DEPARTMENT OF ENERGY
FY 2000 CONGRESSIONAL BUDGET REQUEST
ENERGY EFFICIENCY AND RENEWABLE ENERGY
ENERGY CONSERVATION
(Tabular dollars in thousands, Narrative in whole dollars)

TRANSPORTATION SECTOR

PROGRAM MISSION

Sector Mission, Situation, Goal(s) and Strategic Approach

Mission

The mission of the Transportation Sector program is to support the development and use of advanced transportation vehicles and fuels which will reduce energy demand, particularly for petroleum; reduce criteria pollutant emissions; reduce greenhouse gas emissions; and enable United States transportation to sustain a strong competitive position in domestic and world markets.

Situation: Increasing Vulnerability

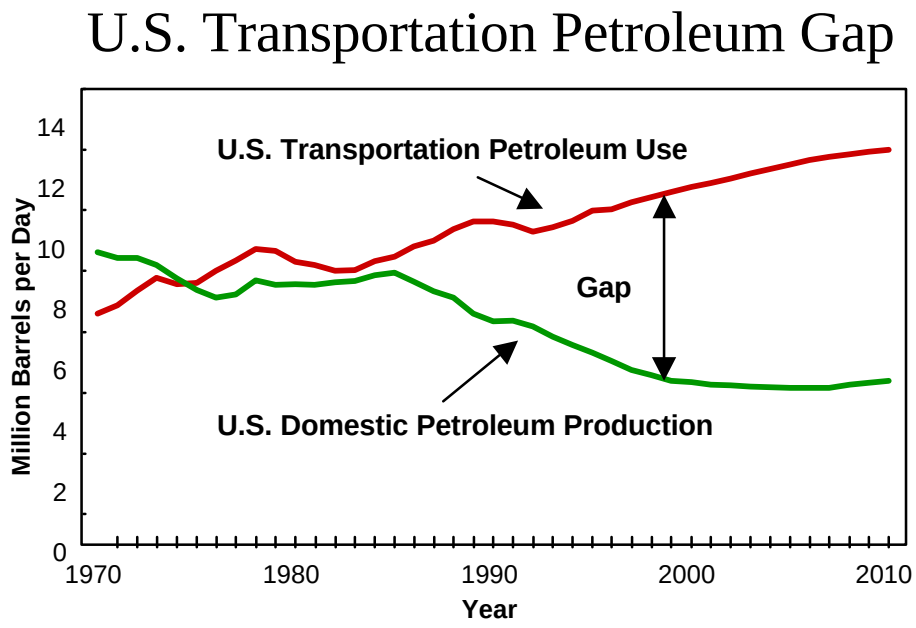
Transportation accounts for 67% of the petroleum consumed in the U.S., and the transportation sector is almost totally dependent on petroleum. The explosive popularity of low fuel economy pickup trucks, vans, and sport utility vehicles used for personal transport, coupled with a growing economy, fuel prices that are at an all-time low in real terms, increasing numbers of drivers, and increasing miles traveled by each vehicle continue to push transportation fuel consumption higher. Other impacts are high levels of air emissions and further growth in greenhouse gas emissions. Given projections of substantial growth in the number of vehicles, the best approach to alleviating such impacts is the development of vehicles with substantially higher fuel economy, and the widespread use of clean, non-petroleum fuels.

The transportation sector budget primarily supports high-risk research and development, with the goal of making breakthroughs which offer potentially large benefits in energy security, reduced emissions and economic growth. Current market pricing of fuels and vehicles mitigate against the private sector making such investments on its own.

PROGRAM MISSION - TRANSPORTATION SECTOR (Cont'd)

- **Growing dependence on petroleum**
  Demand for petroleum has grown steadily during the 1990s. Worldwide 1997 petroleum demand was 73.2 million barrels per day, up from 67 million barrels per day in 1993. The growth of economies among the world's developing nations means competition may greatly increase for petroleum on the world market. U.S. demand will continue to grow, as the number of U.S. light vehicles is projected to increase from 178 million in 1997 to 254 million by 2020, according to the Energy Information Administration (EIA). EIA projects that U.S. oil consumption will rise from 18.4 million barrels per day (mbd) in 1996 to 24.7 mbd in 2020. When these demand trends are coupled with projections that world oil production might peak within 20 years and begin to gradually decline, the potential for serious economic dislocation becomes apparent.

- **Significant contribution of highway vehicles to urban air quality problems**
  In urban areas, a significant portion of air pollution is attributable to transportation (78% of carbon monoxide, 45% of nitrogen oxides, 37% of volatile organic compounds, 26% of particulates). Vehicles also generate 32% of atmospheric carbon dioxide emissions. Concentrations of carbon dioxide, a primary greenhouse gas, are thought to contribute to global climate change.



- **Economic impact of the nation's transportation sector**
  The domestic vehicle industry is the nation's largest manufacturing industry; all transportation activity accounts for 7.4% of American jobs, and total transportation outlays account for 16.3% of the gross domestic product. U.S. car companies are among the nation's leading consumers of glass, iron, and rubber, and they lead the nation in purchases from small business. The development of advanced vehicle technologies for automobiles and trucks will improve U.S. leadership in the increasingly competitive world market for the production of competitively-priced, fuel-efficient, low-emission vehicles.

PROGRAM MISSION - TRANSPORTATION SECTOR (Cont'd)

Strategic Goal and Approach

Reflecting the fact that over three-fourths of total transportation sector energy consumption is used by cars and trucks, the transportation sector's program is focused almost exclusively on reducing oil consumption in these vehicles. In support of DOE's overall strategic goal to promote secure, competitive and environmentally responsible energy systems, the transportation sector program goal is use of advanced petroleum-based transportation fuels, non-petroleum fuels, and more efficient vehicles sufficient to reduce year 2010 projected highway transportation oil consumption by 10% from the 2010 baseline forecast by EIA in its 1999 *Annual Energy Outlook*. The program will contribute to development, by 2004, of prototype mid-sized cars and light trucks with up to three times the fuel economy of their conventional counterparts. These technologies will also reduce vehicle criteria pollutant emissions to at least the more stringent of U.S. EPA or State of California standards, without compromising safety, performance, comfort, and cost.

Recognizing the reality that industry must at some point make a substantially greater financial investment than government, if advanced vehicles and new fuels are to be successfully produced and sold, industry is an indispensable partner in the planning and integration of DOE-funded technology development programs. Nearly all programs are cost shared by the private sector, and programs involving major expenditures are periodically peer-reviewed by independent scientists and engineers. Funds are utilized by hundreds of entities—small and large—including industrial, university, national laboratory, and government organizations. Coordination and establishment of research portfolio priorities are accomplished by technical teams comprised of representatives from industry, government, and national laboratories. Teams develop technical roadmaps to overcome both technological and cost barriers in their respective technology areas.

A relatively small portion of the budget (7%) is for the purpose of informing potential customers about the status of advanced vehicles and fuels, and for participation in highly-leveraged partnerships to accomplish test programs and innovative approaches to the introduction of new technologies. The office participates actively in the Special Project State Grants, working closely with State and local governments to develop and deploy advanced vehicle technologies and alternative fuels.

Budget Structure

A portfolio of technology requirements results from the planning activities accomplished jointly by industry and government. To achieve automobiles and trucks with high fuel economy will require industry to successfully integrate the results of multiple technology development programs—including propulsion systems, energy storage, control systems, and advanced emissions reduction technologies. Development of these "enabling" technologies is included in the Vehicle Technologies R&D element of the budget.

In order to accomplish the broad national goals indicated above for future transportation vehicles, development of the fuels to be used in those vehicles will also be required. Fuels-related activities are included in the Fuels Utilization R&D element of the budget. These activities encompass work required on both petroleum-based fuels and non-petroleum fuels.

PROGRAM MISSION - TRANSPORTATION SECTOR (Cont'd)

Timely availability of new materials and materials manufacturing technologies is critical for the development and engineering of advanced transportation vehicles. Research and development of propulsion system materials and lightweight vehicle materials are included in the Materials Technologies element of the budget.

The Technology Deployment element of the budget supports activities to accelerate the market acceptance and purchase of highly efficient vehicles, fueled by either petroleum, petroleum-based blends, or non-petroleum fuels; and conventional vehicles which use alternative fuels.

The Management and Planning element of the budget provides funds for salaries, travel, and training of DOE staff responsible for managing the transportation sector program.

