2022, EISA incorporates a waiver process if the target cannot be met. The integrated energy modeling results in achievement of the target in 2030, which impacts the program's oil savings most significantly prior to 2030 in comparison to prior year estimates; during this period, annual savings are very small. The program's contribution to carbon emission reductions and consumer savings are also significantly reduced during this period.[a] The program's impact is also reduced in the long-term and the magnitude of benefits does not return to the level of prior year estimates by 2050.

The benefits are generated by modeling both the program goal and baseline cases within two energy-economy models: NEMS-GPRA10 for benefits through 2030, and MARKAL-GPRA10 for benefits through 2050. The full list of modeled benefits appears below. Some benefits may be shown as lower than projected in previous years' budgets. This is due to the models' inclusion of the effects of legislation such as EISA 2007 in the baseline case, which raises the baseline projected fuel economy and petroleum displacement, and thus reduces the incremental benefit that are attributed to the program's

[a] The Biomass Program has consistently had smaller savings in prior years because the program's R&D is defined as accelerating the baseline case cost and performance of cellulosic ethanol technology by only a few years. In the NEMS-GPRA10 analysis, the program case results in cellulosic ethanol production beginning sooner than in the baseline, which requires a smaller EISA 2007 RFS waiver and leads to some oil and carbon savings.

R&D efforts. The first table displays the estimated benefits from the applications of the program's technologies, co-developed with industry, that enable EISA 2007. The second table used standard methodology to allocate all benefits from legislation, such as EISA 2007, in the baseline, and displays benefits expected to accrue because of the program's activities in addition to those expected from the legislation.

Estimated Primary Benefits

(Including Program Contribution to EISA 2007)

	Metric[1]	Model	Year			
			2015	2020	2030	2050
Energy Security	Oil Imports Reduction, cumulative[2] (Bil bbl)	NEMS	ns	ns	0.2	N/A
		MARKAL	ns	ns	0.7	5.7
	Natural Gas Imports Reduction, cumulative (Tcf)	NEMS	ns	ns	0.2	N/A
		MARKAL	ns	ns	ns	0.5
	Reduction in Share of Highway Fuel Demand Derived from Crude Oil[3] (%)	NEMS	ns	ns	1%	N/A
		MARKAL	ns	ns	2%	5%
Environmental Impacts	CO_2 Emissions Reduction, cumulative (Mil $mtCO_2$)	NEMS	ns	ns	55	N/A
		MARKAL	3	33	327	2295
	SO_2 Allowance Price Reduction[4] ($/ton)	NEMS	ns	ns	268	N/A
		MARKAL	N/A	N/A	N/A	N/A
	NO_x Allowance Price Reduction ($/ton)	NEMS	ns	ns	328	N/A
		MARKAL	N/A	N/A	N/A	N/A
	Hg Allowance Price Reduction (thousand $/lb)	NEMS	ns	ns	ns	N/A
		MARKAL	N/A	N/A	N/A	N/A
Economic Impacts	Consumer Savings, cumulative[5] (Bil $)	NEMS	ns	3	29	N/A
		MARKAL	ns	1	30	49
	Electric Power Industry Savings, cumulative (Bil $)	NEMS	ns	2	4	N/A
		MARKAL	ns	ns	2	-18
	Household Energy Expenditures Reduction ($/household/yr)	NEMS	ns	ns	80	N/A
		MARKAL	ns	ns	11	4

1. "Reductions" and "savings" are calculated as the difference between results from the baseline case (i.e. no DOE technology) and the technology case (i.e. all DOE technology R&D programs are successful).
2. All cumulative metrics are based on results beginning in 2009.
3. Metric includes oil-derived fuel use by light-duty vehicles, commercial light trucks and freight trucks; the metric excludes buses. Reported oil use is adjusted to exclude ethanol, biodiesel and CTL.
4. All monetary metrics are in 2005$.
5. Cumulative monetary metrics are in 2005$ that are discounted to 2009 using a 3% discount rate.

ns - Not significant
NA - Not yet available
N/A - Not applicable

Primary Metrics for FY 2010 Budget Request

(Program Impacts to EISA 2007 are not credited to program)

	Metric[1]	Model	Year			
			2015	2020	2030	2050
Energy Security	Oil Imports Reduction, cumulative[2] (Bil bbl)	NEMS	ns	0.2	0.4	N/A
		MARKAL	0.0	0.1	0.2	1.1
	Natural Gas Imports Reduction, cumulative (Tcf)	NEMS	ns	0.1	0.6	N/A
		MARKAL	ns	ns	ns	ns
	Reduction in Share of Highway Fuel Demand Derived from Crude Oil[3] (%)	NEMS	ns	ns	ns	N/A
		MARKAL	0%	0%	0%	1%
Environmental Impacts	CO_2 Emissions Reduction, cumulative (Mil $mtCO_2$)	NEMS	ns	100	255	N/A
		MARKAL	3	11	49	523
	SO_2 Allowance Price Reduction[4] ($/ton)	NEMS	ns	ns	ns	N/A
		MARKAL	N/A	N/A	N/A	N/A
	NO_x Allowance Price Reduction ($/ton)	NEMS	ns	ns	ns	N/A
		MARKAL	N/A	N/A	N/A	N/A
	Hg Allowance Price Reduction (thousand $/lb)	NEMS	ns	ns	ns	N/A
		MARKAL	N/A	N/A	N/A	N/A
Economic Impacts	Consumer Savings, cumulative[5] (Bil $)	NEMS	ns	ns	39	N/A
		MARKAL	2	4	11	34
	Electric Power Industry Savings, cumulative (Bil $)	NEMS	ns	0	6	N/A
		MARKAL	1	4	0	8
	Household Energy Expenditures Reduction ($/household/yr)	NEMS	ns	ns	ns	N/A
		MARKAL	1	3	1	2

1. "Reductions" and "savings" are calculated as the difference between results from the baseline case (i.e. no DOE technology) and the technology case (i.e. all DOE technology R&D programs are successful).
2. All cumulative metrics are based on results beginning in 2010.
3. Metric includes oil-derived fuel use by light-duty vehicles, commercial light trucks and freight trucks; the metric excludes buses. Reported oil use is adjusted to exclude ethanol, biodiesel and CTL.
4. All monetary metrics are in 2006$.
5. Cumulative monetary metrics are in 2006$ that are discounted to 2010 using a 3% discount rate.

ns - Not significant
NA - Not yet available
N/A - Not applicable

The following external factors could affect the program's ability to achieve its strategic goals:

- Cost and availability of conventional fossil energy sources;
- Federal and state farm policies and grower's actual adoption rate for new crops;
- Widespread adoption of sustainable crop management practices;
- Consumer acceptance;
- Cost of competing alternative energy technologies;

- Loan guarantee programs as authorized by EPAct 2005, the 2008 Farm Bill, and other future regulations potentially accelerating the adoption and positively impacting the deployment of biorefinery technologies; and
- The market penetration rate of bio-based technologies which is a function of all the external factors listed and technical breakthroughs, incentives; price trends of coal, oil and natural gas; and policy factors.

Contribution to the Secretary's Priorities

The Biomass Program contributes to several of the Secretary's priorities as enumerated below. The principal focus area is Priority 2, Clean Energy.

Priority 1: Science and Discovery – Invest in science to achieve transformational discoveries

The Biomass Program coordinates with the Office of Science, National Science Foundation, and academic institutions to ensure that the program's R&D work being conducted by National Laboratories, universities, and industry partners remains at the cutting edge of scientific innovation. Additionally, much of the program's R&D work already involves direct interaction between these three partner types.

The Biomass Program manages several small scale international projects involving R&D and analysis work, including partnerships with Brazil, China, and India, while also participating in the IPCC, working with Conservation International, and contributing to the IEA (Bioenergy Agreement participation and task sponsorship).

Priority 2: Clean Energy – Change the landscape of energy demand and supply

The Biomass Program demonstrates and deploys integrated biorefinery technologies with commercial partners, while also aggressively advancing feedstock production and biomass conversion R&D at the cutting edge of technology, working with the National Laboratories, universities, private sector partnerships, and other non-profit research organizations (e.g. Gas Technology Institute).

The Biomass Program coordinates its efforts with the DOE Office of Science in key technology areas such as developing transformational technologies to overcome biomass recalcitrance.

Priority 3: Economic Prosperity – Create millions of green jobs and increase competitiveness

The Biomass Program works to develop biofuels for transportation applications, and is involved in the testing of alternative fuel blends. The program also works with the Vehicle Technologies Program and external stakeholders to develop biofuels distribution and end-use infrastructure to create a market for biofuels.

The Biomass Program's commercial, demonstration and pilot scale projects involve private sector employment. The program's R&D work supports the growth of the domestic biofuels industry. It is estimated that each new commercial biorefinery creates 40 to 77 new jobs.[a] Emerging biofuels production, distribution, and end-use technology industries all promise new green employment opportunities.

Priority 5: Lower GHG Emissions – Position U.S. to lead on climate change policy, technology, and science

[a] Numbers are estimates provided in NREL's 2002 Design Report.

