Fuel Cell Technologies

Funding Profile by Subprogram

(Non-Comparable, or as-Appropriated, Structure)

(dollars in thousands)

	FY 2008 Appropriation[a]	FY 2009 Current Appropriation	FY 2009 Additional Appropriation	FY 2010 Request
Hydrogen Technologies				
Fuel Cell Systems R&D	–	–	–	63,213
Hydrogen Production and Delivery R&D	38,607	10,000	–	0
Hydrogen Storage R&D	42,371	59,200	–	0
Fuel Cell Stack Component R&D	42,344	62,700	–	0
Technology Validation[b]	29,612	–	–	0
Transportation Fuel Cell Systems	7,718	6,600	–	0
Distributed Energy Fuel Cell Systems	7,461	10,000	13,400	0
Fuel Processor R&D	2,896	3,000	–	0
Safety and Codes and Standards[c]	15,442	–	–	0
Education[d]	3,865	–	–	0
Systems Analysis	11,099	7,713	–	5,000
Market Transformation	–	4,747	30,000	0
Manufacturing R&D	4,826	5,000	–	0
Total, Hydrogen Technologies	206,241	168,960	43,400	68,213

[a] SBIR/STTR funding was transferred to the Science Appropriation in FY 2008, which includes a reduction of $4,306,000 that was transferred to the SBIR program, and $515,000 that was transferred to the STTR program.
[b] Funding for this activity appears in the Vehicle Technologies budget in FY 2009, but is included again in Fuel Cell Technologies starting in FY 2010.
[c] Ibid.
[d] Ibid.

Funding Profile by Subprogram
(Comparable Structure to the FY 2010 Request)

(dollars in thousands)

	FY 2008 Appropriation[a]	FY 2009 Current Appropriation	FY 2009 Additional Appropriation	FY 2010 Request
Fuel Cell Technologies				
Fuel Cell Systems R&D	54,201	75,700	–	63,213
Hydrogen Production and Delivery R&D	38,607	10,000	–	0
Hydrogen Storage R&D	42,371	59,200	–	0
Fuel Cell Stack Component R&D	–	–	–	–
Technology Validation[b]	29,612	–	–	0
Transportation Fuel Cell Systems	6,218	6,600	–	0
Distributed Energy Fuel Cell Systems	–	–	13,400	–
Fuel Processor R&D	–	–	–	–
Safety and Codes and Standards[c]	15,442	–	–	0
Education[d]	3,865	–	–	0
Systems Analysis	11,099	7,713	–	5,000
Market Transformation	–	4,747	30,000	0
Manufacturing R&D	4,826	5,000	–	0
Total, Fuel Cell Technologies	206,241	168,960	43,400	68,213

Public Law Authorizations:

P.L. 93-275, "Federal Energy Administration Act" (1974)
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. 94-413, "Electric and Hybrid Vehicle Research, Development and Demonstration Act" (1976)
P.L. 95-91, "Department of Energy Organization Act" (1977)
P.L. 95-238, Title III – "Automotive Propulsion Research and Development Act" (1978)
P.L. 96-512, "Methane Transportation Research, Development and Demonstration Act" (1980)
P.L. 96-294, "Energy Security Act" (1980)
P.L. 100-494, "Alternative Motor Fuels Act" (1988)
P.L. 101-566, "Spark M. Matsunaga, Hydrogen Research, Development, and Demonstration Act of 1990" (1990)
P.L. 102-486, "Energy Policy Act" (1992)
P.L. 104-271, "Hydrogen Future Act of 1996" (1996)
P.L. 109-58, "Energy Policy Act of 2005" (2005)
P.L. 110-140, "Energy Independence and Security Act of 2007"

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[a] SBIR/STTR funding was transferred to the Science Appropriation in FY 2008, which includes a reduction of $4,306,000 that was transferred to the SBIR program, and $515,000 that was transferred to the STTR program.
[b] Funding for Technology Validation appears in the Vehicle Technologies (VT) budget in FY 2009 at $15,000,000; but is included again in Fuel Cell Technologies (FCT) starting in FY 2010.
[c] Funding for Safety and Codes and Standards appears in the VT budget in FY 2009 at $12,500,000; but is included again in FCT starting in FY 2010.
[d] Funding for Education appears in the VT budget in FY 2009 at $4,200,000; but is included again in FCT in FY 2010.

Mission

The mission of the Fuel Cell Technologies (FCT) Program is to reduce petroleum use, greenhouse gas (GHG) emissions, and criteria air pollutants, and to contribute to a more diverse energy supply and more efficient domestic energy use by enabling the widespread commercialization and application of fuel cell technologies. The program's key mission goals are to advance these technologies, through research, development, demonstration (RD&D), to be competitive with alternate technologies in cost, reliability and performance, and to reduce the institutional and market barriers to their commercialization.

Modifications were made to the budget structure to better reflect the Fuel Cell Technologies Program's activities in FY 2010. The two tables above show a non-comparable and comparable funding profile for the program. The non-comparable table presents the FY 2010 funding in the new budget structure only and FY 2008 and FY 2009 funding is shown as appropriated. The comparable table shows the FY 2008 and FY 2009 funding in the new budget structure to assist in comparing year-to-year funding trends. A cross-walk of the new and old structure is provided that describes in detail the modification to the budget structure.

Benefits

The program pursues its mission through integrated activities designed to improve the efficiency, flexibility, and productivity of the domestic energy economy. These improvements are expected to reduce susceptibility to energy price fluctuations, reduce GHG emissions, reduce EPA criteria and other pollutants, and enhance energy security by increasing the production and diversity of domestic fuel supplies.

In FY 2010, the Fuel Cell Technologies Program proposes to re-focus its efforts on fuel cell systems for stationary, portable, and transportation applications. This revised effort is aligned with DOE's portfolio of technologies for near-term impact, improved energy efficiency using multiple fuels, and job creation, consistent with the Presidential objectives. FCT will develop multiple fuel cell technologies (including solid-oxide, alkaline and polymer electrolyte membrane fuel cells) for multiple fuel sources (including diesel, natural gas, bio-derived renewable fuels such as methanol, and fuels derived from other renewable resources). Applications include distributed generation, backup power, auxiliary power units (APUs), portable power systems, material handling equipment, specialty vehicles, and transportation. Distributed generation and backup power systems supported by this activity may be grid-tied or grid-independent, utilize waste heat, operate directly with hydrogen or natural gas, or use reformers to operate with natural gas, bio-derived fuels or coal-derived fuels.

Fuel cells provide energy that can be cleanly produced from a wide range of abundant domestic energy resources, including natural gas, as well renewable resources such as biofuels and by-products from biomass. Depending on the resource used in the fuel cell, substantial reductions in CO_2 emissions and petroleum use considering the entire energy path could be attained. Since fuel cells are quiet, clean and efficient, they are ideal for generating electricity and heat in commercial, industrial, or residential applications, utilizing up to 80 percent of the energy content of the fuel. These systems have been shown to be economically favorable over conventional technologies for material handling equipment in two to three shift indoor warehouse operations and for combined heat and power supply in data centers. Other early market applications include back up power for critical loads, such as telecommunications. Also, reversible fuel cells can be used for storing energy on the Nation's electric grid for dispatch during peak load or to facilitate the use of intermittent energy sources such as solar or wind. Wastewater treatment gas, by-product gases from industrial processes, and gases created from food processing and agricultural waste can be tapped for on-site electrical generation with fuel cell technology.

The proposed FY 2010 Budget investments complement funds provided by the Recovery Act that accelerate fuel cell market transformation and demonstration activities technology awards. 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

Depending on the fuel used, FCT contributes to reducing GHG by providing solutions for many applications. Fuel cells are ideal for using flexible and clean fuels for generating electricity or a combination of electricity and heat for use in commercial, industrial, or residential applications.

Energy Security

FCT aims to help national energy security by reducing reliance on imported oil with widespread commercialization of fuel cells that use domestic and diverse sources of fuel.

Economic Impacts

The program contributes to economic growth in the U.S. by developing fuel cell technologies that lead to new jobs in domestic manufacturing, infrastructure development, and support services. In addition, the reduced dependence on petroleum will improve the Nation's balance of trade and create a more favorable position in the global economy.

Two integrated energy-economy models are used to assess the environmental, energy security and economic benefits from 2010 through 2050 that would result from realization of the program goals: National Energy Modeling System – Government Performance and Results Act 2010 (NEMS-GPRA2010) for benefits through 2030, and Market Allocation Model – Government Performance and Results Act 2010 (MARKAL-GPRA2010) for benefits through 2050.[a] (See table below)

The models do not include any additional policies, incentives or regulatory mechanisms that are expected to support or accelerate the achievement of the program goals. The expected benefits reflect solely the achievement of the program's goals, and do not include any complementary or R&D activities from other Federal agency programs. The vehicle specification used for the basis of the comparison is the same baseline vehicle specification that the EERE Vehicle Technologies Program uses for GPRA 2010 analyses.

[a] Documentation on the analysis and modeling can be found at http://www.eere.energy.gov/ba/pba/program_benefits.html.