Management responsibilities for all research and development activities are aligned with vehicle "platforms." The Office of Transportation Technologies (OTT) reports to the Assistant Secretary for Energy Efficiency and Renewable Energy. Within OTT, the Office of Advanced Automotive Technologies provides "platform management" for automobiles and light trucks (Class 1 and 2); the Office of Heavy Vehicle Technologies is responsible for developing and implementing programs related to medium trucks (Classes 3 through 6) and heavy trucks (Classes 7 and 8).

The following matrix relates each element of the transportation sector budget to the vehicle platform, or platforms, directly supported by that element. In many cases where there is not direct support, the R&D activity also has potential "spin-off" benefits for other platforms. For example, fuel cell development activities are focused specifically on achieving characteristics required for successful applications in automobiles; but advances made could well result in truck, bus, and stationary applications.

PROGRAM MISSION - TRANSPORTATION SECTOR (Cont'd)

Program Activity	Automobiles	Light Trucks (SUVs, minivans, pickups)	Medium Trucks (delivery vans)	Heavy Trucks
Vehicle Technologies R&D				
Hybrid Systems R&D	✔	✔	✔	✔
Fuel Cell R&D	✔			
Advanced Combustion Engine R&D	✔	✔		✔
Cooperative Automotive Research for Advanced Technologies	✔			
Electric Vehicles R&D	✔			
Heavy Vehicle Systems R&D				✔
Fuels Utilization R&D				
Advanced Petroleum Based Fuels	✔	✔	✔	✔
Alternative Fuels	✔	✔	✔	✔
Materials Technologies				
Propulsion Materials Technology	✔	✔		✔
Lightweight Materials Technology	✔			✔
Technology Deployment	✔	✔	✔	✔
Management and Planning	✔	✔	✔	✔

PROGRAM MISSION - TRANSPORTATION SECTOR (Cont'd)

Program Benefits

The following benefits are projected from sustained multi-year funding of the transportation program.

Metric	2000	2010	2020
Primary Energy Displaced (quadrillion Btus)	0.01	1.21	3.04
Primary Oil Displaced (million barrels per day)	0.04	0.85	1.77
Energy Cost Savings ($ billion)	0.19	9.87	22.11
Carbon Reductions (million metric tons)	0.44	24.81	59.78

These benefits correspond to approximately 1.2 million alternative fueled vehicles employed in the year 2000. In the year 2010, the transportation sector would have nearly 2.6 million compressed natural gas vehicles, 1.7 million electric vehicles, and about 8.3 million advanced high fuel economy vehicles resulting from the Partnership for a New Generation of Vehicles (PNGV). By the year 2020, the PNGV vehicle population would be about 32 million vehicles. Also by 2020, the amount of biomass ethanol used in transportation would be about 12 billion gallons, with most of this in gasoline blends. About 613,000 advanced diesels would be employed in heavy trucks, accounting for about 12% of the heavy truck stock.

Studies estimate that developing countries will be major markets for technologies supported by this budget. While U.S. and European vehicle sales will grow modestly, sales in developing countries are expected to increase by over five percent annually. This provides a large export market opportunity for America's transportation industry, potentially also leading to the creation of jobs in the U.S.

In order to realize the market penetration of alternative fueled vehicles estimated above, an aggressive program has been structured to support the widespread use and distribution of natural gas as a transportation fuel. The following table lists the funding sources that support the Office of Transportation Technologies' natural gas activities.

PROGRAM MISSION - TRANSPORTATION SECTOR (Cont'd)

OTT Natural Gas Utilization Programs ($ millions)

Category/Project	FY 1998 Approp.	FY 1999 Approp.	FY 2000 Request	Assumptions
Natural Gas Vehicles (Conventional):				
Automotive Alternative Fuels R&D	2.65	2.00	0.50	Natural Gas R&D Plan
Medium/Heavy Truck Alternative Fuels R&D	8.00	8.30	10.60	Natural Gas R&D Plan; GRI proposal for FY 2000
Technology Deployment	5.50	6.20	8.20	60% Clean Cities; 25% of Testing and Evaluation; 60% of EPACT Replacement Fuels
Total Natural Gas Vehicles	16.15	16.50	19.30	
Natural Gas for Fuel Cells:				
Fuel Cell R&D	4.71	6.70	8.00	20% of program
Total Natural Gas for Fuel Cells	4.71	6.70	8.00	
Materials Technologies:				
Automotive Propulsion Materials	1.30	0.59	0.60	20% of program
Heavy Vehicle Propulsion Materials	1.24	1.31	1.50	25% of program
High Temperature Materials Laboratory	1.30	1.36	1.75	25% of program
Total Materials Technologies	3.84	3.26	3.85	
Total OTT Natural Gas Utilization	24.70	26.46	31.15	

DEPARTMENT OF ENERGY
FY 2000 CONGRESSIONAL BUDGET REQUEST
ENERGY CONSERVATION
(Dollars in thousands)

PROGRAM FUNDING PROFILE

Transportation Sector

Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Base	FY 2000 Request	Program Change Request vs. Base Dollar	Program Change Request vs. Base Percent
Vehicle Technologies R&D Operating Expenses	$ 119,062	$ 125,936	$ 125,936	$ 168,080	$+42,144	+33.5%
Fuels Utilization R&D Operating Expenses	17,024	17,785	17,785	23,500	+5,715	+32.1%
Materials Technologies Operating Expenses	33,870	37,475	37,475	33,000	-4,475	-11.9%
Technology Deployment Operating Expenses	12,416	12,950	12,950	17,700	+4,750	+36.7%
Management and Planning Operating Expenses	7,600	7,925	7,925	9,820	+1,895	+23.9%
TOTAL	$ 189,972	$ 202,071	$ 202,071	$ 252,100	$+50,029	+24.8%
Summary						
Capital Equipment	0	37,475	875	1,700	825	94.2%
Operating Expenses	$ 189,972	$ 202,071	$ 201,196	$ 250,400	$+48,329	+23.9%
Total Program	$ 189,972[a]	$ 202,071	$ 202,071	$ 252,100	$+50,029	+24.8%
Staffing (FTE's)						
HQ FTEs	62	58	58	55		
Field FTEs	1	1	1	1		
Total FTEs	63	59	59	56		

[a/] Reflects adjustment for approved reprogrammings 98-R-6 of $-3,112.0 thousand for the Small Business Innovative Research (SBIR) program and $-187.0 thousand for the Small Business Technology Transfer Pilot Program (STTR) activities.

Authorizations:

P.L. 93-275, "Federal Energy Administration Act of 1974"
P.L. 93-577, "Federal Nonnuclear Energy Research and Development Act of 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 of 1976"
P.L. 95-91, "Department of Energy Organization Act" (1977)
P.L. 95-238, Title III - "Automotive Propulsion Research and Development Act of 1978"
P.L. 96-512, "Methane Transportation Research, Development and Demonstration Act of 1980"
P.L. 100-494, "Alternative Motor Fuels Act of 1988"
P.L. 102-486, "Energy Policy Act of 1992"

DEPARTMENT OF ENERGY
FY 2000 CONGRESSIONAL BUDGET REQUEST
ENERGY CONSERVATION
(dollars in thousands)

SUMMARY OF CHANGES

Transportation Sector

FY 1999 Enacted	$	202,071
- Non-Discretionary		0
FY 2000 Base	$	202,071

Vehicle Technologies R&D

- Hybrid Systems R&D - The increase reflects an increased emphasis on hybrid propulsion system development for heavy duty commercial applications, such as urban delivery vehicles and buses. The increase also supports greater activity on two critical component areas, advanced power electronics and high power energy storage	+6,760
- Fuel Cell R&D - The increase reflects a greater emphasis on fuel processor development, system integration issues, and demonstration of advanced bipolar plate and membrane-electrode assembly manufacturing processes to reduce costs of critical components	+7,879
- Advanced Combustion Engine R&D - The increase reflects the imperative to develop internal combustion engines which can achieve both high fuel economy and very low emissions. Work will increase on both gasoline and diesel-fueled direct injection engines, with greater emphasis on exhaust treatment technologies. The increase is necessitated by strict emission regulations introduced by the California Air Resources Board, and the expected acceleration of heavy duty truck emission regulations by EPA	+18,125
- Cooperative Automotive Research for Advanced Technologies - The increase reflects a modest expansion in Graduate Automotive Technology Education fellowships, and in the Cooperative Automotive Research for Advanced Technology (CARAT) program. A limited number of CARAT projects would move to phase 2, concurrent with providing funding for the highest payoff new projects	+4,700