The Biomass Program leverages both domestic and international R&D partnerships to advance biofuels technology development, which is aimed at demonstrating viable biofuel pathways to support private sector deployment of biofuel technologies. Though the program's current focus is on domestic deployment of biofuel technologies, the program's domestic success has clear international implications, as do its partnerships with private and non-profit entities whose influence extends beyond the borders of the U.S.

The Biomass Program participates in the IPCC, and supports the IEA's Bioenergy Agreement, participating regularly in Tasks (such as Task 33, "Thermal Gasification of Biomass," and Task 39, "Commercializing 1st- and 2nd-Generation Liquid Biofuels from Biomass"). The program also participates in collaborative projects with partners in Brazil, China, Conservation International, the EU, India, and Israel.

Contribution to GPRA Unit Program Goal 1.1.06.00 (Biomass and Biorefinery Systems R&D)

The program directly supports the DOE's Energy Security theme by developing our Nation's biomass resource availability and conducting RD&D on technologies that increase the production of biomass-based substitutes for petroleum-derived fuels, chemicals, materials, and/or heat and power, and thereby diversifying and expanding our energy supply. It also addresses the goals and recommendations of the Farm Security and Rural Investment Act of 2002, Energy Policy Act of 2005, Energy Security and Independence Act of 2007, and Food, Conservation, and Energy Act of 2008.

To increase the probability of success, the program funds key technology pathways that contribute to the achievement of this goal. To realize this, intermediate programmatic cost-competitive ethanol target ranges have been established based on EIA oil price projections. Currently these cost range targets are $1.76 to 2.06 per gallon of ethanol by 2012, and $2.01 to 2.87 per gallon of ethanol by 2017 (both ranges in 2007$). The program's technology pathways and their respective contributions are described below.

Feedstock Infrastructure contributions:

- Reduced costs associated with feedstock production, collection, storage and transportation;
- Overcoming major feedstocks-related technical barriers impeding the growth of the biofuels industry; and
- Ensuring sound production strategies, both economically viable and environmentally sustainable, are developed and utilized.

Platforms Research and Development contributions:

- Biochemical Platform R&D will focus on reducing the cost of producing ethanol from biochemical routes. Work to overcome the recalcitrance of biomass, through research institutions and public-private partnerships, will continue to be a priority. The program will continue to make further improvements to feedstock interface, pretreatment and conditioning, enzymes and fermentation processes in addition to process integration in order to reduce intermediate sugar and ethanol production costs as the springboard to launching the next generation of biofuels technology from a wide range of feedstocks; and
- Thermochemical Platform R&D will focus on technologies for converting feedstocks and bioconversion process residues into cost competitive commodity fuels (e.g. ethanol, gasoline, diesel), as well as bioproducts and biopower. The program will continue to make further

improvements to feedstock interface, gasification and bio-oil processes with an emphasis on increased conversion and selectivity. In addition, process integration will continue to be improved in order reduce overall costs of the next generation of biofuels derived from a wide range of feedstocks.

Utilization of Platform Outputs R&D contributions:

- The Integration of Biorefinery Technologies Platform will continue to support companies with the intent of commercializing biorefineries for the production of transportation fuels as the main product, with co-products (such as materials and chemicals, heat and power) as authorized by Section 932 of EPAct 2005, and in support of EISA 2007 RFS. To this end, the program will continue to support commercial, demonstration, and pilot scale biorefinery projects in FY 2010. These projects are critical to validate technical and economic feasibility of their respective integrated biorefineries and will help attract private sector capital leading to their commercialization. Transportation fuels infrastructure activities will continue to include the conducting of testing of ethanol blends; and
- The Products Development Platform will complete funding five industry cost shared partnership projects for developing a commercially viable fermentative micro-organism (aka "ethanologen") at a cost sufficiently low to achieve the 2012 cost range target. These micro-organisms, capable of fermenting major sugars found in cellulosic biomass, will provide necessary technology to support advances in future integrated biorefineries. In addition, the program will continue to evaluate the potential of co-products to stabilize and reduce costs of fuel production within the biorefinery.

Means and Strategies

The Biomass Program will use various means and strategies to achieve its GPRA Unit program goals as described below. "Means" include operational processes, resources, information, and the development of technologies, and "strategies" include program, policy, management and legislative initiatives and approaches. Various external factors, as listed below, may impact the ability to achieve the program's goals.

The Biomass Program will implement the following means to improve the cost-competitiveness of biomass technologies:

- R&D through competitive solicitations for industrial partnerships with appropriate cost sharing to attract innovation and ensure investment value for industry and university contracts;
- Management of R&D by a series of objectives, milestones, and stage gate reviews, which are tracked by the Project Management Center and verified with reviews from industry and university experts;
- Commercial, demonstration, and pilot scale validation of integrated biorefineries through competitive solicitations to validate their economic and technical feasibility in order to facilitate commercialization; and
- Input from peer reviews.[a] Peer reviews of program plans and activities are aimed at obtaining expert, independent opinion on the program's goals and objectives; feasibility of reaching the goals;

[a] The most recent program peer review was held in November 2007; http://www.obpreview07.govtools.us/. The next program review is scheduled for July 2009; http://www.obpreview2009.govtools.us/.

appropriateness of technical barriers being addressed; appropriateness of the federal role, and, whether the level of Federal funding for projects is commensurate with technical objectives.

The Biomass Program will implement the following strategies:

- For each feedstock targeted, program research will develop handling and conversion technologies specific to feedstock properties and validate the technical performance and projected economics at industrial scale;
- The program will collaborate with the DOE Office of Science to further basic research related to Biochemical Platform R&D, such as overcoming the recalcitrance of certain biomass feedstocks. Additionally, the Biomass Program will collaborate with the DOE Office of Science to target and conduct research on the development of new organisms and techniques for most efficiently processing the variety of sugars found in biomass. This will consolidate several steps in bioprocessing, lead to a significant reduction in tanks and associated equipment currently needed to convert biomass feedstocks into ethanol, and ultimately result in a large reduction in overall biorefinery plant cost;
- The program will continue to support Regional Biomass Feedstock Development Partnerships, thus leveraging local resources through partnerships with agricultural producers, universities, and industry that understand regional opportunities and challenges. These Partnerships will fund research to validate new feedstocks tailored to industrial biorefineries. This will allow the availability of biomass-derived fuels and chemicals to continue to grow beyond the limitations of present commodity crop and forest resources;
- In addition to current collaborations with academia, the program will promote the use of universities' research capabilities in the areas of feedstock interface, biochemical and thermochemical conversion, environmental analysis, and infrastructure development strategies and technologies, while competitively allocating resources;
- The program will support R&D involving high-opportunity, high-impact technologies for converting cellulosic biomass feedstocks to liquid fuels. R&D will include developing process integration methodologies, identifying effective pretreatment catalysts effective on multiple biomass feedstocks, and targeting efficient enzymes. Moreover, as biorefinery plants mature, advanced thermochemical technologies (e.g., catalytic hydroprocessing) will be pursued to increase biofuels production and value; and
- The program will utilize guidance from the Biomass Technical Advisory Committee and the Biomass R&D Board authorized under the Food, Conservation and Energy Act of 2008 to integrate R&D across agencies.

Collaborations are integral to achieving the planned investments, means and strategies, and to addressing external factors. In carrying out its mission, the program performs the following collaborative activities:

- Partnership with DOE's Office of Science on feedstock development and consolidated bioprocessing (technology aimed at reducing the number of unit operations needed in a biorefinery);
- Collaboration on advanced conversion processes and techniques with the DOE Office of Science, which will help define the future of advanced biorefineries;

- Partnership with the DOE Vehicle Technologies and Fuel Cell Technologies Programs, Clean Cities, other Federal agencies, and other key stakeholder organizations to promote the use of biofuels in vehicles, evaluate the viability of ethanol blends, and address biofuels infrastructure barriers;
- Regional Biomass Feedstock Development Partnerships used to enhance the coordination of feedstock R&D efforts with USDA and the Sun Grant Initiative universities; regional information is needed by potential biorefiners in order to assess and improve resource availability and feedstock economics;
- Collaboration with other federal agencies (such as EPA, NSF, and USDA) and non-profit organizations to promote environmentally sustainable biofuel production pathways;
- Interagency Working Groups (IWGs) chartered at the direction of the Biomass R&D Board to improve coordination and technology development within the Biomass Program and Office of Science; and externally with the various agencies of USDA, EPA, DOT, DOI, DOC, Treasury, DOD, NSF, OSTP, and Office of Federal Environmental Executive. These IWGs have been formed for feedstock production, and logistics; sustainability; infrastructure; conversion technologies; and environment, health, and safety;
- An annual USDA-DOE solicitation for biomass technologies R&D and other coordination under the Food, Conservation and Energy Act of 2008; and
- Partnerships with existing biorefineries (e.g., corn-ethanol and pulp and paper mills) to integrate advanced technologies for producing biofuels from lignocellulosic feedstock, for near-term cost effectiveness and environmental sustainability benefits.

Validation and Verification

To validate and verify program performance, the Biomass Program will conduct internal and external reviews and audits. For example, during program peer reviews the programmatic activities are reviewed by experts from universities, state agencies, industry, and the USDA. The sections below summarize validation and verification activities.