Primary Metrics for FY 2010 Budget Request

(Incorporates Approximate Impacts of 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	ns	7.3
	Natural Gas Imports Reduction, cumulative (Tcf)	NEMS	ns	ns	-0.6	N/A
		MARKAL	ns	ns	ns	-2.3
	Reduction in Share of Highway Fuel Demand Derived from Crude Oil[3] (%)	NEMS	ns	ns	1%	N/A
		MARKAL	ns	ns	1%	21%
Environmental Impacts	CO_2 Emissions Reduction, cumulative ($mtCO_2$)	NEMS	ns	ns	95	N/A
		MARKAL	ns	ns	ns	ns
	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	ns	N/A
		MARKAL	0	20	62	105
	Electric Power Industry Savings, cumulative (Bil $)	NEMS	ns	ns	ns	N/A
		MARKAL	ns	ns	ns	-60
	Household Energy Expenditures Reduction ($/household/yr)	NEMS	ns	ns	ns	N/A
		MARKAL	0	11	26	88

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

Secondary Metrics for FY 2010 Budget Request

(Incorporates Approximate Impacts of EISA 2007)

	Metric[1]	Model	Year			
			2015	2020	2030	2050
Energy Security	Oil Imports Reduction, annual (Mbpd)	NEMS	ns	ns	0.2	N/A
		MARKAL	ns	ns	0.0	2.0
	Natural Gas Imports Reduction, annual (Tcf)	NEMS	ns	ns	-0.3	N/A
		MARKAL	ns	ns	ns	0.0
	MPG Improvement[2] (%)	NEMS	ns	ns	3%	N/A
		MARKAL	ns	ns	ns	101%
Environmental Impacts	CO_2 Intensity Reduction of US Economy (Kg CO2/$GDP)	NEMS	ns	ns	ns	N/A
		MARKAL	ns	ns	ns	ns
	CO_2 Intensity Reduction of US Power Sector[3] (Kg CO2/kWh)	NEMS	ns	ns	ns	N/A
		MARKAL	ns	ns	ns	ns
	CO_2 Intensity Reduction of US Transportation Sector[4] (Kg CO2/mile)	NEMS	ns	ns	ns	N/A
		MARKAL	ns	ns	ns	0.06
Economic Impacts	Consumer Savings, annual[5] (Bil $)	NEMS	ns	ns	ns	N/A
		MARKAL	0	3	11	11
	Electric Power Industry Savings, annual (Bil $)	NEMS	ns	ns	ns	N/A
		MARKAL	ns	ns	ns	-12
	Energy Intensity of US Economy (energy/$GDP)	NEMS	ns	ns	0.03	N/A
		MARKAL	ns	ns	ns	0.02
	Net Energy System Cost, annual (Bil $)	NEMS	N/A	N/A	N/A	N/A
		MARKAL	0	11	40	80

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. Change in light duty vehicles miles traveled per gallon of oil, where oil is only that derived from petroleum.
3. Emissions include all power sector emissions. Generation calculated as total net generation adjusted for estimated T&D losses.
4. Emissions calculated using highway fuel use and related carbon emission factor. Miles calculated as highway miles traveled, excluding buses.
5. All monetary metrics are in 2006$.

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

The following external factors could affect the ability of the FCT program to achieve these long-term goals and benefits:

- Fuel availability. Successful deployment of fuel cells will depend on adequate availability of the appropriate fuels for each type of fuel cell.
- Market appeal of fuel-cells. The interest of consumers and businesses in using fuel cells as a substitute for less-efficient power sources will depend in part on the price of conventional sources of energy, such as gasoline and diesel fuel. Historically fluctuating oil prices have not provided a consistent signal to either buyers or manufacturers.

Contribution to the Secretary's Priorities

FCT contributes to several of the Secretary's priorities as enumerated below. The principal focus areas are renewable energy and GHG reduction.

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

The program coordinates with the Office of Science in fields such as nanoscience, biological mechanisms of hydrogen production, and understanding hydrogen interactions with material surfaces. The program has reenergized and focused National Laboratory efforts through the creation of multiple Hydrogen Centers of Excellence. The Centers of Excellence serve as "virtual labs" to integrate National Laboratory, university, and industry activities, as does the program's encouragement of teaming for competitive awards.

The program partners globally through the International Partnership for a Hydrogen Economy (IPHE) with 16 countries and the European Commission, International Energy Agency (IEA) with 25 countries, and other international organizations and agreements. The program builds research networks by coordinating plans with other DOE offices involved in hydrogen and fuel cell research, participation in the IEA and IPHE, cooperation with industry associations and the National Hydrogen and Fuel Cells Codes & Standards Coordinating Committee, the Hydrogen and Fuel Cell Technical Advisory Committee, the Inter-agency Task Force, and the Hydrogen and Fuel Cell Interagency Working Group.

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

The program encourages technology and business model innovation through competitively-awarded industry partnerships and support for innovative deployment mechanisms. Fuel cell applications open new avenues for fuel diversity and distributed generation.

Contribution to GPRA Unit Program Goal 1.1.01.00 (Fuel Cell Technology)

The key FCT contribution to General Goal 4, Energy Security, is domestic energy supply and energy efficiency through:

- Fuel Cell Component R&D, to improve fuel cell durability and performance while reducing cost. The manufacturing cost of hydrogen-fueled fuel cell power systems will be reduced from $275/kW in 2002 for a 50 kW system to $45/kW in 2010 for an 80 kW system at production levels of 500,000 units per year (projected cost).
- Fuel Cell Component R&D, to increase the electrical efficiency of 5-250 kW stationary fuel cell systems operating on natural gas or propane from 29 percent in 2002 to 40 percent in 2011.

Means and Strategies

The FCT 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.

FCT employs the following strategies to accomplish its goals:

To organize R&D activities on fuel cell technology, the program established RD&D subprograms. The subprograms have established cost, performance and/or durability goals to enable fuel cell technologies

to be competitive with alternate technologies. For example, for transportation fuel cell systems to be competitive, the cost target is $30/kW, the performance target is 50 percent efficiency at rated power and the durability target is 5,000 hours. To meet these goals, the subprograms use a competitive selection process to award projects to National Laboratories, universities and industry, and make use of programmatic, policy and legislative approaches in accordance with EPAct 2005 and EISA 2007 to achieve their GPRA Unit goals.

FCT employs the following means to accomplish its goals:

Collaborations leverage the program's activities within and outside DOE. The program coordinates across five DOE Offices: other technology programs within EERE, and the Offices of Science, Nuclear Energy, Fossil Energy, and Electricity Delivery and Energy Reliability. The EERE FCT program is the DOE fuel cell lead and coordinates RD&D planning, budget formulation and execution, and peer review. Within EERE, the program collaborates with the Vehicle Technologies, Biomass and Biorefinery, Solar Technologies, Wind Energy, and Water Power programs. Coordination with organizations outside of DOE includes:

- Interagency Task Force: The program participates in the Task Force in accordance with EPAct 2005, to leverage and coordinate Federal resources and activities.
- International Partnership for the Hydrogen Economy (IPHE): The program is DOE's primary representative to the IPHE, whose goal is to leverage R&D capabilities globally.
- FreedomCAR and Fuel Partnership: DOE (represented by the Vehicle Technologies and the FCT programs) participates in the FreedomCAR and Fuel Partnership with the U.S. Council for Automotive Research (USCAR), five energy companies, and two utilities. The Partnership focuses on precompetitive high-risk research necessary to provide a full range of affordable energy-efficient cars and passenger trucks, and their fueling infrastructure. Fuel cell vehicles represent the long-term end of the R&D spectrum coordinated through the Partnership.
- Cooperation on research for safety and codes and standards: The program collaborates and coordinates with the Department of Transportation (DOT), EPA and the National Institute of Standards and Technology (NIST) to perform safety research and establish the technical groundwork that will be used by code and standard-setting organizations.

Validation and Verification

To validate and verify program performance, the program conducts internal and external reviews and audits. Programmatic activities are subject to continuing review by, for example, Congress, the Government Accountability Office, the National Academies, DOE's Inspector General, as well as by reviewers from other agencies, such as the EPA and state environmental agencies through FCT's Annual Merit Review and Peer Evaluation process. Specific milestones, go/no-go decision points, and technical progress are systematically reviewed through the program's merit review process and independent assessments conducted through the Systems Integration Office. The table below summarizes validation and verification activities.

Data Sources: Merit Review and Peer Evaluation of R&D, Program Peer Reviews, and independent assessments are conducted. Engineering models and experimental results are used to validate technical progress, with documentation provided through quarterly and annual reports. Learning demonstration activities (through FY 2009) also verify and validate technical progress towards meeting targets and help guide R&D. Summary program plans and annual presentations by the program are used to communicate the status of verification/validation activities and to evaluate proposed approaches towards meeting technical targets.

Baselines: The following are the key baselines used in FCT:

- Compressed hydrogen tank-only storage (2003): 1.3 kWh/kg (3.9 percent by weight) and 0.6 kWh/L system capacity
- Solid state materials for storage systems (2003): 1 percent by weight system capacity and 0.5 kWh/L
- Transportation systems/stack component R&D (2002): $275/kW fuel cell cost
- Distributed energy systems/fuel processor R&D (2002): 29 percent electrical efficiency
- Technology validation (2003, laboratory): 1,000 hours durability of fuel cell vehicle systems
- Validated production (delivered) (2004): $3.60/gge (beginning of life testing)

Frequency: Expected results and benefits of the budget are estimated annually in response to GPRA, merit review and peer evaluation of R&D projects and program peer review are conducted biennially. Quarterly reports are submitted to DOE Technology Development Managers. Summary program plans are submitted annually.

Data Storage: EERE Corporate Planning System

Evaluation: The program uses several forms of evaluation to assess progress and to promote program improvement:

- Continue to conduct and build upon the transparent oversight and performance management initiated by Congress and the Administration.
- Technology validation and operational field measurement, as appropriate;
- Peer review by independent outside experts of both the program and sub-program portfolios;
- Annual internal Technical Program Review of the program;
- 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 on Joule (the DOE quarterly performance progress review of budget targets);
- Annual review of methods, and recomputations of potential benefits for GPRA
- The National Academies published a report in 2005 titled: "Review of the

Research Program of the FreedomCAR and Fuel Partnership."[a] The committee's report indicated that DOE's FreedomCAR and Fuel Partnership "has already made an excellent start." The report noted that the partnership faces significant technical challenges, including hydrogen storage in vehicles, commercially viable fuel cells, and the need to build an infrastructure for hydrogen fueling. The report recommended that DOE pay special attention to the challenges of shifting from petroleum to hydrogen as a transportation fuel, including hydrogen safety issues and any environmental impacts of large-scale hydrogen production and use. It also recommended an overall program evaluation to help decide among trade-offs and determine priorities. Finally, the report noted that Congress has appropriated significant portions of the funding for specific projects that are not focused on the partnership's goals, and that the partnership will be unable to meet its milestones if the practice continues;

In 2007, the National Academies conducted a second biennial review of the FreedomCAR and Fuel Partnership and published a report entitled, "Review of the Research Program of the FreedomCAR and Fuel Partnership - Second Report." In this report, the committee noted that, "The FreedomCAR and Fuel Partnership is well planned, organized and managed. It is an excellent example of an effective industry/government cooperative effort." The committee noted that significant progress has been made since the first report but that technological barriers remain to reduce the cost at the vehicle, system and component levels while improving performance in these same areas. In addition to technological barriers, the committee noted that the transition to hydrogen as an energy carrier may be deterred by broad social and economic issues that may arise with the introduction of a new energy carrier. The committee concluded that, "the research efforts of the Partnership are more needed than ever before.";