SUMMARY OF CHANGES: Transportation Sector (Cont'd)

- Electric Vehicle R&D - The increase reflects additional funding for research, development, and validation testing of lithium-based batteries, and initiation of a third phase development with the United States Advanced Battery Consortium . . . . . +2,180

- Heavy Vehicle Systems R&D - The increase reflects enhanced activities aimed at reducing heavy vehicle parasitic energy losses, which could double heavy truck fuel economy independent of improvements in diesel engine efficiency. . . . . +2,500

Fuels Utilization R&D

- Advanced Petroleum Based Fuels - The increase reflects additional support for the investigation of fuel blends to enable propulsion technologies from the Partnership for a New Generation of Vehicles to meet projected emission regulations; and expanded testing of fuels in heavy truck engines to assess the performance, economic, and emissions impacts . . . . . +5,785

- Alternative Fuels - The slight decrease reflects a shift in emphasis to support efforts being done in partnership with energy companies and vehicle/engine manufacturers on Advanced Petroleum Based Fuels. Work will be initiated which supports natural gas hybrid vehicles and small-scale natural gas refueling stations . . . . . -70

Materials Technologies

- Propulsion Materials Technology - The increase reflects the acceleration of: (a) developing thermal barrier coatings for higher efficiency/lower emissions engines; (b) developing materials for the diesel fuel system, to achieve NOx and particulate reduction, and advanced air handling systems; and (c) testing of prototype components for heavy vehicles. . . . . +840

- Lightweight Materials Technology - The decrease reflects completion of development work on lightweight materials for vehicle bodies, and the requirement for planning to establish new research priorities . . . . . -6,875

- High Temperature Materials Laboratory - The increase reflects a request for funds to purchase a one-of-a-kind high resolution electron microscope that will greatly enhance the ability to detect and quantify chemical species that control the physical properties of vehicular materials. This acquisition will maintain the laboratory's state-of-the-art technical and scientific level diagnostic and characterization capabilities for advanced materials . . . . . +1,560

SUMMARY OF CHANGES: Transportation Sector (Cont'd)

Technology Deployment	
- Clean Cities - The increase largely reflects a change in methodology to consolidate State Energy Program special project funding into this budget element, to support the demonstration of alternative fuel and advanced vehicle technologies	+2,795
- Testing and Evaluation - The increase reflects expansion of electric vehicles in the Federal fleet and demonstration of low cost natural gas refueling technology	+1,080
- EPACT Replacement Fuels Program - The increase reflects efforts to track and improve compliance with Energy Policy Act alternative fuel vehicle programs	+715
- Advanced Vehicle Competitions - The increase reflects increased opportunities for university students to work on advanced vehicle technologies and contribute to the development of advanced vehicles	+160
Management and Planning	
- Technology Assessment and Analysis - The increase reflects the initiation of a major analytic study to estimate the incremental cost of technologies such as hybrid vehicles, fuel cell vehicles, and electric vehicles so that incentives and other programs can be refined	+800
- Program Direction - The increase reflects normal pay raises and increased cost of benefits	+1,095
FY 2000 Congressional Budget Request	$ 252,100

TRANSPORTATION TECHNOLOGIES
TRANSPORTATION SECTOR
(dollar in thousands)

VEHICLE TECHNOLOGIES R&D

I. Mission Supporting Goals and Objectives:

I. A. Program Strategy

The mission of the Vehicle Technologies R&D program is to develop technologies that will produce dramatic improvements in fuel economy for automobiles and trucks, without sacrificing either environmental performance or affordability.

Specifically, quantitative goals include:

The Vehicle Technologies R&D Program works with partners in industry, universities, and laboratories to make possible the advanced technologies that will lead to high fuel economy, cleaner vehicles and a stronger economy.

- By 2002, advanced clean diesel engine technologies that enable commercial production of pickup trucks, vans, and sport utility vehicles (SUVs) that achieve at least a 35 percent full efficiency improvement relative to current gasoline-fueled trucks.
- By 2004, advanced technologies that enable pre-production prototype automobiles with three times the fuel economy of today=s conventional automobiles, a primary goal of the Partnership for a New Generation of Vehicles (PNGV).
- By 2004, advanced diesel engine and vehicle systems technologies for Class 7 and 8 trucks which allow fuel flexibility, reduced emissions and reduced parasitic losses (aerodynamic drag, rolling resistance, and drive line losses), thereby increasing the fuel economy of new heavy trucks to 10 miles per gallon (mpg) from the current 7 mpg.

The goals of the Vehicle Technologies R&D program are aligned with the Department of Energy=s Strategic Plan (September 1997) and contribute to achieving the strategic goals for two of the Department=s four business lines: *Energy Resources,* and *Science and Technology*. With its focus on improving the efficiency of transportation energy use, while limiting environmental impacts, this program seeks to reduce U.S. vulnerability to disruptions in energy supplies. The R&D portfolio is structured to deliver leading edge technologies that are critical to the DOE mission and the nation, and to utilize and enhance research capabilities at the national laboratories and educational institutions.

The strategic approach to meeting these goals involves partnering with industry to identify and remove the technology shortfall barriers to the viability of high-payoff technologies. Most of the R&D activities to be conducted through 2004 are in direct support of government/industry partnerships. To overcome specific barriers, technology roadmaps are developed by teams comprised of scientists and engineers from the

I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont=d)

Department of Energy, the national laboratories, and industry. To ensure that developed technologies are indeed practical for vehicle applications and to ensure the maximum ultimate benefit from the R&D investment, all activities are:

Systems driven: All technical targets for R&D of component/subsystem technologies are derived from a common vehicle-level perspective, and the resultant technologies are validated in the context of a vehicle operating environment.

Barrier focused: Funds are concentrated on those technical barriers in the technology development critical path that are of high priority, but require high-risk R&D that would not be conducted independently by industry.

A major principle of this approach is that the program will not address technology R&D that industry is already conducting or is likely to conduct on its own. Continuous coordination with industry will be required to: (1) understand industry=s R&D needs and agenda, and (2) establish and maintain a mutual agreement on the appropriate portfolio of cooperative, high-risk research.

Key Milestones

2000 Major domestic automakers incorporate the most promising Partnership for a New Generation of Vehicles (PNGV) technologies in concept vehicles which would achieve up to three times the average fuel economy of the 1993 Taurus, Lumina, and Concorde models.

2001 Complete test and evaluation of an integrated, 50-kW (vehicle-size) fuel cell propulsion system that includes a fuel-flexible onboard fuel processor, and which demonstrates near-zero emissions and a total system efficiency of 40 percent at 25 percent of peak power.

2002 Complete modifications and initiate field tests of light trucks with engines which demonstrate a 50% increase in mpg and compliance with 2004 emission standards.

Appropriate Federal Role: The primary government research and development role is to support long-range, high-risk activities where breakthroughs offer large potential payoffs to the nation, but are not reflected in current market pricing. This support includes funding, as well as access to unique R&D capabilities within the Federal laboratory system. With fuel prices at historic lows, transportation exemplifies a sector where a lack of market demand, combined with realistic requirements for private sector return on investment, provide industry with little or no incentive to undertake high-risk research on its own to achieve breakthrough improvements in efficiency. Such breakthrough improvements would clearly contribute to achieving national goals of reducing petroleum dependence and decreasing emissions, while having a positive long-run economic impact. It is also appropriate for the government to support research on technologies which foreign competitors may be close to

commercializing. For economical and environmental reasons, our domestic auto producers must continue to be at the leading edge of advanced vehicle technology development.

I. B. Program Benefits

Metric	2010	2020
Primary Energy Displaced (quadrillion Btu)	0.84	1.99
Primary Oil Displaced (million barrels per day)	0.47	1.05
Energy Cost Savings ($ billion)	8.86	20.75
Carbon Reductions (million metric tons)	15.98	38.01

By the year 2000, primary oil displaced by transportation sector programs will exceed 2 billion gallons annually. By 2020, there will be about 72 million light duty advanced direct injection diesel and spark ignited vehicles in operation, and nearly 32 million vehicles using other PNGV-developed technologies, such as hybrids and fuel cells.