Data Sources: The Renewable Fuels Association's production statistics; the National Renewable Energy Laboratory's Renewable Electric Plant Information System (REPIS); the Energy Information Administration's (EIA) Annual Energy Review, Renewable Energy Annual and Annual Energy Outlook; the Gas Technology Institute Survey of Distributed Resources; EIA Form 860 data analyzed by the Resource Dynamics Corporation. Individual projects develop production cost and quantity estimates for sugar, syngas, ethanol, and other fuels and chemicals (these are reviewed and monitored by managers).

Baselines: The following are the key baselines used in the Biomass Program:

- In 2007, the total feedstock baseline delivered cost (which includes collection, preprocessing, grower payment, and delivery to a conversion facility inlet, in 2007$) was $69.60 per dry ton for dry herbaceous (equates to approximately $0.97 per gallon of ethanol). A more vigorous analysis is underway for woody feedstocks; however, a 2007 baseline of $67.55 per dry ton for woody feedstocks (equates to approximately $1.58 per gallon of ethanol, in 2007$) is currently being used. In 2012, the Biomass Program currently anticipates a dry herbaceous feedstock cost of $50.90 per dry ton

(equates to approximately $0.57 per gallon of ethanol, in 2007$) and woody feedstock cost of $50.70 per dry ton (equates to approximately $0.71 per gallon of ethanol, in 2007$), based on the operative 2007 baselines described above.

- In 2005, Thermochemical R&D baseline mature conversion costs for woody feedstocks to ethanol via a gasification route was $1.89 per gallon (2007$) based on bench scale data (see figure in the subsequent Platforms R&D "Funding Schedule by Activity" "Benefits" section).
- In 2005, Biochemical R&D baseline mature conversion costs for dry corn stover to ethanol was $1.79 per gallon (2007$) based on bench scale data (figure below in the subsequent Platforms R&D "Funding Schedule by Activity" "Benefits" section).

Platform R&D projects utilize an analysis model to generate "nth plant" cost and performance data for an integrated biorefinery based on generic NREL designs. The biorefinery projects funded under Integration of Biorefinery Technologies will be validating each project's specific and proprietary economic and technical performance. As these integrated biorefinery projects are based on different designs (feedstocks, conversion technologies, etc.), they will not likely validate or match up to the "nth plant" modeled cost based on the NREL designs, nor will it be possible to disseminate the specific economic and technical performance data due to proprietary restrictions. Therefore, the program will use an aggregate performance metric for the pilot, demonstration, and commercial scale biorefineries as these facilities become operational in order to protect each project's proprietary data.

Evaluation: In carrying out the program's mission, the Biomass Program uses several forms of evaluation to assess progress and to promote program improvement.

- Stage gate review, technology validation and operational field measurement, as appropriate;
- Peer review by independent outside experts of both the program and subprogram portfolios;
- Specialized program evaluation studies to examine process, impacts, or market baseline and effects, as appropriate;
- Quarterly and annual assessment of program and management results based performance through Joule (the DOE quarterly performance progress review of budget targets);
- Annual review of methods, and updated analysis of potential benefits for the Government Performance and Results Act (GPRA); and
- Technical Advisory Committee feedback.

The National Laboratories receive direct funds for technology R&D, based on their capabilities and performance. Advisory panels consisting of non-Federal and industry experts review each laboratory and industry project at scheduled

stage gate reviews and peer evaluation of R&D. Projects are evaluated based on the following criteria: 1) Relevance to overall DOE objectives; 2) Approach to performing the research and development; 3) Technical accomplishments and progress toward project and DOE goals; 4) Technology transfer/collaborations with industry/universities/laboratories; and 5) Approach and relevance of proposed future research. The panels also evaluate the strengths and weaknesses of each project, and recommend additions to or deletions from the scope of work. The program organization facilitates relationships to ensure that Federal R&D results are transferred to industry.

Frequency: Potential benefits are estimated annually. Independent evaluation of R&D projects are performed according to schedule per the stage gate process for moving each project through an independent review "gate", from a less costly stage (such as preliminary paper studies) to a more costly stage (such as bench-scale experiments). Program peer reviews are conducted biennially.

Data Storage: EERE Benefits website, the EERE Corporate Planning System, and other computer-based data systems.

Verification: DOE technology managers verify the achievement of targets through project reviews, including reviews of cost and performance modeling results. Project leaders in the field must provide to the technology managers documentation of experimental and/or analytic results as evidence of success. The evidence is listed in material supporting the DOE Joule performance tracking system. Various trade associations review the data and the modeling processes (e.g., REPIS renewable), and the EIA verifies the REPIS database. Peer reviews are conducted by independent personnel from industry, academia and governmental agencies other than DOE.

Annual Performance Results and Targets

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets	FY 2010 Targets
GPRA Unit Program Goal 1.1.06.00 (Biomass and Biorefinery Systems R&D)					
Feedstock Infrastructure					
		Complete a core R&D engineering design and techno-economic assessment of an integrated wet storage - biomass field pre-processing assembly system with a pretreatment process that could potentially be scaled up to produce feedstocks to achieve a reduction to $35 per ton by 2012 from $53 per ton as of 2003. This is based on the original baseline and cost reduction targets specific to corn stover. [MET]	Conduct replicated field trials across regions to determine the impact of residue removal on grain yield (in subsequent years); field trials (including genetic evaluations) to develop energy crops within a geographical region; resource assessments to determine regional feedstock supply curves (variable costs of feedstock across various sites); and economic studies that identify the best site conditions and general locations for biorefineries within a region, all of which can demonstrably contribute to the goal of producing feedstocks at $32 per dry ton by 2012.[a] [MET]	Initiate a GIS-based regional feedstock atlas system incorporating USDA agricultural datasets, energy crop field test results, residue removal trial results, DOE and USDA funded biorefinery project results, and other assessments from public and private sources to provide the best biomass resource database, models, and tools available for a wide variety of users including Federal and State Governments, biorefinery developers, growers, and researchers. These efforts will enable evaluation of potential future feedstock supply in support of the goal of producing feedstocks at $47 per dry ton by 2012.[b]	Achieve a modeled dry herbaceous feedstock logistics cost of $37.80 per dry ton (excluding grower payment, in 2007$). Using Regional Feedstock Partnership trials and analysis efforts, determine feedstock types and regions in which nutrient use efficiency (tons of feedstock per pound of nutrients applied) and soil organic matter can be increased by at least 5%. This data will be input into designing integrated biomass production systems that incorporate positive services to the environment.
Platforms Research and Development					
Completed a technical and economic evaluation of integrated biomass to fuels systems to validate the sugar cost of $0.135 per pound and syngas cost of $6.13 per million Btu. [MET]	Complete laboratory and economic assessment of 2 different feedstocks, identifying operating conditions that link pretreatment with enzymes that could be scaled-up and have the potential of achieving the goal of $0.125 per pound sugar by	Complete integrated tests of pretreatment and enzymatic hydrolysis in conjunction with existing fermentation organisms at bench-scale on com stover that validate $0.125 per pound sugars on the pathway to achieving $0.064 per pound in 2012.	Achieve a modeled cost of a mixed, dilute sugar stream suitable for fermentation to ethanol of $0.13 per pound of sugars (equivalent to $2.39 per gallon of cellulosic ethanol) through the formulation of improved	Demonstrate alternative pretreatment technologies at bench-scale using advanced cellulase enzymes and integrated technologies that have the potential of achieving $0.12 per pound of sugars on the pathway to $0. 073 per	Achieve reduction of the modeled ethanol conversion cost to $1.33/gallon through improvements in pretreatment and hydrolysis; this is in support of achieving the $0.92 conversion cost necessary to achieve the ethanol production cost within the estimated cost

[a] The program has updated all technical targets based on improved data and modeling and updating to 2007 dollars. Previous 2012 feedstock target was stated as $35 per dry ton by 2012.

[b] This Joule was updated to reflect an improved, more inclusive measurement (includes all costs to the "reactor throat") and based on newer cost information and accounting for market dynamics. Thus, the apparent increase in cost associated with the update is misleading, as the metric is different and cannot be directly compared.

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets	FY 2010 Targets
	2007. [MET]	[MET]	enzyme mixtures and pretreatments (in $2007). The cost of the sugar stream ties directly to the price of ethanol, a substitute for gasoline and key output of a biorefinery. Reduction in the cost of sugars can lead to commercialization of biorefineries that produce fuels (such as ethanol), chemicals, heat, and power from biomass. [MET]	pound by 2012 (in $2007). Reduced sugar costs will reduce cellulosic ethanol costs, leading to increased adoption of ethanol and reduced consumption of petroleum.	competitive range of $1.76-2.06/gallon by 2012 (in 2007$).[a]
		Demonstrate conversion of 50 percent of non-methane (C2+ higher) hydrocarbons that result in a syngas cost of $7.15/MBtu in 2007. [MET]	Achieve a modeled cost of a cleaned and reformed biomass-derived synthesis gas or oils of $6.88/MBtu by demonstrating pilot-scale technology capable of economically converting biomass residues, pulping liquors, or waste fats and greases. Reduction in the cost of syngas can lead to commercialization of biorefineries that produce fuels, chemicals, heat, and power from biomass. [MET]	Achieve a modeled ethanol price of $1.97/gal for thermochemical gasification followed by mixed alcohol synthesis and ethanol separation. This will be achieved by demonstrating pilot-scale technology capable of economically converting biomass feedstocks, and will be based on a feedstock cost of $60/dry ton (calculated in 2007 dollars).[b]	Through improved tar reforming catalysts, achieve a modeled ethanol price of $1.90/gal (2007$ feedstock cost $54.20/ton) for thermochemical gasification followed by mixed alcohol synthesis and ethanol separation.