- Merit reviews and peer evaluations, conducted by energy and fuel cell experts from outside of DOE, are held to evaluate RD&D projects to ensure that priorities and key technology barriers identified in the program's planning documents are addressed;
- In a report released February 11, 2008, the GAO commended DOE for making important R&D progress, for effectively aligning its R&D priorities with industry, and for working with other agencies in coordinating activities and facilitating scientific exchanges. The report stated that DOE and industry officials attribute this progress to DOE's (1) planning process that involved industry and university experts from the earliest stages; (2) use of annual merit reviews, technical teams, centers of excellence, and other coordination mechanisms to continually involve industry and university experts to review the progress and direction of the program; (3) emphasis on both fundamental and applied science, as recommended by independent experts; and (4) continued focus on such high priority areas as hydrogen storage and fuel cell cost and durability. The GAO recognized DOE's increased efforts in stationary and portable fuel cell technologies, as well as the role that these technologies may play in paving the

[a] Report can be found at http://www.nap.edu/catalog.php?record_id=11406.

way for the commercialization of fuel cell vehicles. The report also recognized that difficult technical challenges lie ahead, particularly in hydrogen storage and delivery, fuel cell cost and durability, and hydrogen infrastructure deployment. The GAO recommended that program plans be updated to provide an overall assessment of what DOE reasonably expects to achieve by its technology readiness date. GAO also recommended that the report include a discussion of how these expectations may differ from previous posture plans and project anticipated R&D funding needs.

- The program develops and implements planning documents and supports the development of technology roadmaps with industry.[a] These efforts are used to focus the program's investments on activities that are within the Federal Government's role and that address top priority needs;
- National Laboratories, industry, and universities receive funding through competitive processes. Energy and fuel cell industry experts review each university, laboratory, and industry project at the annual Merit Review and Peer Evaluation. Consistent with the principles of the R&D Investment Criteria, project peer reviews include evaluation of: 1) relevance to overall DOE and FCT 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 panel also evaluates the strengths and weaknesses of each project, and recommends additions to or deletions from the scope of work;
- Most projects are also evaluated by the FreedomCAR joint technical teams each year. The program facilitates supplier-customer relationships to ensure that R&D results from National Laboratories and universities are transferred to industry suppliers and that industry supplier developments are made available to automakers, energy industry and stationary power producers; and
- Reviews are conducted by the Hydrogen Safety Panel to monitor the safety of procedures and facilities throughout the program.

Verification: Quarterly reports from DOE-funded industry, university and National Laboratory partners document the status of quarterly targets and milestones. An Annual Report is used to evaluate progress towards meeting program goals and technical targets. Independent assessments will be conducted by the Systems Integration activity to evaluate research results.

[a] See the following documents: Fuel Cell Report to Congress, Feb. 2003; A National Vision of America's Transition to a Hydrogen Economy, March 2002; National Hydrogen Energy Roadmap, November 2002; FreedomCAR Fuel Cell Technical Roadmap; EERE Hydrogen Program Multi-Year Research, Development and Demonstration Plan; Hydrogen Posture Plan; The 2004 National Academies' Report, The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs; and the National Academies' Report, Review of the Research Program of the FreedomCAR and Fuel Partnership, First Report, August 2005.

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 1.1.01.00 (Fuel Cell Technologies)					
Hydrogen Production and Delivery R&D – Renewable					
Model cost of hydrogen produced from renewable sources and assess versus the 2010 target of $2.85/gge, untaxed at the station at 5,000 psi. [MET]	Due to Congressionally Directed Activities, there will be little activity in FY 2006. Target has been delayed into FY 2007.	Complete lab-scale electrolyzer test to determine whether it achieves 64 percent energy efficiency and evaluate systems capability to meet $5.50/gge hydrogen cost target, untaxed at the station, and with large equipment production volumes [e.g., 500 units/year]. [MET]	Complete benchmark demonstration of reforming technologies and identify development pathways to meet the 2012 target of producing hydrogen from distributed reforming of renewable liquids at 5,000 psi for $<3.80 gge at large equipment production volumes (e.g., 500 units/yr). Reduced costs of hydrogen production will support technology readiness for hydrogen powered vehicles. [MET]		
Hydrogen Production and Delivery R&D-Non Renewable					
Complete the research for a distributed natural gas-to-hydrogen production and dispensing system that can produce 5,000 psi hydrogen for $3.00/gge (untaxed and without co-producing electricity) at the station in 2006. [MET]	Complete the development of a laboratory scale distributed natural gas-to-hydrogen production and dispensing system that can produce 5,000 psi hydrogen for $3.00/gge. [MET]	Complete preliminary lab scale tests to identify technologies that produce 5,000 psi hydrogen from natural gas for $2.50/gge, untaxed at the station and with large equipment production volumes [e.g., 500 units/year]. [MET]			
Hydrogen Storage R&D					
Identify materials with the potential to meet 2010 targets of 2.0 kWh/kg (6 wt percent), 1.5 kWh/L, at $4/kWh. [MET]	Complete fabrication and testing of a sub-scale prototype materials-based storage system to demonstrate projected system capacity of 2.5 wt. percent (0.8 kWh/kg); evaluate progress toward the 2007 target of 4.5 wt. percent (1.5 kWh/kg). [MET]	Complete baseline on-board storage systems analyses, down select materials, and evaluate against 2007 targets of 1.5 kWh/kg (4.5 percent by weight) and 1.2 kWh/L. [MET]	Develop chemical hydrogen storage regeneration methods at laboratory-scale, obtain initial data for efficiency and systems analysis, and demonstrate lab-scale reactions capable of at least 40 percent energy efficiency, leading to greater effective storage density and driving range for fuel cell vehicles. [MET]	Develop solid-state or liquid materials with the potential to meet 2010 targets of 2.0 kWh/kg (6 percent by weight), 1.5 kWh/L, develop system design and evaluate against 2009 interim goal of 5 percent by weight (modeled) or 1.7 kWh/kg.	

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets	FY 2010 Targets
Hydrogen Storage R&D: Tanks					
Complete testing of 10,000 psi hydrogen storage tanks; evaluating against the hydrogen storage system target of 1.5 kWh/kg (4.5 percent by weight), and identify approaches to meet the cost target of $6/kWh. [MET]					
Technology Validation					
Complete validation of an energy station that can produce 5,000 psi hydrogen from natural gas for $3.60 per gallon of gasoline equivalent (including co-production of electricity) untaxed at the station with mature equipment production volumes (e.g., 100 units/year). [MET]	Complete installation and 1,000 hours of testing of a refueling station; determine system performance, fuel quality and availability; and demonstrate the ability to produce 5,000 psi hydrogen from natural gas for a projected cost of $3.00 per gallon of gasoline equivalent, untaxed at the station, assuming commercial deployment with large equipment production volumes (e.g., 100 units/year) by 2009. [MET]	Validate achievement of a refueling time of 5 minutes or less for 5 kg of hydrogen at 5,000 psi through the use of advanced sensor, control, and interface technologies. [MET]	Fuel Cell vehicle(s) demonstrate the ability to achieve 250 mile range without impacting cargo or passenger compartments leading to greater adoption of fuel cell vehicles. Technology Validation shows 103-190 mile range under real world operating conditions. [MET]	Verify under real world conditions hydrogen infrastructure technologies with a cost of $3.00 per gge. [a]	
Fuel Cell demonstration vehicles' durability can be projected to 1,000 hours based on voltage measurements. [PARTIALLY MET]	Operate fuel cell vehicle fleets to determine if 1,000 hour vehicle fuel cell durability, using fuel cell degradation data, was achieved by industry. [MET]				
Fuel Cell Systems R&D					
					Improve the catalyst utilization of fuel cell systems to 3.0 kW per gram of platinum group metal at operating pressures less than 2.5 bar.

[a] In FY 2009 this activity was managed by the Vehicle Technologies Program.

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets	FY 2010 Target
Fuel Cell Component R&D					
DOE-sponsored research will reduce technology cost to $125/kW for a hydrogen-fueled 50kW fuel cell power system. [MET]	DOE-sponsored laboratory scale research will reduce the modeled technology cost to $110/kW for a hydrogen-fueled 80 kW fuel cell power system. [MET]	DOE-sponsored laboratory scale research will reduce the modeled technology cost of a hydrogen-fueled 80kW fuel cell power system to $90/kW. [MET]	DOE-sponsored research will reduce the modeled technology cost of a hydrogen-fueled 80kW fuel cell power system to $70/kW. Reducing automotive fuel cell costs accelerates the market viability and deployment of fuel cell technologies, which contribute to the Department's goal of increased energy security and reduced greenhouse gas and pollutant emissions. [MET]	DOE-sponsored research will reduce the modeled technology cost of a hydrogen-fueled 80kW fuel cell power system to $60/kW. Reducing automotive fuel cell costs accelerates the market viability and deployment of fuel cell technologies, which contribute to the Department's goal of increased energy security and reduced greenhouse gas and pollutant emissions.	
Distributed Energy Fuel Cell Systems and Fuel Processor R&D					
Achieve 32 percent efficiency at full power for a natural gas or propane fueled 5-250 kW stationary fuel cell system. [MET]	Due to Congressionally Directed Activities, there was no activity in this area in FY 2006.	DOE-sponsored research will improve electrical efficiency to 34 percent at full power for a natural gas or propane fueled 5-250 kW stationary fuel cell power system verified by a prototype (5-50 kW system). [MET]	DOE-sponsored research will improve electrical efficiency to 35 percent at full power for a natural gas or propane fueled 5-250 kW stationary fuel cell power system verified by a 5-250 kW prototype. This will support development of fuel cell power systems as alternative power sources to grid-based electricity for buildings and other stationary applications. [MET]	DOE-sponsored research will improve electrical efficiency to 36 percent at full power for a natural gas or propane fueled stationary fuel cell power system verified by a 5-250 kW prototype. This will support development of fuel cell power systems as alternative power sources to grid-based electricity for buildings and other stationary applications.	
Education					
				[Activity moved to Vehicle Technologies in FY 2009; no target set.]	