I. C. Performance Measures

Hybrid Systems R&D

A hybrid propulsion system combines major elements of two propulsion subsystems in an automobile, so that the advantages of each can be exploited. There are generally two energy storage elements (usually a liquid fuel and an electric battery) and two energy conversion elements (generally an engine and an electric motor).

Activity Summary: The Hybrid Systems R&D activities include a number of important vehicle enabling technology areas: propulsion subsystems, high power energy storage, power electronics, and heavy vehicle systems. The R&D for these technologies is determined through a disciplined approach consisting of three elements: (1) setting the Asystem driven@ performance targets and requirements; (2) developing propulsion technologies and integrating them to complete the desired subsystems; and (3) validating performance targets and program objectives within the context of a total vehicle system. The latter activity relies heavily on developing component and system models, and validating them both analytically and experimentally.

One of the key enabling technologies for hybrid vehicle systems is high power energy storage. The focus of the high power energy storage activities is development of two high power battery technologies**C**lithium-ion and nickel-metal hydride. Both are being developed, first to

I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont=d)

establish the basic performance and life capabilities in small laboratory cells, and then to demonstrate the technologies in full-size modules, and ultimately in full capacity battery energy storage systems validated testbed vehicles. Advanced power electronic activities are focused on lowering the cost, weight, and size, and improving the efficiency, of automotive power electronics through the development of an Automotive Integrated Power Module (AIPM), as well as through the development of permanent magnet, switched reluctance, and induction motor technologies.

Truck and bus vehicle manufacturers, and their component providers, are at an early stage of technology demonstration, building on hybrid propulsion technologies that have resulted in large measure from Federally-supported research programs. The tests of these demonstration vehicles show a 50% improvement in fuel efficiency but, more importantly, a 95% reduction in particulates and a 30% reduction in oxides of nitrogen emissions using conventional fuels (and even lower with natural gas). At the current level of effort, demonstration systems will require several more years of development to become cost competitive with conventional systems. Each additional year exposes the technology to increased competitive business pressures. The heavy vehicle hybrid program intends to shorten that exposure by supplementing industry=s investment in the early stages of cost reduction and performance optimizing developments.

Hybrid Systems R&D activities support all light and heavy vehicle platformsCfrom 5-passenger sedans, sport utility vehicles and light trucks, and medium and heavy trucks/buses. Each platform has its own duty cycle, market sector, and performance requirements.

Partners: The Hybrid Systems R&D program involves coordination and cooperation with many industrial firms, other Federal agencies and national laboratories. In the propulsion and ancillary subsystem area, partners include Tier 1 suppliers of the automotive and truck manufacturers to support propulsion development; Argonne National Laboratory for screening, benchmarking, developing, and evaluating concepts; the National Renewable Energy Laboratory for accessory load reduction, systems modeling and analysis; and the United States Council for Automotive Research (USCAR), under a cooperative agreement with the PNGV systems analysis technical team. The high power energy storage development efforts are conducted through a cost-shared cooperative agreement with the U. S. Advanced Battery Consortium (USABC), a partnership composed of Chrysler, Ford, General Motors, and the Electric Power Research Institute (EPRI), and, through development contracts with the USABC, Saft America, Inc., PolyStor, and VARTA. High power electronics development is coordinated among AIPM suppliers, the Institute of Electrical and Electronic Engineers (IEEE) committee that develops specifications, and USCAR through cost-shared financial assistance agreements with the AIPM candidate suppliers. The Defense Advanced Research Projects Agency, EPRI, the Navy, and other agencies assist in selection and sub-component development. Cost-sharing for the Hybrid Systems R&D program is estimated at 50%.

In support of DOE=s strategic goal, the Office of Advanced Automotive Technologies R&D Plan (March 1998, DOE/ORO/2065) addresses the goals, objectives, technical barriers, approach, and plans for developing advanced automotive technologies. Technology roadmaps jointly developed with USCAR and USABC provide a list of technical goals and strategies for developing high power batteries, power electronics,

I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont'd)

and electric machines by 2004. These roadmaps are coordinated with PNGV technical teams, and include the Department's strategic goal to promote secure, competitive, and environmentally responsible energy systems. Laboratory R&D is also coordinated with the technical roadmaps and is addressed in each of the laboratory's annual operating plans. The technology roadmap of the Office of Heavy Vehicle Technologies reflects the growing interest in the use of hybrid propulsion technology in commercial transportation. The roadmap is coordinated with programs in the Department of Transportation and the Environmental Protection Agency, and is supported by the truck and bus manufacturing industry as an appropriate strategy for introducing advanced technology into commercial practice.

Goals: In FY 2000, the Hybrid Systems R&D program goals for light duty vehicles include demonstrating achievement of performance targets for two key enabling technologies: (1) a 50-volt lithium-ion battery module with a 10-second power to energy ratio of 25 watts/watt-hour, a specific energy of 45 watt-hours/kilogram, cycle life of 125,000, and a projected cost of $350/kilowatt-hour; and (2) a high power electronic power module that has a specific power of 4 kilowatts per kilogram (kW/kg), efficiency of 95 percent, and costs $10/kW at 100,000 units per year. Achievement of these goals will be a major step toward removing energy storage and energy management barriers to hybrid systems for 80 mpg vehicles, and will allow integration of these technologies in testbed vehicles for test and validation the next year. For medium and heavy trucks, an 80% improvement in fuel efficiency, a 95% reduction in particulate emissions, and a 30% reduction in oxides of nitrogen emissions will be demonstrated in a test vehicle in FY 2000.

Pre-FY 1998 Accomplishments

- Completed preliminary Power Electronic Building Block modules (PEBB) for use in motor inverters intended to achieve 50% reduction in cost, weight, and volume.
- Completed testing of four baseline prototype high power battery cells, and selected two baseline technologies for development of 50-volt prototype modules.

FY 1998 Accomplishments

- Completed development and testing of 50 mpg series hybrid propulsion system for a mid-size vehicle.
- Fabricated first generation 50-volt nickel metal hydride power modules and initiated life cycle testing.
- Completed PEBB basic R&D technology and validated performance against PNGV targets; redirected efforts to integrate PEBB component technologies toward developing an Automotive Integrated Power Module (AIPM).

FY 1999 Planned Accomplishments

- Complete development and testing of 50 mpg parallel hybrid propulsion systems for mid-size vehicles, and continue technology development and integration activities aimed at 80 mpg vehicles.
- Complete 1st generation 50-volt high power energy storage lithium-ion module development; initiate performance characterization and life cycle testing at DOE laboratories. Complete cycle testing of 1st generation 50-volt nickel metal hydride high power modules.

I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont=d)

FY 2000 Planned Accomplishments

- Complete testing of baseline, prototype, 50-volt high power lithium-ion modules. Select one or two of the baseline technologies for development of 200-volt battery aimed at satisfying the PNGV high power energy storage requirements of hybrid vehicles.
- For medium and heavy trucks, initiate cooperative agreements with two development teams. During the first year, demonstrate an 80% improvement in fuel efficiency, 95% reduction in particulate emissions, and 30% reduction in oxides of nitrogen emissions compared to current production. Test vehicle results will be the basis for a production feasible design development over the following 3-year program.

FY 2001 - FY 2004 Accomplishments

- Complete design of a multi-platform propulsion system to be used in urban trucks and buses. The design will incorporate the inputs from fleet managers involved in initial test vehicle trials. (FY 2003)
- Demonstrate propulsion system, advanced battery, high power electronic and accessory technologies in a rolling test platform capable of meeting PNGV goals. (FY 2004)

Fuel Cell R&D

Activity Summary: The Fuel Cell R&D program focuses on overcoming the critical technology barriers to developing and validating viable fuel cell systems for automotive applications. Fuel cell technology developed under the program is also directly applicable to light truck and heavy duty vehicle applications (e.g., buses). Fuel cells are critical to meeting the goal of an 80 mpg vehicle with extremely low emissions, and have been selected by the PNGV as a priority technology. Particular emphasis is placed on achieving high fuel use efficiency, long life, very low emissions, and low manufacturing costs. This is done through component development, subsystem development, and technology integration and validation of fuel cell stack systems, fuel-flexible fuel processors, and onboard hydrogen storage.