[a] This Joule target has been updated to standardize our conversion R&D Joules, and as the modeled ethanol price has been determined to be a metric more accessible and meaningful to those outside our agency, even though sugar intermediate costs remain a valuable metric still used to internally measure progress.
[b] This Joule target has been updated, as the modeled ethanol price has been determined to be a more useful metric, and newer multiple pass syngas systems make the older measurement less accurate than a modeled price. It is also noted that this modeled price must necessarily be based on a fixed feedstock price for comparison across market periods due to market dynamism.

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets	FY 2010 Targets
Utilization of Platform Outputs R&D					
		Complete a preliminary engineering design package, market analysis, and financial projection for at least one industrial-scale project for near term agricultural pathways (corn wet mill, corn dry mill, oilseed) to produce a minimum of 15 million gallons of biofuels per year (as mandated by the Energy Policy Act. [MET]	Approve a final engineering design package of at least one commercial scale biorefinery capable of processing up to 700 metric tones per day of lignocellulosic feedstocks. The approved design package must address any findings from an independent engineering review to validate contractor costs and scheduled timeline. Validation of biorefinery concepts will reduce technological risk and attract additional sources of capital to accelerate deployment and oil displacement. [MET]	Initiate construction of at least one commercial-scale biorefinery project (designed to 700 ton per day feedstock processed) including orders for long lead items, vendor packages, and structural steel. Validation of biorefinery concepts will reduce technological risk and attract additional sources of capital to accelerate deployment and oil displacement.	Initiate construction of two additional commercial-scale biorefinery projects selected in FY 2007 (three in total).
				Approve engineering design of one additional commercial scale biorefineries (two in total) including orders for long lead items, vendor packages, and structural steel. The result of this will ultimately be to complete construction by 2011. Approve preliminary engineering design package, market analysis and financial projections for at least four demonstration scale biorefineries (designed to 70 ton per day feedstock) selected in FY 2008. These efforts work toward validating the programmatic $2.01-2.87 per gallon estimated cost competitive target range in integrated biorefineries by 2017 (in 2007$).	Complete sufficient engineering design to allow initiating construction (after financial and other requirements, i.e. NEPA, are met) for two demonstration projects selected in FY 2008. Complete at least one trial run of an innovative integrated biorefinery process to demonstrate the integrated operation of processing biomass into a biofuel. This will support validating the programmatic $2.01-2.87 per gallon estimated cost competitive target range in integrated biorefineries by 2017 (in 2007$).
Established the technical and market potential of a new bio based product. [MET]	Identify at least one sugar-derived or biomass oil-derived bio-based chemical or material (among those being evaluated) that possesses sufficient				

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets	FY 2010 Targets
	potential to enter into the scaled-up developmental phase of R&D from the previous bench-scale phase. [MET]				
Contributed proportionately to EERE's corporate goal of reducing corporate and program adjusted uncosted obligated balances to a range of 20-25 percent by reducing program annual adjusted uncosteds by 10 percent in 2005 relative to the Biomass & Biomass Refinery Systems Program FY 2004 end of year adjusted uncosted baseline ($62,235K) until the target range is met. [MET]	Maintain total administrative overhead costs (defined as program direction and program support excluding earmarks) in relation to total program costs of less than 12 percent. [MET]	Maintain total administrative overhead costs (defined as program direction and program support excluding earmarks) in relation to total program costs of less than 12 percent. [MET]	Maintain administrative costs as a percent of total program costs less than 12 percent [MET]	Maintain administrative costs as a percent of total program costs less than 12 percent. [Baseline and targets under development.]	Maintain total administrative overhead costs in relation to total program costs of less than 12 percent[a].

[a] Administrative costs are comprised of Program Direction and elements of Program Support (Technology Advancement and Outreach; and Planning, Analysis and Evaluation), baseline and targets under development.

Feedstock Infrastructure

Funding Schedule by Activity

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Feedstock Infrastructure	12,144	15,092	26,776
SBIR/STTR	—[a]	408	724
Total, Feedstock Infrastructure	12, 144	15,500	27,500

Description

Feedstock Infrastructure Platform activities are critically important to increasing the availability and accessibility of domestic biomass resources and improving the infrastructure technologies needed to reliably supply lignocellulosic feedstocks to future large-scale biorefineries at reasonable costs. Investments in resource availability and feedstock infrastructure development are needed to ensure a stable feedstock supply critical to the economic viability of a domestic biofuels industry. An increased and reliable domestic supply of environmentally sustainable biomass feedstocks is needed for an expanded bioenergy industry. Considered inseparable from traditional economic cost measures of delivering feedstocks competitively, a greater emphasis is now being placed on the context of sustainability, which encompasses environmental criteria and societal values. The Feedstock Infrastructure Platform's overarching strategic goal is to develop technologies to provide reliable, cost-competitive, and environmentally sustainable biomass feedstock supplies for the U.S. biofuels industry in partnership with USDA and other key stakeholders from all sectors. Three main areas of focus within the platform address this overarching strategic goal: feedstock production, feedstock logistics, and environmental sustainability.

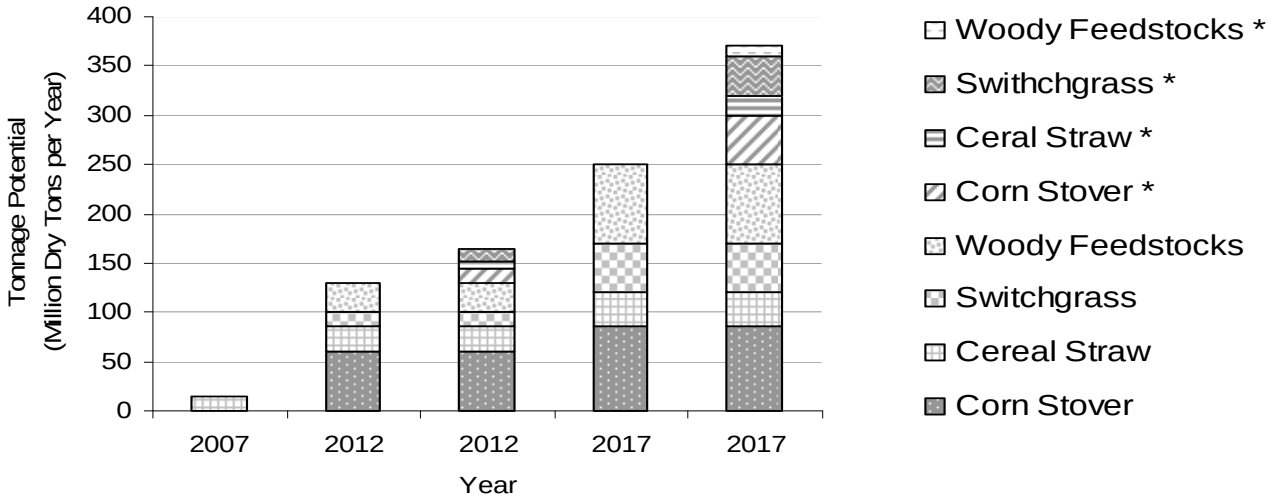
Benefits

To increase feedstock production, the major focus is on support of Regional Feedstock Partnership activities, involving regional stakeholder collaboration and research efforts aimed at collectively achieving an overall volumetric goal of 1.3 billion dry tons of biomass. Additionally, a series of replicated, regionally focused cellulosic feedstock crop trials will be conducted in potential crop growing regions of the U.S. These trials will be monitored for yield, major limiting factors, and carbon management. Results of these Regional Biomass Feedstock Development Partnership trials will be incorporated into a GIS-based regional feedstock decision support tool incorporating best-available data from Federal agencies including DOE and USDA biorefinery project results and other assessments from public and private sources. This process will provide the best information to users, which will include Federal and state government, biorefinery developers, growers, and researchers.

In the near term, the feedstock production goal is to validate that a sufficient, high quality, accessible feedstock supply of 130 million dry tons per year would be available in 2012, growing to 250 million dry tons per year in 2017. This goal is necessary to spatially quantify the accessible resources and

[a] SBIR/STTR funding was transferred to the Science appropriation in FY 2008.