Safety and Codes and Standards

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets	FY 2010 Targets
			Develop a hydrogen materials technical reference which reports on embrittlement issues for hydrogen usage up to 10,000 psi delivered. Publish a Best Practices Manual describing hydrogen safety guidelines and lessons learned. Wide acceptance of hydrogen technologies depends on developing and meeting safety standards in which the public has confidence. [MET]	[Activity moved to Vehicle Technologies in FY 2009; no target set.]	

Systems Analysis

			Complete and validate Macro-System Model for complete hydrogen and delivery pathway analysis. This will aid in understanding and assessing technology needs and progress, potential environmental impacts, and the energy-related economic benefits of various hydrogen supply and demand pathways. [MET]	Complete feedstock, capital, capacity and utility sensitivity analyses on the cost of delivered hydrogen for 6 pathways using the Macro-System Model. This will aid in understanding and assessing technology needs and progress, potential environmental impacts, and the energy-related economic benefits of various hydrogen supply and demand pathways.	Identify technology gaps and metrics for 2 different fuel cell systems (solid-oxide and methanol) for at least 2 applications.

Operational Efficiency					
Contribute 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 /Fuel Cell Program FY 2004 end of year adjusted uncosted baseline ($29,283K) until the target range is met. [MET]	Maintained 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.	Maintain administrative costs as a percent of total program costs 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.

Fuel Cell Systems R&D

Funding Schedule by Activity

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Fuel Cell Systems R&D	–	–	61,443
SBIR/STTR	–[a]	–	1,770
Total, Fuel Cell Systems R&D	–	–	63,213

Description

The Fuel Cell Systems R&D subprogram is a new subprogram proposed for FY 2010. This modification was made to better reflect Fuel Cell Technologies program activities in FY 2010.

In FY 2010, FCT proposes to re-focus its efforts on fuel cell systems for stationary, portable and transportation applications. Fuel Cell Systems R&D will develop multiple fuel cell technologies (including solid-oxide, alkaline and polymer electrolyte membrane fuel cells) for multiple fuel sources (including diesel, natural gas, bio-derived renewable fuels such as methanol, and fuels derived from other renewable resources). Applications include distributed generation, backup power, auxiliary power units (APUs), portable power systems, material handling equipment, specialty vehicles, and transportation. Distributed generation and backup power systems supported by this activity may be grid-tied or grid-independent, utilize waste heat, operate directly with hydrogen or natural gas, or use reformers to operate with natural gas, bio-derived fuels or coal-derived fuels.

The core of Fuel Cell Systems is materials R&D for fuel cell stack components. These efforts will lead to cost reduction and an increase in fuel cell stack durability, enabling fuel cells to transition from a niche market to a robust portfolio of applications, allowing the economic and environmental benefits that are shown in niche applications to expand into larger markets. As recommended in the 2008 National Research Council (NRC) report,[b] FCT reallocated funding to prioritize and emphasize the R&D that addresses the most critical barriers, such as membranes, catalysts, electrodes, and modes of operation. The program is also placing greater emphasis on the science and engineering at the cell level and, from a systems perspective, on integration and subcomponent interactions. In addition, the program is reducing research on carbon-based supported catalysts in favor of developing carbon-free electrocatalysts.

Several years ago, the cost of a fuel cell "stack" (core) was much higher than the cost of the rest of the fuel cell system ("balance of plant"), thus R&D funding focused on reducing the stack cost. Those R&D efforts succeeded in reducing the cost of fuel cell stacks to the point at which their projected high-volume cost is nearly equal to the cost of the rest of the fuel cell system. In FY 2010, the program will therefore increase emphasis on balance-of-plant component R&D (humidification, heat management, and air compression) that can lead to lower cost and lower parasitic loss. Fuel processors will enable

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

[b] National Research Council of the National Academies; Committee on Review of the FreedomCAR and Fuel Research Program, Phase 2; Board on Energy and Environmental Systems, Division on Engineering and Physical Sciences; *Review of the Research Program of the FreedomCAR and Fuel Partnership: Second Report,* (Washington, DC: National Academies Press, 2008)

the conversion of fuels such as methanol, ethanol, biomass derived liquids, natural gas, propane or diesel into hydrogen for use in fuel cells, and will result in fuel processors for integrated distributed applications and catalysts suitable for a variety of fuel processing applications.

Integration of components into fuel cell systems ensures the developed components will operate together as they are intended. Fuel cell system modeling will serve to guide component R&D, help to benchmark complete systems before they are built and explore alternate system components and configurations. The modeling activity includes the effect of impurities and evaluating water and thermal management strategies. System control optimizations for efficiency and mitigation of degradation will improve performance and durability, while lowering cost. Analytical tools have been developed and are used to view water transport within bipolar plate channels and gas diffusion media in order to maintain enough humidity in the stack while purging product water and preventing product water from freezing inside the fuel cell stack in sub-freezing environments.

Benefits

Fuel cells offer significant benefits for a wide range of applications. These include direct benefits for the end-user, including improved performance and reliability, and reduced lifecycle costs. Broader benefits for the Nation include reduced petroleum consumption, reduced greenhouse gas emissions, and a more secure, diversified energy infrastructure.

Fuel cells use a highly efficient electrochemical process to produce electricity from a variety of fuels. Fuel cells have gained traction in the marketplace for a few applications that are proven to be economically feasible and beneficial, and can be competitive in other markets. Continuing technological progress will allow fuel cells to expand into applications and markets that have more stringent requirements in terms of cost, durability, and performance. The growth of current markets and expansion into broader markets will allow fuel cell technologies to have significant economic and environmental benefits on a national scale.

Applications for fuel cells that are currently commercially viable or are expected to achieve viability in the near-term include specialty vehicles (including material handling, airport ground support vehicles), backup power, auxiliary power units, primary power systems, combined heat and power systems, and portable power. Although fuel cells used to power light-duty vehicles stand to provide the greatest benefits, they also face some of the steepest challenges including stringent technical requirements for fuel cell cost, durability and operating conditions, significant investment in infrastructure, and the need for large-scale and well-refined manufacturing capability in order to compete with incumbent technologies.

As fuel cells become viable in each new market, the resulting increase in market demand will help reduce costs through economies of scale, promote consumer acceptance, expand the infrastructure, and develop domestic mass manufacturing techniques and capacity, paving the way for future applications. The current FCT focus emphasizes near-term applications that can provide benefits in real-time. As the industry matures through success of near-term applications, transportation applications will become viable.

Fuel cells offer a highly efficient and fuel-flexible technology for distributed power generation and combined heat-and-power (CHP) systems. Key applications include primary power for critical load facilities and remote power applications, power for locations where inexpensive fuel cell-compatible fuels are available (such as wastewater treatment gases and industrial byproducts), and CHP for residential and commercial buildings. While this effort supports small to mid-size fuel cell systems,

DOE's Office of Fossil Energy (FE) develops large-scale solid-oxide fuel cell systems for utility-scale distributed generation.

Fuel cells can provide the benefits of distributed generation, such as elimination of electrical transmission and distribution losses, increased reliability, and reduction of peak demand on the electric grid. In addition to these benefits, fuel cells provide higher efficiency, and can make use of waste gases found at municipal landfills, agricultural sites, wastewater treatment, and food and beverage processing plants (methane-based biogas and hydrogen-rich waste streams) as renewable energy resources. Using these resources not only offsets demand of conventional energy sources, but also prevents the release of climate-damaging gases.

Fuel Cell Systems R&D reduces the cost, and increases the durability, reliability, and efficiency of stationary fuel cell systems. For example, the table below shows that R&D has lead to significant improvement in electrical efficiency of primary power stationary fuel cell systems.

Primary Fuel Cell Power System Performance Metrics: Electrical Efficiency

Year	Target %	Actual %
2002	29	29
2003	30	30
2004	31	31
2005	32	32
2006	32	32
2007	34	34
2008	35	35
2009	36	–
2010	38	–
2011	40	–
2012	40	–
2013	40	–

Distributed Stationary Prime-Power (including combined heat-and-power)

Fuel cells have unique advantages in CHP applications. Currently in the U.S., two thirds (or about 28 quadrillion Btu) of the total energy consumed for power generation is lost in the form of waste heat.[a] The vast majority of this energy loss occurs at centralized power generation facilities. The advantage of CHP systems is that they are able to utilize the heat that would otherwise be lost, and thereby reduce total energy consumption. CHP systems are typically able to use as much as 80 percent of the fuel energy, compared to the roughly 34 percent efficiency of grid-power generation[b]. Fuel cells are uniquely suitable for many commercial and residential applications due to their quiet and vibration-free operation, their ability to use existing natural gas fuel supply, their low operation and maintenance requirements, and their ability to maintain high efficiency over a wide range of loads.

[a] Energy Information Administration Annual Energy Review, 2007
[b] Combined Heat and Power: Effective Energy Solutions for a Sustainable Future, Oak Ridge National Laboratory, 2008.

Backup Power

Fuel cells have emerged as an economically viable option for providing backup power, particularly for telecommunications towers, data centers, hospitals, and communications facilities for emergency services. Compared with batteries, fuel cells offer longer continuous run-time and greater durability in harsh outdoor environments under a wide range of temperature conditions. And compared with generators, fuel cells are quieter and have low to zero emissions (depending on fuel source). In addition, they require less maintenance than both generators and batteries. In a study for DOE, Battelle Memorial Institute found that fuel cells can provide potential savings in the lifecycle cost of backup power for emergency response radio towers, where 2 to 5kW of power are required, with runtimes of eight to 72 hours. The current U.S. market size for emergency backup power for wireless communication is approximately 200,000 sites.[a] Backup power systems need at least eight hours of available power during a grid power failure for each wireless communication tower. The potential U.S. market for emergency back-up fuel cells applied to existing towers is approximately 40,000 units per year and 50,000 units per year of new towers.