Partners: Industrial partners perform research and development through cost-shared contracts and cooperative agreements in the areas of integrated fuel cell systems, stack subsystems, air management and fuel cell components. Current partners are: International Fuel Cells, Plug Power, Epyx, Hydrogen Burner Technology, AlliedSignal, Energy Partners, the Institute of Gas Technology, Electrochem, Spectracorp, Foster-Miller, 3M, A.D. Little, Vairex, and Meruit. National laboratories have a major role in this program performing fundamental research, technology transfer, independent testing and evaluation, and technical support. Through PNGV, automotive partners assist in establishing systems requirements, goals, and R&D priorities, and support performing systems analyses and technical project reviews. Cost-sharing for the Fuel Cell R&D program is estimated at 20%.

The five-year Fuel Cells Program Plan is described in Section 3.3 of the Office of Advanced Automotive Technologies R&D Plan (March 1998, DOE/ORO/2065). Program technical targets are consistent with the PNGV Fuel Cell Technical Team Roadmap. This is a synergistic

I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont=d)

program with many interactions among DOE laboratory and industry partners. These relationships have resulted in Memoranda of Understanding, Non-Disclosure Agreements for Cooperative Research, and informal joint ventures. Laboratory research and development is planned and managed through Annual Operating Plans.

Goals: Detailed technical targets have been established for system cost, efficiency, power density, specific power, start-up and transient response times, durability, and emissions. In FY 2000, system level goals include achieving 40% energy efficiency, near-zero emissions, 250 watts/liter (w/l) power density, and $150 per kilowatt (kW) cost. By 2004, in collaboration with the fuel cell industry, national laboratories, and automotive suppliers, the goal is to develop and validate automotive fuel cell power systems that operate on conventional and alternative fuels, and that are highly efficient, have low or zero emissions, and are equivalent to the internal combustion engine in terms of projected high volume cost, performance, range, safety, and reliability.

Pre-FY 1998 Accomplishments

- Demonstrated a fuel-flexible 50-kW fuel processor for fuel cell applications operating at high efficiency and capable of reforming conventional and alternative transportation fuels (i.e., gasoline, ethanol, etc.).

FY 1998 Accomplishments

- Completed laboratory validation of 50-kW hydrogen-fueled proton-exchange-membrane (PEM) fuel cell brassboard and 30-kW methanol-fueled PEM fuel cell brassboard.
- Conducted the world=s first demonstration of a PEM fuel cell system running on gasoline.

FY 1999 Planned Accomplishments

- Initial validation of fuel cell membrane electrode assemblies manufactured under a continuous process, incorporating less precious metals and a unique catalyst structure.

FY 2000 Planned Accomplishments

- Demonstrate a 50-kW fuel cell stack system that runs on fuel other than pure hydrogen, and is integrated with sensors, controls, and thermal and air management systems.
- Demonstrate a high efficiency fuel-flexible 50-kW fuel processor integrated with advanced shift reactor, fuel vaporizer and CO clean-up.

FY 2001 - FY 2004 Planned Accomplishments

- Complete test and evaluation of a fuel-flexible 50-kW integrated fuel cell power system (near-zero emissions, limited start-up and transient response, and high efficiency). (FY 2002)

I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont=d)

- Complete development of a fuel-flexible 50-kW integrated system meeting year 2004 PNGV technical targets. (FY 2004)

Advanced Combustion Engine R&D

Activity Summary: The Advanced Combustion Engine R&D program is focused on overcoming the critical technical barriers to developing highly efficient, emissions compliant, direct injection gasoline and diesel engines. The program seeks to achieve low particulate and NOx emissions while pursuing further improvements in thermal efficiency. The engine research is applicable to hybrid as well as conventional vehicles. Applications of the resulting engine and emissions aftertreatment technologies will be in light truck, heavy truck, and automotive platforms.

Partners: In the automobile program, partners include Chrysler, Ford, General Motors and their Tier I suppliers of catalysts and fuel injection equipment. For the light truck program, partners include Caterpillar, Cummins, and Detroit Diesel Corporation, with U.S. vehicle manufacturers as the vehicle integrators. For the heavy truck program, partners include the diesel engine industry, heavy truck manufacturers and their suppliers. Combustion and exhaust aftertreatment research is also carried out by several national laboratories through Cooperative Research and Development Agreements (CRADAs) with industrial partners, and with universities through grants. Cost-sharing for the Advanced Combustion Engine R&D program is estimated at 50%.

The Office of Advanced Automotive Technologies R&D Plan (March 1998, DOE/ORO/2065) is the guiding document for all automotive technology development in the Hybrid Direct Injection Engine and Combustion and Aftertreatment R&D programs. The technical targets in the plan are consistent with the PNGV Four Stroke Direct Injection Technical Team Roadmap. Light Truck and Heavy Truck Engine R&D programs are guided by the Multi-Year Program Plan and the Technology Roadmap of the Office of Heavy Vehicle Technologies.

Goals: The goal of the Hybrid Direct Injection and Combustion and Aftertreatment R&D activities is to develop viable advanced direct injection engine technology which can achieve energy conversion efficiencies consistent with an 80 mpg fuel economy, in emissions compliant mid-size automobiles, by 2004. Technology developed under Combustion and Aftertreatment R&D programs is also applicable to light trucks. The Light Truck Engine R&D program goal is to achieve at least 35% thermal efficiency improvement relative to current gasoline powered light trucks by 2002, while meeting 2004 EPA emission standards. The Heavy Truck Engine Program goal is to increase the efficiency of heavy duty diesel engines to 55% while reducing emissions to near zero levels.

Pre-FY 1998 Accomplishments

- Initiated engine/component design, which includes modeling estimates of engine efficiency and emissions, power, size, weight, cost, and configuration, for light truck engines.

I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont=d)

FY 1998 Accomplishments
- Established a high-speed, optical access, single-cylinder engine test cell to support compression ignition (diesel) direct injection (CIDI) combustion research.
- Completed initial performance specifications of critical enabling technologies, as well as cost goals, for the high efficiency diesel engine for light trucks.

FY 1999 Planned Accomplishments
- Complete preliminary design of a PNGV CIDI aftertreatment subsystem meeting intermediate emissions targets of 0.3g/mile NOx and 0.025 g/mile particulates.
- Demonstrate advanced engine technologies that lead to at least 40-45% thermal efficiency in multi-cylinder diesel engines for light trucks, while substantially reducing NOx and particulates.

FY 2000 Planned Accomplishments
- Complete component-level testing to achieve PNGV CIDI intermediate targets of 0.3g/mile NOx and 0.025 g/mile particulates.
- Down Select an aftertreatment system, integrate into the engine system, and demonstrate performance and EPA emissions standards for prototype clean diesel engines to be used in light trucks.

FY 2001- 2004 Planned Accomplishments
- Complete modifications and initiate field test of light trucks with diesel engines, to demonstrate 35% increase in fuel efficiency relative to current gasoline powered vehicles and compliance with 2004 EPA emission standards. (FY 2002)
- Demonstrate spark ignition direct injection technology on a multi-cylinder gasoline engine achieving 35% peak thermal efficiency and meeting 2004 EPA emission standards. (FY 2003)

Cooperative Automotive Research for Advanced Technologies (CARAT)

Activity Summary: Early in FY 1998, DOE launched CARAT to ensure that universities and small businesses can fully participate in advanced automotive R&D activities. Although DOE has long funded minor R&D efforts with small businesses and universities, CARAT represents the first effort to consolidate these activities and to provide opportunities to contribute more directly to larger technology goals. The participation of small businesses and universities will help tap the full range of available technical innovation and expertise necessary to overcome the critical technology barriers preventing production of highly fuel efficient, emission compliant vehicles. CARAT supports development of high priority technologies, from laboratory scale through technology validation. The program also fosters links between the innovators and the auto

industry early in the development cycle, to enhance the potential for commercialization success. Competitive solicitations are issued each year on carefully selected technical topics. Resulting cooperative agreements can extend through three phases, with detailed reviews and go/no-go decisions after each phase.

In FY 1998, DOE launched its Graduate Automotive Technology Education (GATE) initiative to establish university graduate study programs in several critical, multi-disciplinary engineering areas. The program will provide graduate-level engineer training in the most advanced automotive technologies. Because these technologies cross normal engineering disciplines, few schools are able to offer a focused curriculum in these areas. In FY 2000, GATE will provide fellowships for the most talented engineering students to pursue graduate work in the selected technology areas. Those universities selected to participate in GATE must identify a relationship with the automotive industry and contributions that industry members will make to the program. Contributions can take the form of shared research facilities or equipment, internships for students, guest lectureships, funds, or identification of research topics for student projects. These research topics will address critical PNGV technical targets.