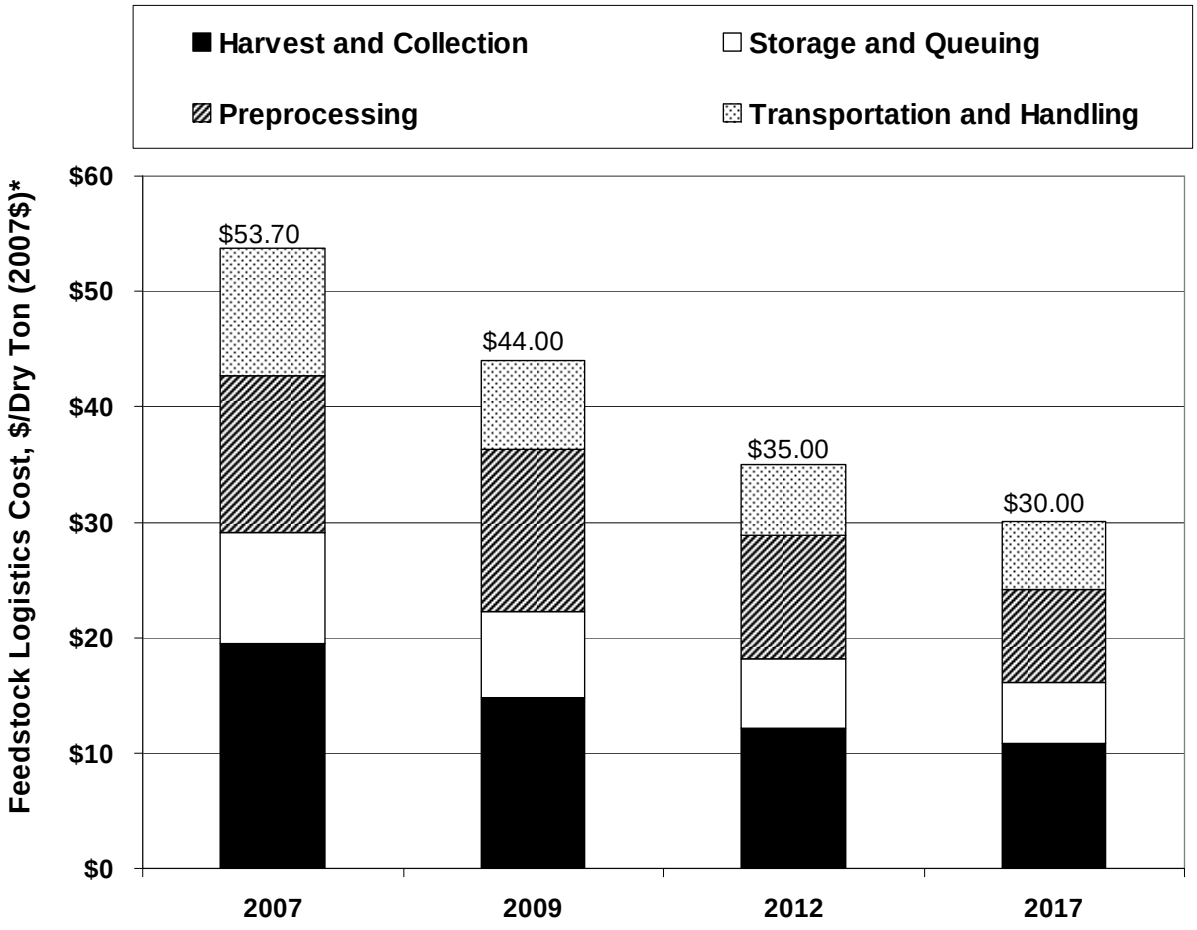
validate the percentage of resources that could be recovered cost effectively. A new effort is also being established to explore the viability of algae as a biofuels feedstock.



Totals assume the following minimum grower payments: for 2007, $15.90/ton; for 2012, $15.90/ton; for 2017, $26.20/ton.
* Shows additional feedstock available through agronomic and environmental improvements or new crop

Industry partnerships are used to improve feedstock logistics to enhance the economic viability of the domestic biofuels. These collaborative efforts involve improvements in existing or the development of new feedstock handling and storage technologies and proving their success through demonstrative trials. The near-term feedstock logistics goal is to reduce feedstock logistics costs, including harvesting, storage, preprocessing and transportation, to $0.39 per gallon of ethanol in 2012 (or approximately $35.00 per dry ton, in $2007 and excluding payment to the grower). In order to reach this goal, biomass feedstock density needs to be increased to 16 lbs per cubic foot. Providing a denser feedstock will have positive cost ramifications throughout the feedstock supply chain. Indicators of progress toward this goal include cost shared industrial partnerships for developing feedstock logistics systems.

Feedstock Logistics Cost Projections



*Excludes grower payment

Year	2007	2009	2012	2017
Total, Feedstocks Logisitics, $/Dry Ton	**$53.70**	**$44.00**	**$35.00**	**$30.00**
Harvest and Collection	$19.45	$14.81	$12.15	$10.81
Storage and Queuing	$9.64	$7.44	$5.95	$5.29
Preprocessing	$13.54	$14.05	$10.74	$8.03
Transportation and Handling	$11.07	$7.70	$6.16	$5.87

Environmentally-sound designs for integrated dedicated energy cropping systems will also be developed. Currently, there is insufficient information about the potential for well-designed biofuel cropping systems to minimize negative environmental impacts of increased feedstock production while still achieving mandated volumetric targets. This is especially true as it relates to carbon, nutrient, and water fluxes. Dedicated energy cropping systems will measure fluxes of water, nitrogen, phosphorous, and carbon. When coupled with the research-scale energy cropping systems developed through the Regional Biomass Feedstock Development Partnership program, researchers at the National Laboratories can develop new models to predict how agricultural landscapes can deliver optimum environmental benefits. This work will help identify conservation practices that can be widely

implemented on biofuel production landscapes and can be easily verified by field experiments from future solicitations. Models will also lead to a complete accounting of various biofuel options that include technology, economics, net energy, and environment.

The Feedstock Infrastructure Platform is an integral part of the Biomass Program's partnered strategic pathway of advancing biomass technologies from basic science to applied research and demonstration, through utilizing a market interdependent approach that incorporates linkages and feedback among each step in order to accelerate the benefits of technology development

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Feedstock Infrastructure	**12,144**	**15,092**	**26,776**

There are three main areas included in Feedstock Infrastructure:

1) Feedstock Production; 2) Feedstock Logistics; and 3) Sustainability.

Feedstock Production addresses resource assessment, yield improvement, sustainable feedstock systems development, and biomass quality. One major component of this effort is the continuation of existing feedstock production trials with the Regional Biomass Feedstock Development Partnerships (now in the third feedstock growing year of the 6-year study). These replicated field trials are organized by species (energycane, miscanthus, switchgrass, and sorghum) to realize the resource potential of biomass feedstocks for advanced biofuels production on a regional basis. In further efforts, corn stover removal field testing will validate and enhance a tool developed by USDA/Agricultural Research Service and Idaho National Laboratory (INL) to measure the sustainability of corn stover removal from the field. Results of these various trials are one of the inputs into a national GIS assessment tool, which can be used for visualization of scenarios of future biofuels development.

Section 228 of EISA 2007 requires DOE to report the potential of microalgae as a feedstock for biofuels. The report concluded that microalgae are a potentially viable feedstock in the long-term, though algal biofuel technologies are still in relatively early stages of development. The Biomass Program sponsored an algal biofuels workshop, in December 2008, which produced a roadmap that included barriers for algae production. The feedstock production component of microalgae development will be incorporated into other algae efforts within the program.

In partnership with industry, Feedstock Logistics R&D addresses barriers associated with accessing and delivering the feedstock supply to an integrated biorefinery. Unit operations for Feedstock Logistics include harvesting, collection, preprocessing, storage, queuing, handling, and transport for all major feedstock categories of cellulosic biomass (e.g., wet, dry and woody). The Feedstock Infrastructure Platform's efforts have expanded from laboratory design work into industrial partnerships. In collaboration with the Integrated Biorefinery Platform, a deployable process demonstration unit housed at INL will develop feedstock logistics systems for different industrial partners on a cost-shared basis.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

The Environmental Sustainability focus area will address potential environmental barriers related to supplying feedstock for the full-scale development of a significant national biofuels industry, as identified by an Interagency Sustainability Task Force. Dedicated energy cropping systems will address a range of criteria necessary to ensure the environmental sustainability of commercial-scale feedstock production and logistics systems (such as fluxes of water, nitrogen, phosphorous, and carbon). When coupled with smaller Regional Biomass Feedstock Development Partnership field research trials, this work will enable the development of decision support tools that, when fully utilized, will advance the adoption of sustainable cropping practices.

SBIR/STTR	**—**	**408**	**724**

In FY 2008, $268,000 and $32,000 were transferred to the SBIR and STTR programs respectively. The FY 2009 and 2010 amounts shown are estimated requirements for the continuation of the SBIR and STTR program.