Specialty Vehicles

Fuel cells powered by hydrogen have become a cost-competitive option for powering specialty vehicles such as forklifts. Many specialty vehicles require power in the 5 to 20kW range, and often operate in indoor facilities and locations where air quality is important and internal combustion engines cannot be used. Like batteries, fuel cells do not emit criteria pollutants (e.g., NO_x, SO_x, and CO) at the point of use. Fuel cells can increase productivity because they can be rapidly refueled, eliminating the time and labor spent charging and changing batteries. This makes fuel cells a particularly appealing alternative to battery-powered forklifts used continuously in two to three shifts per day. Furthermore, batteries require significant space for charging, storage and change-outs, and the power output of batteries diminishes as they are discharged, while fuel cell power remains constant. Forklifts powered by fuel cells can provide significant potential savings in lifecycle costs over battery-powered forklifts. The electric battery-powered lift truck market is approximately 600,000 units annually worldwide. A 50 percent share of this market by U.S. fuel cell manufacturers would add more than 20,000 U.S. manufacturing jobs.[b]

Auxiliary Power Units (APUs)

Fuel cells can provide auxiliary power for tractor trailers, recreational vehicles, yachts, commercial ships, locomotives, jets and similar applications that frequently use power while stationary, which is very inefficient for the large primary motive-power engines to provide. Every year, locomotive and truck engine idling emits 11 million tons of CO_2, 200,000 tons of NO_x, and 5,000 tons of particulate matter.[c] For these reasons, idling restrictions have been placed on trucks in some states. In comparison to internal combustion engine (ICE) generators, fuel cells are more efficient and operate much more quietly. Fuel cells produce no NO_x, SO_x, or particulate emissions, and can utilize a number of fuels: hydrogen, propane, diesel, methanol and ethanol. They can be used in EPA designated nonattainment areas, where emissions restrictions prevent other technologies, such as ICE generators, from being used.

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[a] Fuel Cells in Distributed Telecomm Backup, Citigroup Global Markets, August 24, 2005. Identification and Characterization of Near Term Fuel Cell Markets," Battelle Memorial Institute, April, 2007

[b] 8kW per unit X $3,000/kW X 300,000units = $7.2 Billion X 3 Mfg jobs (per $1 million) = 21,600

[c] Blake, Gary D., "Solid Oxide Fuel Cell System Development for Auxiliary Power in Heavy Duty Vehicle Applications", Delphi Corporation.

Portable Power

Fuel cells for portable applications are beginning to enter the consumer marketplace. Portable fuel cells are being developed for a range of applications including use in cell phones, cameras, PDAs, MP3 players, and laptops, as well as portable generators and battery chargers, and can use diverse fuels such as propane, hydrogen, and methanol. Benefits over current technologies include smaller packaging, lower weight, elimination of recharge time, and longer run-time. Some small fuel cells are beginning to become commercially available for some portable consumer electronic devices.

Transportation Applications

In transportation applications, fuel cell systems could substantially reduce the Nation's dependence on imported petroleum and emissions of CO_2 and criteria pollutants. Fuel cell systems produce only water and heat as byproducts, thus there are no direct emissions of CO_2 or criteria pollutants at the point of use. In addition, fuel cells are powered by fuels that can be produced from a diverse and domestic portfolio of energy resources.

Fuel cells have the greatest potential for reducing CO_2 emissions within the transportation sector, particularly in light-duty vehicles. Analysis of well-to-wheels emissions using models developed by Argonne National Laboratory indicate that the use of fuel cell vehicles will produce among the lowest quantities of GHGs per mile of all conventional and alternative vehicle and fuel pathways being developed. Even in the case where hydrogen is produced from natural gas, the resulting emissions per mile traveled in 2020 will be more than 50 percent less than those from advanced gasoline internal combustion engine vehicles, 20 percent less than those from advanced gasoline hybrid vehicles, and more than 15 percent less than those from gasoline powered plug-in hybrid vehicles.[a]

Fuel cell systems must be cost-competitive in the marketplace. The program established cost targets for light-duty transportation fuel cell systems in 2002. Research activities will reduce the cost of the hydrogen-fueled, 80kW fuel cell power systems as indicated below:[b]

[a] DOE Hydrogen Program Record #9002: http://www.hydrogen.energy.gov/program_records.html

[b] Cost of 80 kW fuel cell power systems estimated for production rate of 500,000 units yearly and includes fuel cell stack and balance of plant.

Fuel Cell Power System Performance Metrics

80kW System Cost

Year	Target $/kW	Actual $/kW
2002	–	275
2003	225	225
2004	200	200
2005	125	110
2006	110	107
2007	90	90
2008	70	73
2009	60	–

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Fuel Cell Systems R&D	–	–	**61,443**

A key to meeting the goals of fuel cell systems will be improving performance and durability, and reducing the cost of stack components in fuel cells. For consumer acceptance, the fuel cell system must be cost-competitive with today's incumbent technologies and expected advances in technologies.

In FY 2010, Fuel Cell Systems catalyst R&D will include new Platinum Group Metal (PGM) catalyst approaches that increase activity and utilization of current PGM and PGM alloy catalysts. Non-PGM catalyst investigations will provide a better understanding of the active site, including detailed studies of oxygen reduction reaction mechanisms. Tasks will include development of viable supports that allow an increase in loading and thickness for these catalysts. Activities will also include investigation of durable catalysts to enhance stability under start-stop conditions. *In situ* studies will examine the effects of catalyst-support interactions, catalyst particle size, and catalyst structure. Innovative fuel cell component structures will also be investigated. Non-carbon support projects will develop materials with superior corrosion resistance and with electrical and structural properties that exceed the properties of carbon.

(dollars in thousands)

FY 2008	FY 2009	FY 2010

Stack Component R&D will be transferred to Fuel Cell Systems R&D subprogram and will develop high temperature membranes that allow better catalyst utilization, reduce the negative effects of impurities and decrease the size of the cooling system, as well as develop bipolar plates and seals that will be inexpensive and corrosion resistant. In addition, R&D will continue to improve the gas diffusion layers between the membrane electrode assemblies (MEAs) and bipolar plates to enhance fuel cell performance. Development of transport models and *in situ* and *ex situ* experiments that provide data for model validation will begin. This effort will include measurement and modeling of mass and electronic/protonic transport in each layer and interface in an MEA.

In FY 2010, Fuel Cell Systems degradation R&D will include studies of fuel cell materials and components to identify the degradation mechanisms, as well as approaches for mitigating the effects. Studies will include the development of integrated degradation models at the component, interface, and cell levels. The performance of MEAs in a single cell and short stacks will be evaluated and compared to FY 2010 targets. Impurities present in both the fuel stream and the air intake have a negative impact on fuel cell performance and durability. In FY 2010, investigation and quantification of the effects of impurities on fuel cell performance will continue, including parametric studies of the effect of poisons on cell performance and durability, identification of poisoning mechanisms and recommendations for mitigation, and modeling of impurity effects on cell performance and durability. Impurity effects R&D will aid the development of fuel quality standards.

To reduce the amount of time required to evaluate fuel cell components for durability during development, correlations will be determined between fuel cell component degradation in real-world applications to accelerated stress testing conducted in National Laboratories. Projects aimed at evaluating full-scale fuel cell system durability will also begin in FY 2010 because of the inherent lead time required to prove the durability of full-scale systems as they approach their target specifications.

Water management continues to be a challenge due to extremes in ambient temperature, humidity, and pressures at which fuel cells must operate to ensure that the residual water in the system does not cause damage after shut-down if the water freezes. In FY 2010, Fuel Cell Systems R&D will focus on the development of low-cost novel and durable humidification materials that perform in all operating environments while meeting size and weight restrictions. Projects will examine concepts for novel water management devices and fuel cell system configurations that facilitate water management. Fuel cell system performance modeling will optimize water management device concepts and configurations, and ensure development of robust solutions. Third-party evaluation of fuel cell stacks and systems will increase as these technologies mature.

In FY 2010, portable power R&D will focus on materials such as the anode, cathode, and membrane improvements for fuel cells that convert methanol to electrical power. Anode and cathode catalyst loading for portable power fuel cells will be reduced, while improving catalytic activity and durability. Membrane R&D will be directed to reduce crossover and increase proton conductivity. Small and durable low power pumps, fans, and power conditioning components for use in portable power systems will be developed for reliability and packaging.

Auxiliary power R&D will focus on developing fuel cell systems for heavy duty trucks as an

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

alternative to idling the main diesel engine for providing overnight power to the truck's cab. The fuel cell APUs (auxiliary power units) will supplement the technologies developed in the Vehicle Technologies Program's 21st Century Truck Partnership. Because solid oxide fuel cell (SOFC) technology is more compatible with heavy fuels than polymer electrolyte fuel cells technology, SOFC technology is being developed for these APU applications in coordination with FE's SOFC R&D effort. Cell conductivity, catalyst performance, and chemical degradation issues will also be addressed. In FY 2010, SOFC hardware will be tested for potential application as an APU on heavy duty trucks. Results from these tests will help to assess the impact of the critical issues on SOFC performance and to direct future R&D efforts.

Fuel processors aid the widespread use of fuel cell power technology in distributed applications. Processing conventional fuels (such as natural gas, propane, methanol, ethanol, biomass derived liquids, or diesel) enables environmental and efficiency advantages of fuel cell technologies to be realized in an integrated fuel cell system. The option of using a variety of fuels to power fuel cells contributes to energy independence.

Activities may include promoting early adoption of fuel cell systems to validate performance, durability, and reliability through field testing. The Fuel Cell Systems R&D effort is supported by multiple Research & Development Investment Criteria factors: address market barriers and provide a public benefit; build on existing technology and complement current R&D; incorporate industry involvement in planning, industry cost-sharing, performance indicators, and "off ramps"; and is competitively awarded and peer reviewed.

In addition, these funds may be used to support efforts such as EPAct 2005 and EISA 2007 requirements; peer reviews; data collection and dissemination; and technical, market, economic, and other analyses.

SBIR/STTR	—	—	**1,770**

In FY 2008, no funds were transferred to the SBIR and STTR programs. The FY 2010 amount shown is the estimated requirement for the continuation of the SBIR and STTR program.