Partners: During the first two phases of CARAT projects, partners include small businesses, universities, and national laboratories. Phase 3 projects will add appropriate industrial partners that have the technical and financial resources to commercialize the prototype technology developed under Phases 1 and 2. Under the GATE program, DOE establishes partnerships with universities that have demonstrated strong involvement and commitment with industry partners, including both major auto manufacturers and suppliers.

Goals: One of the most significant goals in CARAT is to further progress on overcoming technology barriers which are preventing the manufacture of highly efficient, lower emission vehicles. By FY 2000, at least 13 components will be designed, tested, and evaluated for potential application in on-road vehicles. The goals of GATE are twofold: to train a future workforce of automotive engineering professionals who are knowledgeable about and experienced in developing and commercializing critical advanced automotive technologies; and to marshal the resources of the brightest university graduate students to help solve the technology barriers identified by government and industry. By FY 2000, 20 to 25 graduate students will be receiving fellowships to study and conduct research on the most critical automotive technologies.

FY 1998 Accomplishments

- Launched the Cooperative Automotive Research for Advanced Technology (CARAT) program and awarded approximately 26 cooperative agreements in 18 technical areas.

FY 1999 Planned Accomplishments

- Award approximately 20 to 25 Graduate Automotive Technology Education (GATE) fellowships at selected universities to the most qualified students.

FY 2000 Planned Accomplishments

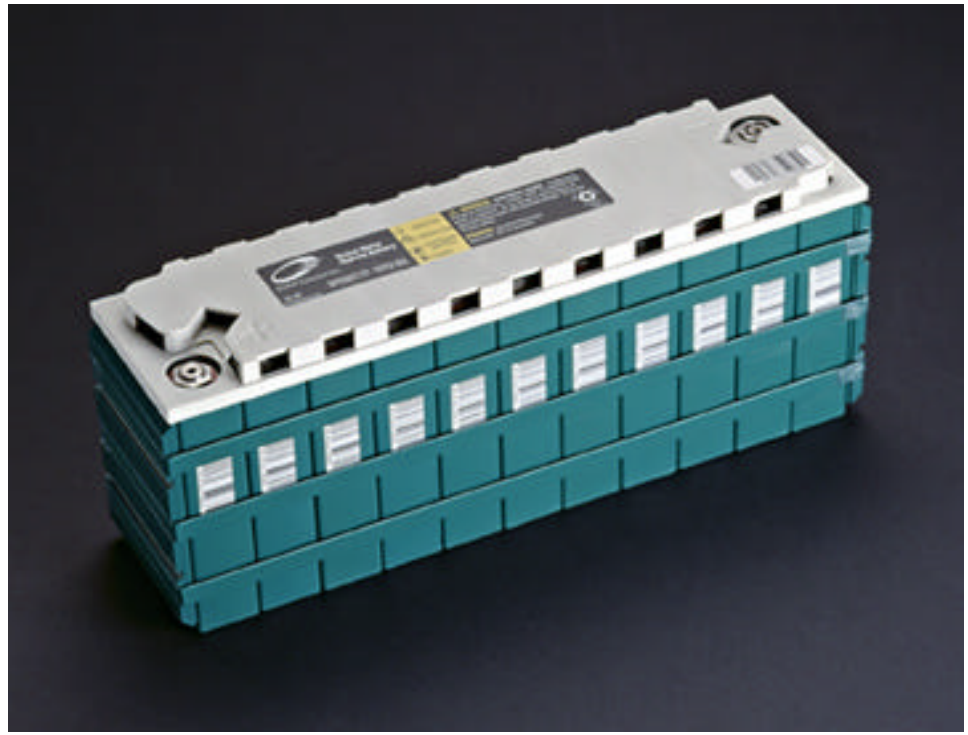
I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont=d)

- Sponsor a CARAT Workshop for auto manufacturers and suppliers to evaluate results and assess potential partnerships for Phase 3 efforts.
- Test and evaluate 13 components developed from Phase 1 and initiate at least three Phase 2 CARAT projects that show feasibility for hardware development to improve vehicle fuel economy.

FY 2001 - FY 2004 Planned Accomplishments

- Conduct an evaluation of CARAT and GATE to determine the costs and benefits. (FY 2000)
- Complete at least two successful Phase 3 CARAT projects that result in preproduction prototype components for advanced vehicles. (FY 2004)

Electric Vehicle R&D



Activity Summary: The key to the market success of electric vehicles (EVs) is the battery technology. Vehicle range is limited by current battery performance and the high cost of batteries. Under a cooperative agreement with the United States Advanced Battery Consortium (USABC), R&D resources are focused on the most promising battery candidates for electric vehicle applications. These batteries include nickel metal hydride, lithium-ion, and lithium polymer. Beginning in FY 1999, successfully developed nickel metal hydride batteries are being introduced in General Motors= EV1 automobile and S-10 pickup truck, and Chrysler=s EPIC electric van. The use of nickel metal hydride batteries instead of lead acid batteries doubles the range of these electric vehicles. In FY 2000, the R&D activities are aimed at development and validation of lithium-ion and lithium polymer batteries, which would increase the range even further. The EV platforms supported by DOE=s advanced battery development efforts are family sedans, vans, and light duty trucks.

Partners: DOE=s battery hardware development efforts are conducted through the cost-shared cooperative agreement with the USABC. Through development contracts with the USABC, VARTA is developing lithium-ion batteries and 3M/HydroQuebec is developing lithium polymer batteries. The Exploratory Technology Research program provides an exploratory and applied research base in electrochemistry

I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont=d)

focused on solving the key lithium battery barriers of calendar life, abuse tolerance, and cost. Within the Office of Transportation Technologies, test and evaluation of EVs is provided by the Testing and Evaluation program in the Technology Deployment budget. Interagency coordination on advanced battery development between DOE and the Defense Advanced Research Projects Agency is conducted through a Memorandum of Understanding. Cost-sharing for the Electric Vehicle R&D program is estimated at 50%.

In support of DOE=s strategic goal, the Office of Advanced Automotive Technologies R&D Plan (March 1998, DOE/ORO/2065) addresses the goals, objectives, technical barriers, approach, and plans for developing advanced EV batteries. The cooperative agreement between the USABC and DOE focuses on the Department=s strategic goal to promote secure, competitive, and environmentally responsible energy systems by developing advanced batteries for electric vehicles. Technology roadmaps provide a list of technical goals for advanced batteries capable of providing EVs with range and performance competitive with petroleum-fueled vehicles. Yearly program plans establish research priorities and hardware deliverables for assessment against the technical goals and incorporation into testbed vehicles.

Goals: In FY 2000, the goal of the Electric Vehicle R&D program is to fabricate lithium-based batteries with a specific power of 300 watts/kilogram, a specific energy of 135 watt-hours/kilogram, a cycle life of 1,000, and a projected cost to the original equipment manufacturer of $150/kilowatt-hour. Achievement of this goal would enable U.S. industry to commercialize increased range electric vehicles and to expand its market share in response to agreements with the States on zero-emission vehicles in 2003-2004.

Pre-FY 1998 Accomplishments

- Achieved the mid-term goal of 70 watt-hours/kilogram (Wh/kg) specific energy for nickel metal hydride batteries.

FY 1998 Accomplishments

- Initiated extensive laboratory testing of lithium-polymer electric vehicle batteries (modules and cells) which will provide 3 to 4 times the range, and significantly greater performance and life, compared to conventional lead-acid batteries.

FY 1999 Planned Accomplishments

- Initiate life cycle testing of advanced electric vehicle lithium-polymer batteries and assess performance against USABC long-term battery goal of 1,000 cycles.

FY 2000 Planned Accomplishments

- Complete extended testing of USABC long-term, lithium-polymer batteries to determine life and safety under accident conditions.