Total, Feedstock Infrastructure	**12,144**	**15,500**	**27,500**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Feedstock Infrastructure	
Increased funding will support the expansion of projects to address potential environmental sustainability barriers that, if ignored, could constrain the development of a national biofuels industry. Smaller existing field trials will be supplemented by projects encompassing a greater diversity of crops and growing locations than is currently part of the Feedstock Infrastructure program of work. Dedicated energy cropping trials will allow for the measurement of the effects on key environmental criteria including carbon, water, and nutrient fluxes to establish best practices for future feedstock development efforts. In collaboration with the integrated biorefinery platform, a deployable process demonstration unit housed at INL will develop feedstock logistics systems for different industrial partners on a cost-shared basis.	
A limited new effort will also be initiated for algae feedstock development.	**+11,684**
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities.	**+316**
Total Funding Change, Feedstock Infrastructure	**+12,000**

Platforms Research and Development

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Platforms Research and Development			
Thermochemical Platform R&D	26,413	19,863	27,263
Biochemical Platform R&D	39,431	32,131	30,866
SBIR/STTR	—[a]	1,406	1,571
Total, Platforms Research and Development	65,844	53,400	59,700

Description

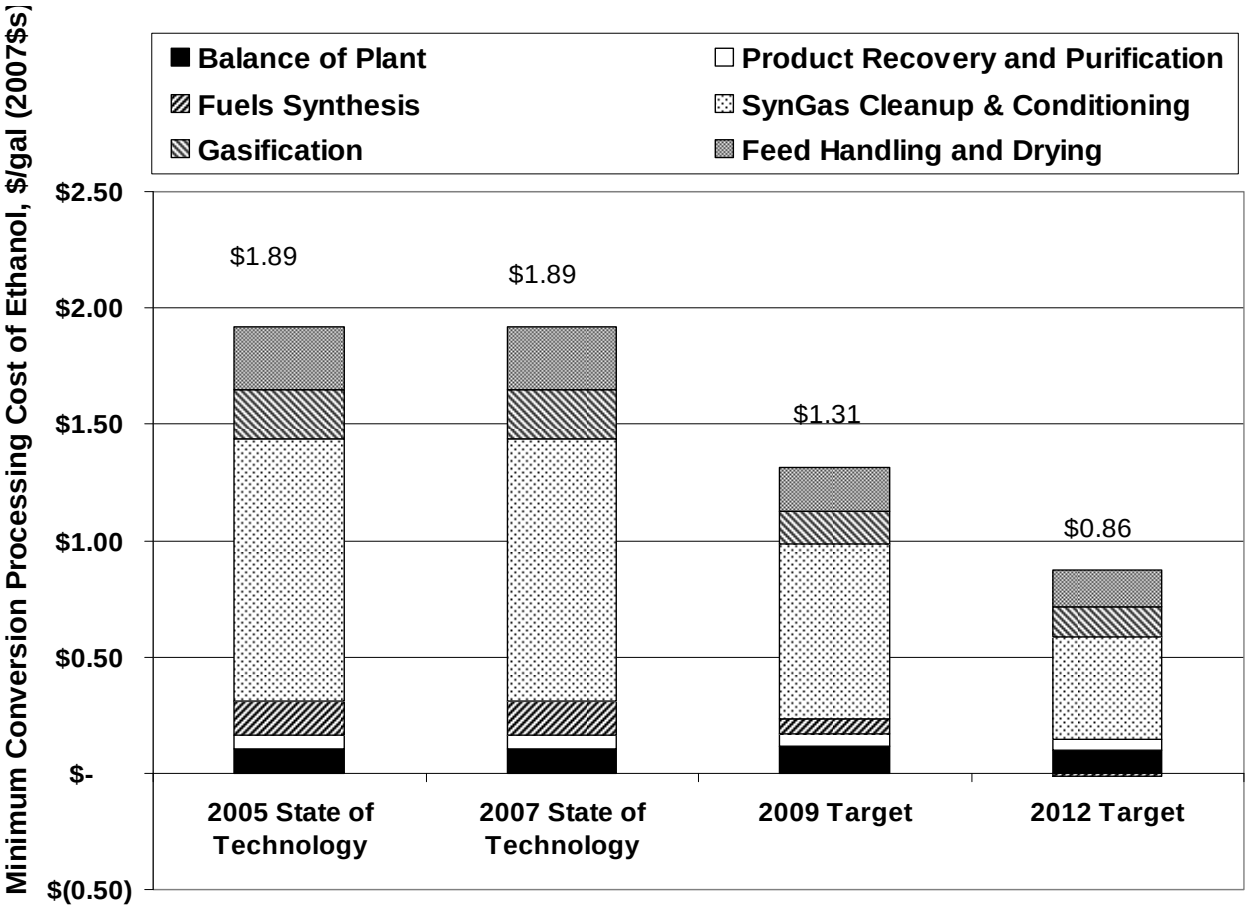
The Platforms Research and Development subprogram supports the advancement of technologies developed within the Thermochemical and Biochemical Platforms for converting feedstocks and intermediates into quality, cost-competitive liquid transportation fuels, materials, and other chemicals. Activities performed in the Products Development interface with Thermochemical and Biochemical Platforms and assist meeting the Platforms' cost competitive conversion goals. The Thermochemical Platform R&D focuses on reducing the costs associated with producing liquid transportation biofuels from gasification and pyrolysis technologies, which includes R&D in feedstock interface, thermochemical processing, intermediate cleanup and conditioning, and upgrading for fuel synsthesis. Biochemical Platform R&D will focus on further improvements to feedstock interface (pre-processing), pretreatment, enzymatic and chemical hydrolysis, and process integration. These integrated steps are required to reduce sugar costs and enable economically viable cellulosic ethanol production by biorefineries. This includes awarding payments to projects associated with solicitations initiated in FY 2007 and 2008. For the Thermochemical Platform, this work involves synthesis gas cleanup and subsequent synthesis gas conversion to fuel products, as well as technology development and pyrolysis oil stabilization and upgrading. For the Biochemical Platform, this work involves the development of improved cellulases with increased activities.

Benefits

The R&D work conducted by Platforms Research and Development will result in the development of technologies capable of converting biomass feedstocks into biofuels. The technical projections of the two R&D platforms comprising the Platforms Research and Development subprogram align their progress with the achievement of modeled ethanol costs within the overall Biomass Program target ranges of $1.76 to $2.06 per gallon of cellulosic ethanol in 2012, and $2.01 to $2.87 per gallon in 2017 (all in $2007). The two sets of charts and tables below contain the Biomass Program's current conversion cost projections.

[a] SBIR/STTR funding was transferred to the Science appropriation in FY 2008.

Thermochemical Conversion to Ethanol

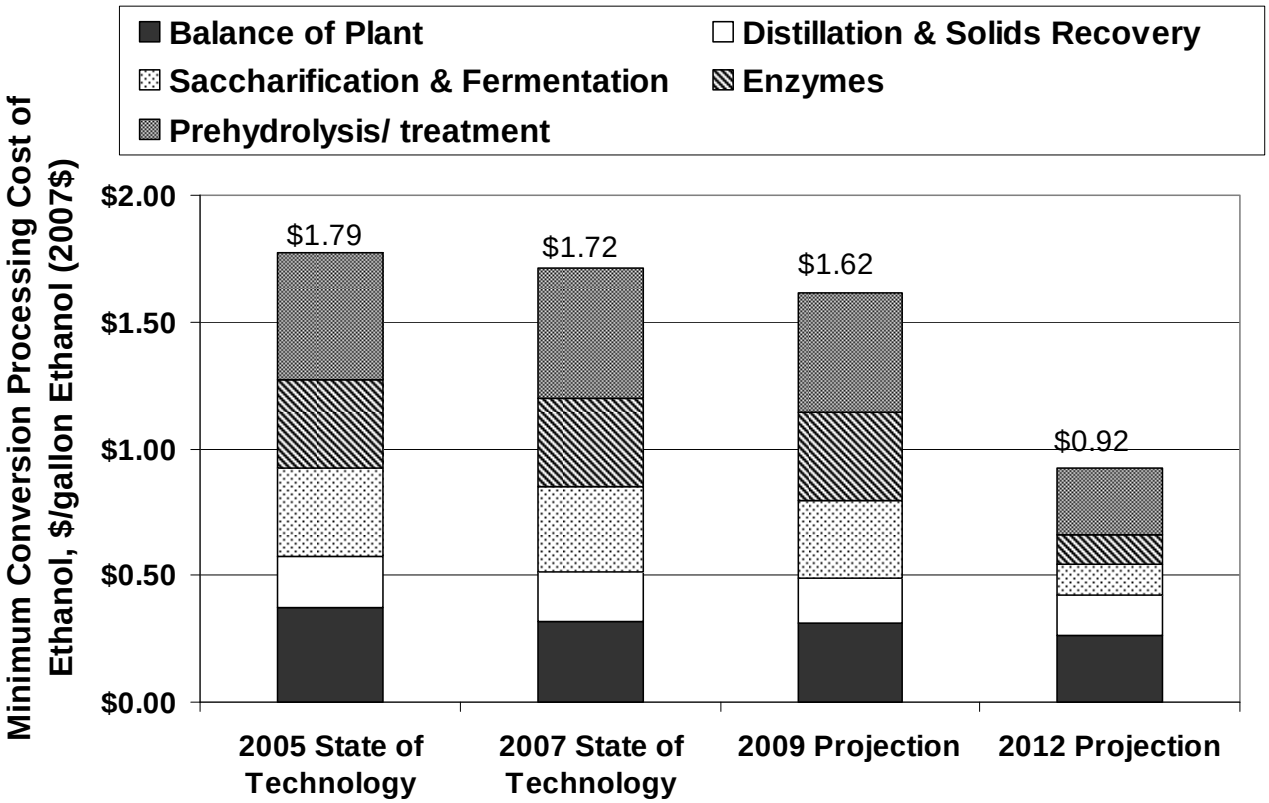


	2005 State of Technology[a]	2007 State of Technology	2009 Projection	2012 Projection
Processing Total	**$ 1.89**	**$ 1.89**	**$ 1.31**	**$ 0.86**
Balance of Plant	$ 0.11	$ 0.11	$ 0.12	$ 0.10
Product Recovery and Purification	$ 0.06	$ 0.06	$ 0.05	$ 0.05
Fuels Synthesis	$ 0.15	$ 0.15	$ 0.07	$ (0.01[b])
SynGas Cleanup & Conditioning	$ 1.13	$ 1.13	$ 0.75	$ 0.44
Gasification	$ 0.21	$ 0.21	$ 0.15	$ 0.13
Feed Handling and Drying	$ 0.27	$ 0.27	$ 0.19	$ 0.16

[a] Note: the numbers in the column below don't exactly add up to this value due to rounding in Microsoft Excel™. When the proper calculations were performed without rounding individual values, this number resulted; it is considered the most technically accurate.