Total, Fuel Cell Systems R&D	—	—	**63,213**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Fuel Cell Systems R&D	
This activity consolidates and refocuses efforts in the previously funded subprograms of Fuel Cell Components R&D, Distributed Energy Fuel Cell Systems, Transportation Fuel Cell Systems, and Fuel Processor R&D. By focusing Fuel Cell Systems R&D on critical-path issues in materials, stack components, balance-of-plant and integrated fuel cell systems, and by reducing system demonstrations, the proposed budget is more streamlined and will have more near-term impacts than the previous structure.	+61,443
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities and projected allocation among activities.	+1,770
Total Funding Change, Fuel Cell Systems R&D	**+63,213**

Hydrogen Production and Delivery R&D

Funding Schedule by Activity

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Hydrogen Production and Delivery R&D	38,607	9,733	0
SBIR/STTR	—[a]	267	0
Total, Hydrogen Production and Delivery R&D	38,607	10,000	0

Description

Hydrogen Production and Delivery R&D encompassed distributed production through renewable liquids reforming and electrolysis, and central production through biomass gasification, wind-powered electrolysis, solar driven high temperature thermochemical cycles, and biological and photoelectrochemical pathways. It also included the technology for hydrogen delivery: transporting and distributing hydrogen both to and at fueling sites. In addition, both production and delivery technologies are applicable for energy storage to enable intermittent, renewable energy resources and combined heat, hydrogen, and power (CHHP) applications. Work involving coal and nuclear-based hydrogen production has been funded by the DOE Fossil Energy and Nuclear Energy offices. The DOE Office of Science conducts basic research to understand the fundamentals of catalysts and of the biological and photoelectrochemical pathways. Areas of collaboration with other offices include production technologies such as gasification, reforming, separations, and purification.

In FY 2010 the program is rebalancing its portfolio to focus on fuel cell systems for stationary, portable, and transportation applications. Due to the long-term nature of Production and Delivery R&D, further funding requests for this subprogram are deferred. This revised effort is aligned with DOE's portfolio of technologies for near-term impact, improved energy efficiency using multiple fuels and job creation, consistent with Presidential objectives.

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

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Hydrogen Production and Delivery R&D	
In FY 2010 the program is rebalancing its portfolio to focus on fuel cell systems for stationary, portable, and transportation applications. Due to the long-term nature of Production and Delivery R&D, no funding is requested for this subprogram in FY 2010.	-9,733
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities and projected allocation among activities.	-267
Total Funding Change, Hydrogen Production and Delivery R&D	**-10,000**

Hydrogen Storage R&D

Funding Schedule by Activity

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Hydrogen Storage R&D	42,371	57,542	0
SBIR/STTR	—[a]	1,658	0
Total, Hydrogen Storage R&D	42,371	59,200	0

Description

Hydrogen Storage R&D focuses primarily on the R&D of on-board vehicular storage systems that allow for a driving range of more than 300 miles to enable full market penetration across the North American light-duty vehicle market, within the constraints of weight, volume, safety, durability, refueling time, efficiency, and total cost, to meet consumer expectations. The Hydrogen Storage portfolio concentrates on low-pressure, materials-based technologies and will also explore advanced conformable and low cost tank technologies for hydrogen storage systems to meet performance targets. In addition, the portfolio includes activities relevant to non-automotive hydrogen storage such as early-market stationary and materials handling applications, and energy storage to enable renewable energy.

In FY 2010 the program is rebalancing its portfolio to focus on fuel cell systems for stationary, portable, and transportation applications. Due to the long-term nature of Hydrogen Storage R&D (and of the market for such storage), funding for this subprogram is deferred in FY 2010. This revised effort is aligned with DOE's portfolio of technologies for near-term impact, improved energy efficiency using multiple fuels and job creation, consistent with Presidential objectives.

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Hydrogen Storage R&D	
In FY 2010 the program is rebalancing its portfolio to focus on fuel cell systems for stationary, portable, and transportation applications. Due to the long-term nature of Hydrogen Storage R&D (and of the market for such storage), no funding is requested for this subprogram in FY 2010.	-57,542

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

	FY 2010 vs. FY 2009 ($000)
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities and projected allocation among activities.	-1,658
Total Funding Change, Hydrogen Storage R&D	**-59,200**

Fuel Cell Stack Component R&D

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Fuel Cell Stack Component R&D	42,344	61,034	0
SBIR/STTR	—[a]	1,666	0
Total, Fuel Cell Stack Component R&D	42,344	62,700	0

Description

For fuel cell vehicles to be competitive, fuel cell stacks must become less expensive and more durable. The high cost and insufficient durability of polymer electrolyte membrane (PEM) fuel cell stack components (the membranes, oxygen reduction electrodes, advanced catalysts, bipolar plates, etc.) are currently the most challenging hurdles facing the adoption of fuel cell systems. The program's collaborative R&D efforts with industry, National Laboratories and academia are focused on the critical technical barriers of cost, durability, efficiency, and overall performance of fuel cell stack components for both transportation and stationary applications.

In FY 2010, the program is reprioritizing and restructuring its fuel-cell-related activities, and as a result this subprogram is not funded in FY 2010. Many activities previously funded in this subprogram will continue in the new Fuel Cell Systems R&D subprogram.

Benefits

Fuel cells have the potential to enable the reduction of energy use and dependence on imported petroleum because they are highly efficient and can be powered by fuels that can be produced from a variety of domestic resources. Fuel Cell Stack Component R&D supports the program's mission by focusing on improvement of overall fuel cell performance and durability while lowering cost. These improvements will help make fuel cells competitive with conventional technologies in order to realize benefits in energy security and environmental quality.

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Fuel Cell Stack Component R&D	
Fuel-cell-related activities are being consolidated and reprioritized in the new Fuel Cell Systems R&D subprogram.	-61,034
SBIR/STTR	

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

	FY 2010 vs. FY 2009 ($000)
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities and projected allocation among activities.	-1,666
Total Funding Change, Fuel Cell Component R&D	**-62,700**

Technology Validation
Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Technology Validation[a]	29,612	–	0
SBIR/STTR	–[b]	–	0
Total, Technology Validation	29,612	–	0

Description

Technology Validation includes both Fuel Cell Technology Validation and Hydrogen Infrastructure Validation. Beginning in FY 2009, this activity was funded in the Vehicle Technologies (VT) program, within the Hybrid Electric Systems subprogram and transfers back to the FCT program in FY 2010; however, additional funding requests are deferred.

The Technology Validation activity included validation of both fuel cell vehicle (FCV) technology and hydrogen infrastructure through the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project. The project is both a "Learning Demonstration" to manage the hydrogen and fuel cell component and materials research, and a validation of the technology under real-world operating conditions against time-phased performance-based targets. The project is 50/50 cost-shared between government and industry, including automobile manufacturers, energy companies, suppliers, universities, and state governments. Extensive data have been collected on vehicles operating on-road and during dynamometer testing. Validation of the hydrogen infrastructure included verification of hydrogen production cost and fueling time while gaining experience in the safe operation of stations.

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Technology Validation	
Beginning with FY 2009, this subprogram was included in the VT budget. In FY 2010 the Technology Validation activity is transferred back from the VT Program to the FCT as part of a reprioritization of fuel cell and hydrogen-related work. Due to the program's rebalancing of its portfolio to focus on an array of fuel cell technologies, further funding requests for the Technology Validation activity are deferred.	0

[a] Funding for Technology Validation appears in the Vehicle Technologies budget in FY 2009 at $15,000,000, but is included again in Fuel Cell Technologies starting in FY 2010.
[b] SBIR/STTR funding was transferred to the Science Appropriation in FY 2008.

	FY 2010 vs. FY 2009 ($000)
SBIR/STTR	
No change.	0
Total Funding Change, Technology Validation	**0**

Transportation Fuel Cell Systems

Funding Schedule by Activity

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Transportation Fuel Cell Systems	7,718	6,424	0
SBIR/STTR	—[a]	176	0
Total, Transportation Fuel Cell Systems	7,718	6,600	0

Description

In FY 2010, the program is reprioritizing and restructuring its fuel-cell-related activities to cover a broader array of fuel cell types and applications, and as a result this subprogram is not funded in FY 2010. Some activities previously funded in this subprogram may continue in the new Fuel Cell Systems R&D subprogram.

Transportation Fuel Cell Systems R&D supports the program's mission by developing system balance of plant components and optimizing operating strategies to improve performance and durability, while lowering cost. The improvements help to make energy efficient and zero emissions fuel cells competitive with conventional technologies, contributing to DOE's initiatives for energy security, environmental quality and energy productivity.

The Transportation Fuel Cell Systems activity involves R&D and analyses that address key barriers to developing fuel cell systems for transportation. Key challenges addressed in this subprogram include the cost, durability, performance and size of water, thermal, and air management devices that meet automotive requirements. This activity supports the development of component technologies critical to systems integration, as well as system performance. The activity also supports cost-modeling activities that serve to guide component R&D, benchmarks progress of complete systems and explores alternate system components and configurations. Other activities include modeling of impurity effects and evaluating water and thermal management configurations. In addition to passenger vehicles, other applications supported include material handling equipment and replacing diesel-fueled auxiliary power units for heavy duty trucks. For off-road applications, issues such as vibration, dust, contaminants and harsh duty cycles that could have an adverse effect on stack performance and life are addressed.

Benefits

Research activities for transportation applications (including transportation systems and stack component R&D) have been projected to reduce the cost of the hydrogen-fueled, 80kW vehicle fuel cell power systems through FY 2009 as indicated below:[b]

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

[b] Cost of 80 kW vehicle fuel cell power systems estimated for production rate of 500,000 units yearly and includes fuel cell stack and balance of plant.