FY 2001 - FY 2004 Accomplishments

I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont=d)

- Complete core performance tests of 1st generation lithium-polymer batteries with low-cost components, and transfer the low-cost batteries to the developers for incorporation into electric vehicle platforms. (FY 2003)

Heavy Vehicle Systems R&D

Activity Summary: The Heavy Vehicle Systems R&D activity considers the total vehicle as an integrated system, and then addresses the development and application of technologies that can significantly reduce the substantial parasitic energy losses encountered in the operation of Class 7 and 8 trucks, thus contributing to the achievement of a 10 mpg heavy truck. Currently, parasitic energy consumption arises from aerodynamic drag, rolling resistance, and auxiliary onboard systems, accounting for 52%, 28%, and 20%, respectively, of all non-engine energy losses (at 65 miles per hour) in heavy vehicles. The technologies are applicable mainly to the heavy vehicle platform and contribute to increased energy efficiency, concomitant emissions reductions, and technology cost effectiveness. These technologies will be identified through the Energy Efficiency and Renewable Energy broad based solicitation to stimulate truck innovative concepts and knowledge, and competitively evaluated based on their potential for energy and emissions reduction. Devolution to lighter, smaller platforms, including passenger vehicles, is considered achievable for some technologies. Smaller but similarly focused activities addressing energy efficient buses and rail vehicles completes the program=s portfolio.

Partners: Active and potential partners and stakeholders include tractor and trailer original equipment manufacturers (OEMs), such as Freightliner, Paccar, and Wabash; equipment and component manufacturers, such as Allied Chemical and Eaton Corporation; diesel engine manufacturers, such as Cummins, Caterpillar, and Detroit Diesel Corporation; materials suppliers, such as ALCOA and Thompson Aluminum Casting; universities (Massachusetts Institute of Technology, West Virginia University, University of California, Georgia Tech Research Institute, University of Kentucky, and Tufts); other government agencies such as DOT, DOD, and DARPA, and most of the DOE national laboratories. General technical consensus is sought with industry through one-on-one confidential industry discussions and focused plenary topical workshops. Such information exchanges provide the bases for the compilation and dissemination by DOE of detailed industry-, university-, and government laboratory-reviewed and approved Multi-Year Program Plans that shape most of the R&D efforts in the programmatic area. Cost-sharing for the Heavy Vehicle Systems R&D program is estimated at 50%.
The Heavy Vehicle Systems R&D approach is incorporated into the Office of Heavy Vehicle Technologies (OHVT) Multi-Year Program Plan (MYPP) for 1998-2002 and the OHVT Technology Roadmap. Specific technology area MYPPs have been developed with industry/university/government/laboratory participation and overview. Periodic reviews and mid-course programmatic corrections and adjustments are conducted on a scheduled basis. All goals and plans are coincident with those in the strategic plan for the Office of Transportation Technologies.

I. Mission Supporting Goals and Objectives: VEHICLE TECHNOLOGIES R&D (Cont'd)

Goals: In FY 2000, the Heavy Vehicle Systems R&D goal is to identify and qualify effective technical approaches for substantially reducing parasitic energy losses due to aerodynamic drag and rolling resistance in Class 7 and 8 heavy vehicles, leading to establishment of cost-effective operational applications by 2004.

Pre-FY 1998 Accomplishments
- Conceptualized the systems approach to the non-engine energy losses in heavy vehicles; this was not an approach previously considered at DOE and not even widely recognized in the heavy vehicle industry itself.

FY 1998 Accomplishments
- Completed initial analysis of vehicle dynamics to determine prospective program direction in planning discussions with industry.

FY 1999 Planned Accomplishments
- Initiate active projects in the computational simulation and manipulation of air flow fields which create the energy-consuming aerodynamic drag of heavy vehicles.
- Initiate programs for reducing heavy vehicle energy consumption due to rolling resistance, onboard thermal management, and auxiliary power systems.
- Develop a joint program with DOT to determine safety impacts to the truck system by changes adopted to achieve operational energy efficiencies.

FY 2000 Planned Accomplishments
- Validate aerodynamic drag simulation models and initiate predictive reduced drag, higher efficiency vehicular design modifications.

FY 2001-2004 Planned Accomplishments
- Validate manufacturing cost-effectiveness of new designs. (FY 2001)
- Characterize and qualify concepts such as circulation control devices for increased operational energy efficiency and greater stability of heavy vehicles. (FY 2003)

II. A. Funding Table: VEHICLE TECHNOLOGIES R&D

Program Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Request	$ Change	% Change
Hybrid Systems R&D	$ 55,336	$ 42,140	$ 48,900	$+6,760	+16.0%
Fuel Cell R&D	22,614	33,501	41,380	+7,879	+23.5%
Advanced Combustion Engine R&D	18,318	37,675	55,800	+18,125	+48.1%
Cooperative Automotive Research for Advanced Technologies	3,276	2,300	7,000	+4,700	+204.3%
Electric Vehicle R&D	17,818	8,820	11,000	+2,180	+24.7%
Heavy Vehicle Systems R&D	1,700	1,500	4,000	+2,500	+166.7%
Total, Vehicle Technologies R&D	$ 119,062	$ 125,936	$ 168,080	$+42,144	+33.5%

II. B. Laboratory and Facility Funding Table: VEHICLE TECHNOLOGIES R&D

Program Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Request	$ Change	% Change
Argonne National Lab (East)	$ 13,192	$ 15,447	$ 15,405	$ -42	-0.3%
Brookhaven National Lab	300	425	425	0	0.0%
Idaho National Engineering and Environmental Lab	865	1,755	1,834	+79	+4.5%
Lawrence Berkeley National Lab	3,400	3,800	4,150	+350	+9.2%
Lawrence Livermore National Lab	1,035	2,570	2,688	+118	+4.6%
Los Alamos National Laboratory	5,252	5,788	6,825	+1,037	+17.9%
National Renewable Energy Lab	30,830	15,683	3,500	-12,183	-77.7%
Oak Ridge National Lab	7,271	7,620	7,645	+25	+0.3%
Pacific Northwest National Lab	1,857	2,090	2,580	+490	+23.4%
Sandia National Laboratories	3,431	7,815	6,102	-1,713	-21.9%
All Other	51,629	62,943	116,926	+53,983	+85.8%

Total, Vehicle Technologies R&D	$ 119,062	$ 125,936	$ 168,080	$+42,144	+33.5%

Vehicle Technologies R&D			
Hybrid Systems R&D	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Vehicle Systems R&D:	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Vehicle Systems R&D:	
	LIGHT VEHICLES PROPULSION & ANCILLARY SUBSYSTEMS: Supported final development stages of production feasible automotive hybrid propulsion technologies. Each Original Equipment Manufacturer (Ford, Chrysler, GM) fabricated next generation hybrid components and integrated into testbed vehicles to assess propulsion system configurations, design approaches, control strategies, and performance under various operational conditions and test cycles. Focused efforts to refine and improve propulsion system integration, control strategies, and reliability. Used propulsion system test data to initiate validation of predicted performance models. Completed the GM series hybrid propulsion system development	LIGHT VEHICLES PROPULSION & ANCILLARY SUBSYSTEMS: Complete integration of hybrid propulsion system components, and conduct performance testing on final deliverable testbed vehicles demonstrating achievement of 50 miles per gallon (mpg) goal. Vehicles and systems incorporate technology advancements in the areas of advanced high power batteries, CIDI engines, and thermal and mechanical integration. Validate simulation models using test data, and evaluate data against performance and cost targets. Complete Ford and Chrysler parallel hybrid propulsion system development programs.	LIGHT VEHICLES PROPULSION & ANCILLARY SUBSYSTEMS: The propulsion systems development activities required to achieve the 50 mpg goal are completed in FY 1999. The light vehicles key activities listed below for FY 2000 are re-focused on R&D directed at achieving the overall goals for the light vehicles program: (1) Develop component technologies enabling 80 mpg mid-size automobiles; and (2) 50% improvement in fuel efficiency of light trucks. Further develop computer tools by adding thermal management and optimization models. Incorporate a cost estimating function to be used as an additional parameter for making component tradeoffs for 80