[b] A credit for a mixed alcohols coproduct is factored into the calculation, so in this particular instance, costs are reduced enough that the credit for the coproduct is larger than the rest of the costs; a negative cost is shown here to reflect this.

Biochemical Conversion to Ethanol



	2005 State of Technology	2007 State of Technology	2009 Projection	2012 Projection
Processing Total	**$1.79**	**$1.72[a]**	**$1.62**	**$0.92**
Prehydrolysis/ treatment	$0.50	$0.51	$0.47	$0.26
Enzymes	$0.35	$0.35	$0.35	$0.12
Saccharification & Fermentation	$0.35	$0.34	$0.31	$0.12
Distillation & Solids Recovery	$0.21	$0.19	$0.18	$0.16
Balance of Plant	$0.37	$0.32	$0.31	$0.26

The Platforms Research and Development subprogram is an integral part of the Biomass Program's partnered strategic pathway of science to research to technologies to market interdependent approach using linkages and feedback to accelerate the benefits of technology development and adoption.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Thermochemical Platform R&D	**26,413**	**19,863**	**27,263**

Robust and cost-effective biomass thermal/catalytic conversion processes that can convert a variety of biomass materials to suitable clean intermediates (e.g. syngas and bio-oils) for subsequent conversion to fuels are under development. The Thermochemical Platform works to reduce costs of converting biomass and its intermediaries to fuels, chemicals and power via gasification, pyrolysis, and catalytic hydrotreating and hydrocracking processing technologies. Intermediate products include clean synthesis gas, or syngas, (a mixture of primarily hydrogen and carbon monoxide), bio-oil (a liquid product from pyrolysis or liquefaction), and gases rich in methane or hydrogen. These intermediate products can be upgraded to products such as ethanol, other alcohols, gasoline, diesel, jet fuel, ethers, synthetic natural gas, or high-purity hydrogen, or may be used directly for heat and power generation. Core research addresses key technical barriers such as the need for higher yields and selectivity of the intermediates and end products. Due to subsequent catalytic conversion of syngas to ethanol, there is also a need for purification of the syngas and more robust ethanol production catalysts. A critical barrier for bio-oil is the need to stabilize bio-oil from unwanted side reactions and upgrading to a form that is more amenable to hydrotreating and hydrocracking catalysts.

FY 2010 activities include the continuation of validation of technology capable of economically converting biomass feedstocks, biomass residues, forest residues and other woody resources to synthesis gas or bio-oils that are suitable for fuels and chemicals production. The target for gasification and subsequent ethanol production is a modeled conversion cost of $1.10/gallon of ethanol ($2007, feedstock cost of $54.20/dry ton). This conversion cost is associated with a modeled ethanol selling price of $1.90/gallon in 2010 ($2007, feedstock cost $54.20/dry ton). The data for completing this modeling target will be produced via both National Laboratory and competitively selected projects. The competitively selected projects will involve developing syngas to liquid fuels technologies (initiated in FY 2007, and slated to be completed in 2010) and pyrolysis oil to liquid fuel conversion technologies (initiated in FY 2008, and planned to be completed in 2011). The objective will also be supported by expanding three key research areas to gain a better understanding of the fundamental sciences involved. Gasification fundamentals will include understanding the mechanisms involved in tar reforming, syngas “cleaning”, and fuel synthesis particularly for infrastructure compatible fuels. Pyrolysis fundamentals will support efforts to improve bio-oil quality (reduction of total acid number, oxygen content, and residual char fines content) and bio-oil upgrading to gasoline and diesel blends. Catalyst fundamentals will include examining the chemical and physical mechanisms involved in syngas and bio-oil catalysis, as well as developing catalysts to improve stability, selectivity and activity for fuel intermediate and fuel production. A fundamental understanding of the factors controlling thermochemical conversion is needed to be able to develop new or improved technologies that increase the efficiency and/or reduce the cost. As feedstock prices increase due to supply and demand, decreased conversion costs will allow the industry to utilize higher priced feedstocks.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

Work will be done in collaboration with competitively selected industrial partners. In addition, these funds may be used to support efforts such as peer reviews data collection and dissemination and technical, market, economic, and other analyses.

Biochemical Platform R&D	**39,431**	**32,131**	**30,866**

Biochemical Platform R&D focuses on reducing the cost of converting lignocellulosic biomass to mixed, dilute sugars, and further conversion to liquid fuels, like ethanol, to advance technologies needed for successful integrated biorefineries and support the realizing a modeled ethanol cost within the estimated 2012 cost-competitive target range of $1.76 to 2.06 per gallon.

In FY 2010, the Biochemical Platform will continue efforts toward reducing cellulosic biofuel costs by focusing on barriers related to feedstock interface, pretreatment and conditioning, and hydrolysis and fermentation processes (in addition to process integration). The development of these technologies will enable the conversion of a wider range of feedstocks and launch the production of the next generation of cellulosic biofuels. In addition, much of this work will benefit biofuels targeted for development in FY 2010 and beyond, including cellulosic ethanol.

Specific objectives include improved pretreatment, chemical and enzymatic methods to achieve 85 percent of xylan to xylose conversion. Current efforts toward achieving this 2010 target are described below.

Establishing the value of and requirements for feedstock assembly processes to feed bioconversion processes is important in the development of biorefineries. Activities will include developing cost and quality specifications for feedstock assembly technologies that are compatible with biochemical conversion technologies. The key technical objective is improved feedstock yield potential through targeted logistics operations between the field or forest and the biorefinery, in addition to the integration of the feedstock supply with conversion processes. While these activities will focus on the current portfolio of feedstocks, the results will inform future activities as we consider additional feedstocks (e.g. energy crops, other agricultural residues, algal biomass).

Activities will also include continuing support of public-private partnered projects from the 2007 Biochemical solicitation to support the development of commercially-viable enzymes – a key component in the production of biofuels, including cellulosic ethanol. Key objectives for these projects include increasing enzyme productivities and decreasing overall enzyme costs. These efforts will increase sugar yields, which translate into increased yields of fuels. All potential enzymes, such as cellulases and hemicellulases, will be of interest in this effort.

Integration of biomass pretreatment, saccharification and fermentation steps is needed to improve overall efficiency and reduce conversion cost. Thus, initial results from the enzyme development work started in FY 2008 will be combined with the ethanologen development work begun in FY 2007 under the Products Development Platform activity. This integration of technologies will occur at the integrated biorefinery pilot scale facility at NREL and in pilot plant operations conducted with other private sector partners. The aim of this work is to validate the integration of the separate unit operations.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

A greater fundamental understanding of the factors and causes underlying the recalcitrance of biomass to biological and chemical degradation is needed to make processing more specific and less costly. Recalcitrance refers to the "resistance of plant cell walls to break down." This work will continue to be a priority in FY 2010. Barriers and technical challenges identified in the first of a kind integrated biorefineries under development will determine the necessary fundamental research needs. Work outlined in DOE's EERE and Office of Science joint research agenda "Breaking the Biological Barriers to Cellulosic Ethanol" (June 2006), will also be directly applied to this R&D area. These efforts will provide the basic science groundwork to develop applied, and ultimately integrated, process solutions for biomass conversion. Specifically, this work will produce advanced conversion processes and techniques for future biorefinery concepts.

Work will be done in collaboration with competitively selected industrial partners. In addition, funds may be used to support efforts such as peer reviews; data collection and dissemination; and technical, market, economic, and other analyses.

SBIR/STTR	**–**	**1,406**	**1,571**

In FY 2008, $1,454,000 and $174,000 were transferred to the SBIR and STTR programs respectively. The FY 2009 and 2010 amounts shown are estimated requirements for the continuation of the SBIR and STTR program.