Fuel Cell Power System Performance Metrics
80 kW System Cost

Year	Target $/kW	Actual $/kW
2002*	–	275
2003*	225	225
2004*	200	200
2005	125	110
2006	110	107
2007	90	90
2008	70	73
2009	60	–

* Costs in years 2002 to 2004 are for a 50 kW System

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Transportation Fuel Cell Systems	**7,718**	**6,424**	**0**
In FY 2010, there will be no work performed in this key activity, any continuing work will be conducted as needed under Fuel Cell Systems R&D.			
SBIR/STTR	**–**	**176**	**0**
In FY 2009, $176,000 was transferred to the SBIR and STTR programs.			
Total, Transportation Fuel Cell Systems	**7,718**	**6,600**	**0**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Transportation Fuel Cell Systems	
Fuel-cell-related activities are being consolidated and reprioritized in the new Fuel Cell Systems R&D subprogram.	-6,424
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities and projected allocation among activities.	-176
Total Funding Change, Transportation Fuel Cell Systems	**-6,600**

Distributed Energy Fuel Cell Systems

Funding Schedule by Activity

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Distributed Energy Fuel Cell Systems	7,461	9,776	0
SBIR/STTR	—[a]	224	0
Total, Distributed Energy Fuel Cell Systems	7,461	10,000	0

Description

Distributed Energy Systems supports R&D for distributed generation, backup power, auxiliary power units (APUs), portable power systems, and material handling equipment. Distributed generation and backup power systems supported by this activity may be grid-tied or grid-independent, utilize waste heat, operate directly with gaseous fuels, or use reformers to operate with natural gas, bio-derived fuels or coal-derived fuels.

In FY 2010, the program is reprioritizing and restructuring its fuel-cell-related activities to cover a broader array of fuel cell types and applications, and as a result this subprogram is not funded in FY 2010. As this subprogram leverages improved materials developed in Fuel Cell Component R&D, such as high-temperature membranes, catalysts and improved fuel cell stack component durability, any continuing activities will be completed within the new Fuel Cell Systems R&D subprogram.

Benefits

Distributed generation fuel cell systems provide high efficiency and reliability for uninterruptible power sources, remote power and back-up power. Applications include highly efficient fuel cell heating appliances for residential and commercial buildings that cogenerate electricity, highly reliable and cost-effective fuel cell systems which meet the requirements for critical loads and remote power applications, and power for locations where inexpensive fuel cell-compatible fuels are available. Backup power applications include critical loads such as data centers, telecommunication facilities, hospitals, and first-responders. Portable power fuel cell systems are being developed for consumer electronics applications, emphasizing energy density and refueling via fuel cartridge exchange rather than re-charging batteries. While this subprogram supports small to mid-size fuel cell systems, DOE's Office of Fossil Energy develops large-scale solid-oxide fuel cell systems for utility-scale distributed generation.

R&D focuses on overcoming the barriers to stationary fuel cell systems, including cost, durability, heat utilization, start-up time, managing power transients and optimizing control to maximize system efficiency for given power demand. Improvements will help accelerate commercialization of fuel cells by achieving the 2011 stationary system durability target of 40,000 hours and cost of $750 per kW, making fuel cells competitive with conventional technologies.

Distributed Energy Fuel Cell Systems activities include development of fuel cell systems for heavy-duty vehicle applications to reduce fuel consumption and emissions in commercial trucks that idle their

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

main engines to supply accessory power when parked for long durations.

Fuel cell systems for portable power can potentially provide much longer run-times than batteries for consumer electronics and are also being developed as an early market application. The size constraints for portable power systems result in packaging challenges and require development of small-scale balance of plant components. Methanol, sodium borohydride and other fuels are used. In some cases, the behavior of liquid reactants or the release of hydrogen from a solid hydrogen carrier must be addressed.

Activities may include promoting early adoption of these systems to validate performance, durability, and reliability and conduct field testing. Commercialization of fuel cells for portable power aid in developing the manufacturing base and will introduce the technology to consumers, thus paving the way for fuel cell systems being used in other applications.

Stationary Fuel Cell Power System Performance Metrics: Electrical Efficiency

Year	Target %	Actual %
2002	29	29
2003	30	30
2004	31	31
2005	32	32
2006*	32	32
2007	34	34
2008	35	35
2009	36	–

* Virtually all work was deferred due to reduced funding. Targets were delayed one year.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Distributed Energy Fuel Cell Systems	**7,461**	**9,776**	**0**
In FY 2010, there will be no work performed in this key activity, any continuing work will be conducted as needed under Fuel Cell Systems R&D.			
SBIR/STTR	**–**	**224**	**0**
In FY 2009, $224,000 was transferred to the SBIR and STTR programs.			
Total, Distributed Energy Fuel Cell Systems	**7,461**	**10,000**	**0**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Distributed Energy Fuel Cell Systems	
Fuel-cell-related activities are being consolidated and reprioritized in the new Fuel Cell Systems R&D subprogram.	-9,776
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities and projected allocation among activities.	-224
Total Funding Change, Distributed Energy Fuel Cell Systems	**-10,000**

Fuel Processor R&D

Funding Schedule by Activity

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Fuel Processor R&D	2,896	2,933	0
SBIR/STTR	—[a]	67	0
Total, Fuel Processor R&D	2,896	3,000	0

Description

Fuel Processor R&D was previously conducted to enable the conversion of fuels such as methanol, ethanol, biomass derived liquids, natural gas, propane or diesel into hydrogen for use in fuel cells. Fuel Processor R&D resulted in fuel processors for integrated distributed applications and catalysts suitable for a variety of fuel processing applications. On-board fuel processing for transportation applications was discontinued as a result of the program's "no go" decision in 2004, and in FY 2009, development of fuel processors for stationary (distributed energy) fuel cell applications concluded. Any future fuel-processing R&D needs can be best addressed within the context of the specific type of fuel cell and application where the processing is needed.

In FY 2010, the program is reprioritizing and restructuring its fuel cell-related activities to cover a broader array of fuel cell types and applications, and as a result this subprogram is not funded in FY 2010. Some activities previously funded in this subprogram may continue in the new Fuel Cell Systems R&D subprogram.

Benefits

Fuel Processor R&D has supported the FCT mission by developing the subsystem that aids the widespread use of fuel cell power technology in distributed applications. Processing conventional fuels (such as natural gas, propane, methanol, ethanol, biomass derived liquids, or diesel) enables environmental and efficiency advantages of fuel cell technologies to be realized in an integrated fuel cell system without needing a hydrogen-delivery infrastructure. The option of using a variety of fuels to power fuel cells contributes to energy independence.

Detailed Justification

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Fuel Processor R&D	**2,896**	**2,933**	**0**

In FY 2010, there will be no work performed in this key activity because stand-alone fuel processing

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

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

work has been completed. Further refinements, within the context of a complete system, will be conducted as needed under Fuel Cell Systems R&D.

SBIR/STTR	–	**67**	**0**

In FY 2008, $69,000 and $8,000 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, Fuel Processor R&D	**2,896**	**3,000**	**0**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Fuel Processor R&D	
This decrease reflects completion of stand-alone fuel processor work. System-integrated fuel processor development for distributed power systems will be performed as needed within the Fuel Cell Systems R&D subprogram.	-2,933
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities and projected reallocation of continuing work to other areas.	-67
Total Funding Change, Fuel Processor R&D	**-3,000**

Safety and Codes and Standards

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Safety and Codes and Standards[a]	15,442	—	0
SBIR/STTR	—[b]	—	0
Total, Safety and Codes and Standards	15,442	—	0

Description

Beginning in FY 2009, the Safety and Codes and Standards subprogram was funded in the Vehicle Technologies Program and is transferred back to FCT in FY 2010. Due to the program's rebalancing of its portfolio to focus on an array of fuel cell technologies, further funding requests for the Safety and Codes and Standards activity are deferred.

The Safety and Codes and Standards subprogram funded research to provide the technical data on hydrogen technologies (such as fuel cells and hydrogen production, storage, and distribution systems) that are necessary to support and inform the codes and standards development process. Its work included studies to determine the flammability, reactive, and dispersion properties of hydrogen. It also subjected components, subsystems, and systems to environmental conditions that could result in failure to check design practices and failure-mode prediction analysis.

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Safety and Codes and Standards	
Beginning with FY 2009, this subprogram was included in the Vehicle Technologies budget. In FY 2010 the Safety and Codes and Standards activity is transferred back from the Vehicle Technologies Program to the FCT as part of a reprioritization of fuel cell and hydrogen-related work. Due to the program's rebalancing of its portfolio to focus on an array of fuel cell technologies, further funding requests for the Safety and Codes and Standards activity are deferred.	0
SBIR/STTR	
No Change.	0
Total Funding Change, Safety and Codes and Standards	**0**

[a] Funding for Safety and Codes and Standards appears in the Vehicle Technologies budget in FY 2009 at $12,500,000, but is included again in Fuel Cell Technologies starting in FY 2010.
[b] SBIR/STTR funding was transferred to the Science Appropriation in FY 2008.

Education

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Education[a]	3,865	–	0
SBIR/STTR	0	–	0
Total, Education	3,865	–	0

Description

Beginning in FY 2009, hydrogen education activities were funded within the Vehicle Technologies budget and in FY 2010 they transfer back to the FCT Program.

In FY 2010 the program is rebalancing its portfolio to focus on fuel cell systems for stationary, portable, and transportation applications, expanding its coverage to include multiple fuels and fuel cell technologies. Because of the focus of the Education subprogram on a single long-term fuel type, further funding requests for this subprogram are deferred.

Education aids in overcoming institutional barriers to widespread use of hydrogen. Education activities have been designed to increase understanding of hydrogen and fuel cell technologies, the facts about hydrogen safety, and the role that certain key target audiences can play in advancing the development and use of hydrogen as an energy carrier. Target audiences, identified by key government and industry stakeholders in the National Hydrogen Energy Roadmap, include state and local government representatives, safety and code officials, potential end-users, and the public. Over the long term, education of teachers and students will also be required.

[a] Funding for Education appears in the Vehicle Technologies budget in FY 2009 at $4,200,000, but is included again in Fuel Cell Technologies starting in FY 2010.

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Education	
Beginning with FY 2009, this subprogram was included in the Vehicle Technologies budget. In FY 2010 the Education activity is transferred back from the Vehicle Technologies Program to the FCT as part of a reprioritization of fuel cell and hydrogen-related work Due to the program's rebalancing of its portfolio to focus on an array of fuel cell technologies, further funding requests for the Education activity are deferred.	0
SBIR/STTR	
No change.	0
Total Funding Change, Education	**0**

Systems Analysis

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Systems Analysis	11,099	7,508	4,860
SBIR/STTR	—[a]	205	140
Total, Systems Analysis	11,099	7,713	5,000

Description

The Systems Analysis subprogram supports the development of independent systems analysis and evaluation functions to identify the energy efficiency, economic, and environmental impacts of various fuel cell and fuel technology pathways by assessing associated cost elements and drivers, identifying key costs and technological gaps, evaluating the status and validation of research results, determining the market growth and job creation through application of fuel cell technologies, and assisting in the prioritization of research and development directions.