Total, Platforms Research and Development	**65,844**	**53,400**	**59,700**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Thermochemical Platform R&D	
The increase is due to the final phase of funding for projects initiated in FY 2008 to FY 2009. In addition, a competitive solicitation is planned to develop technology for integrated syngas to infrastructure ready fuels. The solicitation will target established industrial partners, include fuel synthesis, and total $40 million between FY 2010 to FY 2014 in support of the EISA 2007 RFS targets for advanced biofuels. The solicitation will allow for core technology development, as well as scale-up of near term options in order to accelerate deployment. This funding level will support projects that utilize thermochemical processing pathways as supported by the platform, as well as existing and new project multi-year contractual agreements in the Thermochemical Platform subprogram linked to supporting the EISA 2007 volumetric targets of the RFS. A competitive National Laboratory call for new ideas (biomass-to-fuels synthesis) will also be initiated.	**+7,400**

	FY 2010 vs. FY 2009 ($000)
Biochemical Platform R&D	
This level of funding will support the continuation of multi-year projects initiated in prior fiscal years at the National Laboratories or with other competitively selected R&D partners, but not support the initiation of new projects.	**-1,265**
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities.	**+165**
Total Funding Change, Platforms Research and Development	**+6,300**

Utilization of Platform Outputs R&D

Funding Schedule by Activity

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Utilization of Platform Outputs R&D			
Integration of Biorefinery Technologies	102,769	131,483	132,977
Products Development	9,921	15,677	13,924
SBIR/STTR	—[a]	940	899
Total, Utilization of Platform Outputs R&D	112,690	148,100	147,800

Description

The Utilization of Platform Outputs R&D subprogram consists of two major sub-elements: Integration of Biorefinery Technologies and Products Development. The Integrated Biorefineries Platform's strategic goal is to demonstrate and validate integrated technologies to achieve commercially acceptable performance and cost pro forma targets. This performance and cost data is essential to benchmarking the state of technology and production costs for current and future biorefineries. The Biomass Program is developing a suite of technologies across the biorefinery pathways to enable a broad spectrum of biomass resources to be used in the production of a variety of biofuels. The Integration of Biorefinery Technologies Platform facilitates the integrated demonstration and validation of suites of technologies including those developed under the Feedstock Infrastructure, Platforms R&D, and Products Development Platforms. Currently, the program is focused on implementing public-private cost-shared pilot, demonstration, and commercial-scale biorefinery projects.

These biorefinery projects of various scales are using a diverse spectrum of feedstocks. The projects will demonstrate and validate biorefinery concepts, and reduce technological and financial risks to enable the commercialization of future biorefineries. The program has competitively selected commercial scale (700 dry tonnes per day) and demonstration scale (minimum 70 dry tonnes per day) biorefinery projects, in FY 2007 and 2008, respectively. In FY 2009, the program issued a request for proposals for pilot scale (minimum 1 dry tonne per day) and demonstration scale (minimum 50 dry tonnes per day) projects for a broader range of feedstocks, conversion technologies, and biofuels. The program seeks project partners with credible data to support the next level of technology scale up. These cost-shared partnerships are essential to alleviating the high technical risk which will help encourage capital investment.

The Products Development Platform is currently involved in the conversion of sugars from the Biochemical R&D Platform into biofuels. The present focus on public/private partnerships works to develop a commercially viable fermentation organism which can help reduce the cost of cellulosic biofuel production.

The Integration of Biorefinery Technologies subactivity also includes the transportation fuels infrastructure activities of the Biomass Program. Transportation fuels infrastructure efforts involve collaboration with the DOE Vehicle Technologies Program, other DOE programs, and various external

stakeholders to facilitate the development of a viable biofuels transportation infrastructure to support growth in the biofuels industry. To encourage large-scale market adoption of biofuels, these activities address challenges along the supply chain from the point of fuel production at the biorefinery to the point of use at the pump and in the vehicle. Activities include fuel testing on vehicles, specialty engines, and infrastructure components; development of analytical tools and data to optimize infrastructure investments (e.g. the Bioenergy Knowledge Discovery Framework, a GIS-based decision support framework incorporating the best-available feedstock and distribution infrastructure data to facilitate efficient infrastructure development by allowing data, modeling and visualization tools to be accessed and shared by multiple stakeholders, including Federal, state, and local government, researchers, and industry); and, input in the development of relevant biofuels standards.

Benefits

The Utilization of Platform Outputs R&D subprogram is comprised of the Integration of Biorefinery Technologies and Products Development key activities. The Integration of Biorefinery Technologies commercial deployment efforts are central to the Biomass Program's present strategy to support the EISA 2007 RFS by helping the American biofuels industry overcome key technical and economic barriers to rapid growth, which is essential for the meeting of EISA advanced biofuels volumetric targets. Presently, the Biomass Program is working with 4 competitively selected industry partners to establish biorefineries at full commercial scale, and with another 8 for biorefineries at 10 percent of full commercial scale. The continuation of these significant multi-year efforts, and their expansion through solicitations for additional projects, such as that currently underway in FY 2009, will validate technology, fine tune processes and subsequently reduce the risk of the commercialization of novel biorefinery technologies. Following successful Biomass Program demonstrations, the possibility for private sector partner project replication will be enhanced through their leveraging of lessons learned and the ability to garner additional capital for new projects based on proven successes. This will support the achievement of the volumetric objectives of the EISA 2007 RFS. Additionally, the testing of ethanol blends and collaborative work with external stakeholders will help to ensure a market for the transportation fuels produced by these biorefineries exists.

The efforts associated with the Products Development key activity will result in greater overall efficiency of cellulosic ethanol biorefineries, contributing to successful commercial demonstration and deployment. Improvements in all processes, including fermentation, are critical to the viability of these biorefineries, and, thus, meeting the EISA 2007 RFS volumetric goal of 16 billion gallons of cellulosic biofuels by 2022.

Collectively, these activities will promote large-scale market adaptation and private sector acceptance of biofuels as more technologies (for making biofuels, biopower, and bioproducts) involving a diversity of feedstocks are demonstrated, validated, and integrated into scalable commercially viable production systems. This will attract additional sources of financial capital at competitive rates and accelerate biorefinery commercialization and, thus, oil displacement.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Integration of Biorefinery Technologies	**102,769**	**131,483**	**132,977**

In FY 2010, Integration of Biorefinery Technologies will continue cost-shared partnerships from competitive solicitations to demonstrate integrated biorefineries at various scales and across various pathways. Specifically, the program will continue to support multi-year contractual agreements from public-private partnerships initiated in FY 2007, 2008, and 2009 for commercial, demonstration, and pilot scale biorefineries, involving the production of transportation fuels and co-products (such as materials and chemicals, heat and power). Funding levels will increase on a project by project basis, as cost-share partners meet the necessary requirements in the negotiated award to move from Award 1's (pre-construction engineering design, NEPA compliance) to Award 2's (facility construction).

During FY 2010, transportation fuels infrastructure efforts will continue, which involve the testing of intermediate ethanol blends on legacy vehicles, distribution systems, small engines, and materials. In addition, studies and analyses will be conducted on the requirements for an infrastructure system that will deliver biofuels efficiently from production centers to end-users.

Products Development	**9,921**	**15,677**	**13,924**

In FY 2010, the program will continue to support the five cost-share projects selected under the FY 2007 solicitation aimed at developing fermentation organisms that display an increased productivity, stability, and robustness, at a lower cost. The goal of this effort is to accelerate the development of advanced micro-organisms capable of efficiently fermenting mixed sugars from cellulosic residues to increase biofuels production from future biorefineries, ultimately contributing to their commercial viability. This funding will also be used to conduct necessary analysis and assessment activities for conversion of advanced feedstocks such as algae to biofuels. Collectively, this work will contribute to meeting the EISA 2007 RFS targets.

SBIR/STTR	**—**	**940**	**899**

In FY 2008, $553,000 and $66,000 were transferred to the SBIR and STTR programs respectively. The FY 2009 and 2010 amounts shown are estimated requirements for the continuation of the SBIR and STTR program.

Total, Utilization of Platform Outputs R&D	**112,690**	**148,100**	**147,800**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Integration of Biorefinery Technologies	
Funding increases support multi-year contractual agreements for commercial, demonstration, and pilot scale integrated biorefinery projects initiated by prior year solicitations.	**+1,494**
Products Development	
The funding decrease is due to reduced needs associated with the finalization of five public-private partnership projects for fermentation organism (aka ethanologen) development selected for award in FY 2007.	**-1,753**
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities.	**-41**
Total Funding Change, Utilization of Platform Outputs R&D	**-300**

Cellulosic Ethanol Reverse Auction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Cellulosic Ethanol Reverse Auction	4,955	0	0
Total, Cellulosic Ethanol Reverse Auction	4,955	0	0

Description

The Biomass Program established the framework for implementing a cellulosic ethanol reverse auction in accordance with Section 942 of the EPAct 2005.

The purpose of the Cellulosic Ethanol Reverse Auction was to potentially accelerate rate of introduction of cellulosic ethanol into the market place, in line with production incentives outlined in Section 942 of the EPAct 2005.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Cellulosic Ethanol Reverse Auction	**4,955**	**0**	**0**
The Biomass Program evaluated and developed a framework for an ethanol reverse auction in accordance with Section 942 of EPAct 2005.			
Total, Cellulosic Ethanol Reverse Auction	**4,955**	**0**	**0**