Benefits

The Systems Analysis subprogram provides the analytical and technical basis for informed decision-making for the Fuel Cell Systems R&D direction and prioritization. Systems Analysis is an essential component of the program in terms of understanding and assessing market growth and job creation, technology needs and progress, potential environmental impacts, and the energy-related economic benefits of fuel cells across applications and for multiple fuel pathways. This analysis assesses technology manufacturing and market uptake, R&D gaps, planning and budgeting, and interactions with other energy domains. The subprogram results provide metrics for multiple components, subsystems and systems that are needed to determine customer requirements and to support annual updates to key program planning documents that provide the current direction and planned milestones for the program.

The subprogram is supported by multiple Research Development Investment Criteria (RDIC) factors: builds on existing technology and complements current R&D; incorporates industry involvement in planning, industry cost-sharing, and performance indicators; and, is competitively awarded and peer reviewed.

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

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Systems Analysis	**11,099**	**7,508**	**4,860**

Systems Analysis provides the analytical and technical basis for determining technology gaps for R&D prioritization. The subprogram will quantify energy efficiency, economic, and environmental benefits of fuels across applications and for multiple fuel pathways, and optimize cross-cutting synergies with other renewable technologies. In FY 2010, the subprogram will develop the new analytical models and tools to help quantify benefits and identify gaps for various applications, such as materials handling, stationary and portable power, and combined heat and power. The new models, combined with existing systems analysis models, will enable the program to identify resource limitations, options for stationary power production from fuel cells, renewable fuel supply evolution, infrastructure issues, and the potential environmental impacts of wide scale commercialization.

Building on efforts completed in FY 2009 to develop the Macro System Model (MSM), which provides overarching analysis for the program, additional linkages will be developed in FY 2010 to provide analytical capabilities for market and job creation analysis in the near- and mid-term. Additional features will be added to the MSM to enable evaluation of the benefits of integrating stationary power generation with the electrical sector.

In collaboration with the Fuel Cells Systems R&D subprogram, the subprogram will:

- Develop models for program analysis with emerging cost, performance, yield and environmental information from independent reviews and research projects. Model experts and project representatives will perform required model upgrades to improve model capabilities and representation of actual technology performance;
- Provide system analysis support and input for all the program elements such as go/no-go decisions;
- Assess market penetration, job creation and opportunities for fuel cell applications in the near term, such as materials handling, backup power, and residential combined heat and power (CHP) markets; and
- Update and maintain the Analysis Portfolio, the prioritized analysis list, and the Analysis Resource Center database, to ensure analysis consistency and transparency. The program will also update the Systems Analysis Plan, Technical Requirements Document and the Multi-Year Research, Development and Demonstration Plan.

Integration of stationary fuel cell power generation for the electrical sector will be examined to determine the potential benefits of and synergistic impact on cost and GHG reductions. Cross-cutting analysis of tradeoffs and synergies amongst regions for infrastructure and resource availability will be completed. Market studies, including an assessment of the opportunities for early market applications of fuel cells and the resulting impacts on job growth, will be conducted. The effects of a Federal fuel cell acquisition program on fuel cell cost reduction will be estimated. Program element risk analysis will be conducted with Systems Integration to evaluate progress towards program targets and goals. In addition, these funds will be used to support peer reviews as required.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
SBIR/STTR	**—**	**205**	**140**
In FY 2008, $265,000 and $31,000 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, Systems Analysis	**11,099**	**7,713**	**5,000**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Systems Analysis	
With the reprioritization of the program's fuel cell activities, less vehicle-related systems analysis will be needed, and this activity will focus on identification of technology gaps across a range of fuel cell types and applications.	-2,648
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities and projected allocation among activities.	-65
Total Funding Change, Systems Analysis	**-2,713**

Market Transformation

Funding Schedule by Activity

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Market Transformation	—	4,740	0
SBIR/STTR	—[a]	7	0
Total, Market Transformation	—	4,747	0

Description

The Market Transformation subprogram accelerates commercialization of fuel cell power systems. The goal of these activities is to eliminate non-technical barriers and increase opportunities for market expansion. The pathway to expanded use of fuel cells will likely include the introduction of direct hydrogen polymer electrolyte membrane (PEM) fuel cells in near-term markets with fewer technical and cost challenges than later developing markets. By increasing product purchases, these early market applications will accelerate development of manufacturing capability and domestic supplier base, and reduce manufacturing costs. Early markets facilitate the development of codes and standards, raise public acceptance and increase market demand.

The most promising near-term opportunities for PEM fuel cells are in specialty vehicle and backup power applications, as described in an evaluation conducted by Battelle Memorial Institute.[b] Some PEM fuel cell systems are commercially available to support these applications and offer several potential advantages over current technologies, including lower emissions, lower O&M requirements, and longer runtimes. However, the incremental cost as compared with conventional technologies is preventing widespread adoption of hydrogen and fuel cell systems.

PEM fuel cells can provide standby or emergency power to ensure uninterrupted service. These fuel cells can be used to provide electricity that meets standard backup requirements (e.g., in blackout conditions), as well as high quality backup power requirements for industries such as financial services and telecommunications, which are willing to pay more to secure reliable service. In backup applications, efficiency is not as critical as reliability and availability of the system. PEM fuel cells in these applications provide longer runtimes than batteries. They also have low operations and maintenance requirements, and have no emissions as compared to generators. PEM fuel cells can be less expensive, on a life cycle basis, than lead acid batteries because they do not require replacement as often. The FCT program pursues competitively awarded cost shared projects with industry and government that collect valuable data to validate the technology in the field and increase acceptance of fuel cell technologies. These projects increase consumer confidence and promote the adoption of these technologies without government financial assistance. Market Transformation activities are consistent with EPAct 2005 provisions that recognize the need for activities in addition to R&D for disruptive technologies with major societal benefits.

Specialty vehicle users, such as lift truck operators, are looking for alternatives to batteries to increase runtime and productivity, to reduce safety risks, and to reduce O&M costs associated with battery and

[a] SBIR/STTR funding was transferred to the Science appropriation in FY 2008.
[b] http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=10798

internal combustion engine powered vehicles. PEM fuel cells can provide value over battery-powered forklifts in high productivity environments. When forklifts are operated under conditions of near continuous use, fuel cell vehicles are significantly less expensive than similar battery-powered systems from a life cycle cost perspective. Advantages of PEM fuel cell systems operating under such conditions include rapid refueling, eliminating time and cost of replacing batteries, constant voltage delivery, productivity increases by eliminating battery recharging time, fewer repairs due to fewer moving parts, and elimination of battery storage/changing rooms. Federal agencies can play a critical role in enhancing the market introduction of new technologies by being early adopters to stimulate initial markets. The FCT program collaborates with DOD in deploying fuel cell lift trucks in several locations and supports Federal deployments for backup power applications. In addition, the program considers providing financial assistance to industry in the form of cost-sharing for fuel cell purchases. These purchases generate "market pull" – stimulating market demand – for certain applications.

Benefits

Early market fuel cell deployments stimulate market pull and facilitate the market penetration of hydrogen and fuel cell products through volume purchases of these technologies.

Higher volume purchases of these technologies are expected to lower market barriers by: (a) enabling developers to move down the learning curve, reduce manufacturing costs, and develop manufacturing capability; (b) increasing public awareness of hydrogen and fuel cell technologies; (c) enabling assessments of infrastructure needs (which will help to develop codes and standards and lay the groundwork for financing); (d) creating a demand for technology developers, which will, in turn, encourage expansion of relevant training and education opportunities; and, (e) familiarizing the end-user communities with the technologies.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Market Transformation	**—**	**4,740**	**0**

To facilitate early adoption of hydrogen and fuel cell technologies, the Market Transformation subprogram uses cost-shared projects with partners from industry and government agencies (Federal, state and local) to deploy fuel cell systems in stationary and transportation applications such as specialty vehicles. Such applications include warehouse lift-trucks currently employing battery or internal combustion systems, and fuel cells for battery recharging.

This effort supports projects enabling Federal, state, and local government leadership in the adoption of fuel cells for critical early markets including emergency back up power, lift trucks, and data center power. Projects at Federal agencies are supported on a cost-shared basis through interagency agreements. State and local governments are supported through competitively–awarded, cost-shared grants that include industry participation. These projects stimulate the development of a domestic supply base. All projects incorporate a data collection element, providing important third-party test data that validate performance characteristics and help to increase consumer acceptance of fuel cell technologies.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
The Market Transformation subprogram builds on existing technology and complements current R&D in support of the program plan.			
SBIR/STTR	**—**	**7**	**0**
In FY 2008, no funds were transferred to the SBIR and STTR programs. The FY 2009 and 2010 amounts shown are estimated requirements for the continuation of the SBIR and STTR program.			
Total, Market Transformation	**—**	**4,747**	**0**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Market Transformation	
Market transformation activities are being accelerated with Recovery Act funding, thus additional funding is not requested in FY 2010.	-4,740
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities and projected allocation among activities.	**-7**
Total Funding Change, Market Transformation R&D	**-4,747**

Manufacturing R&D

Funding Schedule by Activity

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Manufacturing R&D	4,826	4,867	0
SBIR/STTR	—[a]	133	0
Total, Manufacturing R&D	4,826	5,000	0

Description

Manufacturing R&D has supported the FCT technology readiness goal by developing advanced high-volume fabrication and process technologies for hydrogen fuel cells, storage, production and delivery materials, components and systems that meet the cost targets critical for mass penetration in the light-duty vehicle, stationary power, back-up power, and material handling markets. Due to the program's rebalancing of its portfolio to focus on an array of fuel cell technologies, funding for the Manufacturing R&D activity is deferred.

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Manufacturing R&D	
Due to the program's rebalancing of its portfolio to focus on an array of fuel cell technologies, funding for the Manufacturing R&D activity is deferred.	-4,867
SBIR/STTR	
Changes in the SBIR/STTR funding are a direct result of changes in the funding of program activities and projected allocation among activities.	-133
Total Funding Change, Manufacturing R&D	**-5,000**

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