Activity	FY 1998	FY 1999	FY 2000
Hybrid Systems R&D (Cont=d)	program. Achieved needed technological advancements in the areas of battery pack energy management, power electronics integration and packaging, and drive train efficiency improvements. Transitioned the hybrid propulsion R&D activities from a propulsion system development focus, toward a more comprehensive systems driven, barrier focused initiative to develop technologies needed to achieve the 80 mpg goal. Through systems modeling, began evaluating the spectrum of technology options, including lightweight materials, improved accessories, lower aerodynamic and rolling resistance losses, advanced power electronics, electric motors, transmissions, advanced compression ignition direct injection (CIDI) engines, and fuel cells to determine the best possible candidate technologies with the potential for meeting the performance and cost goals of the program. Initiated a vehicle systems integration effort to design and fabricate testbeds to evaluate advanced technologies in the	Develop and refine vehicle systems modeling, particularly in the areas of emissions and transient performance. Perform trade-off studies to determine the candidate technologies, configurations, and control strategies required to achieve the PNGV=s 80 mpg fuel efficiency, emission, and cost goals. Improve understanding of performance targets and system requirements for technologies being developed in the program. Employing models, further define concepts that can achieve the goals of the program. (NREL, INEEL, GM, Ford, Chrysler, subcontractors) (PNGV: $22,515) ($22,515)	mpg vehicle concepts. Develop methods to perform virtual component prototyping which enables examination of component concepts and designs without the cost of building and testing components. Test newly-developed components and component combinations needed for hybrid propulsion systems, to measure performance, dynamic effects, and compatibility. Evaluate components developed in other vehicle technology programs. Use test data collected to validate analytical models, feedback technical requirements to technology development programs, and assess progress toward the 80 mpg program goal. Continue to improve the definition of advanced propulsion system components and estimate their fuel economy potential, cost differential, and technical feasibility. For the most promising concepts, develop representative test articles for comprehensive evaluation. Evaluate these components and establish a
Hybrid Systems			

III. Performance Summary: VEHICLE TECHNOLOGIES R&D (Cont=d)

Activity	FY 1998	FY 1999	FY 2000
R&D (Cont=d)	context of a lightweight PNGV vehicle. Initiated focused R&D projects aimed at overcoming the critical barriers to commercialization of high efficiency hybrid technologies. Continued systems analysis work with the PNGV partnership under a cooperative agreement with the United States Council for Automotive Research (USCAR). (ANL, NREL, INEEL, GM, Ford, Chrysler, subcontractors) (PNGV: $42,306) ($42,306)		technology database for use by the automotive industry and its suppliers. (ANL, NREL, INEEL, ORNL, USCAR, other contractors) (PNGV: $16,900) ($16,900)
	HIGH POWER ENERGY STORAGE: Supported R&D on high power batteries with the U. S. Advanced Battery Consortium (USABC), with an industry cost share of 50% in FY 1998.	HIGH POWER ENERGY STORAGE: Support R&D on high power batteries with the USABC, with an industry cost share of 50% in FY 1999.	HIGH POWER ENERGY STORAGE: Support R&D on high power batteries with the USABC, with an industry cost share of 50% in FY 2000.
Hybrid Systems R&D (Cont=d)	High power energy storage devices are one of the performance-limiting subsystems in the hybrid vehicle program. Continued development of the most promising advanced battery technologies**C**nickel metal hydride and lithium-ion. Scaled up from laboratory cells to 50-volt	Complete the development of high power nickel metal hydride modules, and continue the development of lithium-ion technologies. Fabricate 50-volt high power energy storage nickel metal	Complete life verification testing of four 50-volt nickel metal hydride modules at a DOE laboratory, to validate the performance against PNGV energy storage requirements. Transfer data base and nickel metal hydride technology to Chrysler, Ford, and GM for use in their

Activity	FY 1998	FY 1999	FY 2000
	demonstration modules. Provided results from the tests on prototype full-size cells for industry application in PNGV concept vehicles. Refined energy storage/vehicle system requirements, using the test data to validate energy storage models.	hydride modules having optimized chemistry, integrated electronics, and lightweight components and cell cases. Initiate life verification testing on four of these modules at a DOE laboratory to characterize the performance against PNGV energy storage requirements for a 50-volt subsystem battery pack. Complete 1st generation 50-volt high power energy storage lithium-ion module development, initiate performance characterization and life cycle testing at DOE laboratories, and compare results to PNGV technical targets for a 50-volt module.	hybrid-electric vehicle (HEV) development efforts. Complete performance characterization of baseline prototype 50-volt lithium-ion modules and life cycle testing at DOE laboratories; compare results to PNGV technical targets. Based on the lithium-ion test results, select one or two of the competing lithium-based technologies for scale-up development to a 200-volt subsystem battery pack for application in the PNGV concept vehicle(s). Identify manufacturing processes with potential for high-volume production, and estimate subsystem lithium-ion production costs at two specified rates of production. Initiate process cost reduction efforts to meet PNGV cost targets for high power energy storage.
Hybrid Systems R&D (Cont'd)	Reassessed longer term technologies that promise further performance, life, and/or cost benefits to determine their priority for development and possible application in future energy storage systems. Acquired high voltage test equipment and accelerated rate calorimeter, to improve ability to	Initiate a national, multi-laboratory effort to focus on the research and development of diagnostic methods to evaluate and help solve high power lithium-ion degradation/failure mechanisms; to identify low cost conventional	Complete development of baseline lithium-ion cell technology. Use results in developing diagnostic techniques leading to better understanding of performance and safety as a function of changes in cell chemistry and design. Assess diagnostic techniques for ability to

Activity	FY 1998	FY 1999	FY 2000
	assess performance and thermal behavior characteristics of candidate high power battery systems.	organic electrolytes and packaging technology options which can reduce the high cost of lithium-ion cells; and to identify abuse tolerant lithium-ion electrochemical systems which enhance safety in HEV applications.	identify lithium-ion degradation/failure mechanisms as a function of cycle life and thermal cycling; develop a plan to address technical deficiencies. Select one or two low cost lithium-ion packaging technologies, fabricate cells, and validate performance against PNGV high power energy storage technical targets, with emphasis on realistic cost projections. Select one or two low cost conventional electrolytes for incorporation into full-size cells, to evaluate performance against PNGV technical targets and to assess abuse tolerance.
	Completed flywheel safety and containment efforts by demonstrating the safe containment of a flywheel during a burst test.	Complete close out of the flywheel high power energy storage program, consistent with the PNGV technology selection decisions.	No activity. ($0)
	Completed close out of the ultra-capacitor high power energy storage program, consistent with the PNGV technology selection decisions.	No activity. ($0)	No activity. ($0)
Hybrid Systems R&D (Cont'd)	(USABC, LBNL, LLNL, ORNL, INEEL) (PNGV: $8,620) ($8,620)	(USABC, ANL, BNL, LBNL, INEEL, SNL) (PNGV: $12,750) ($12,750)	(USABC, ANL, BNL, LBNL, INEEL, SNL) (PNGV: $15,000) ($15,000)

Activity	FY 1998	FY 1999	FY 2000
Hybrid Systems R&D (Cont'd)	ADVANCED POWER ELECTRONICS: Focused DOE power electronic building block (PEBB) semiconductor module technology R&D, by initiating competitive financial assistance agreements to fabricate automotive integrated power modules (AIPM) that integrate power bus, filter capacitors, low cost switch devices, and passive/active thermal management for use in PNGV concept vehicles. Transitioned PEBB improved processing and fabrication technologies to the AIPM development program, to assist potential suppliers with production of power devices at power levels, density, and cost targets required for automotive applications. Developed an auxiliary resonant tank soft-switching technique for lower cost high efficiency power circuits, eliminating the losses inherent in hard switched devices. Initiated automotive evaluation of PEBB and AIPM module cooling concepts.	ADVANCED POWER ELECTRONICS: Award two 50 percent cost-shared financial assistance agreements to fabricate automotive integrated power modules. Select baseline design based on component trade-off studies. Initiate systems analysis, digital simulation, and trade-off studies of AIPM supplier technology using PNGV systems analysis tools. Award contracts to develop advanced motor technology containing high temperature windings, advanced magnetic materials, and innovative processing techniques to reduce size, weight, and volume compared to the current technology.	ADVANCED POWER ELECTRONICS: Under the 50 percent cost-shared agreements and contracts, fabricate AIPMs and advanced motors. Validate performance of intermediate AIPM hardware against PNGV technical targets. Define motor system requirements to enable selection of final motor designs and components. Develop and validate models for switched reluctance, permanent magnet, and induction motor technology. Validate motor technology developments against PNGV technical targets. Initiate evaluation of AIPM in hybrid vehicle propulsion systems. Initiate a project with IEEE P1461 working group to address international automotive standards and recommended practices promoting competition and scalable architecture for automotive integrated power modules.
	Completed the power electronics materials needs assessment study.	Based on the results of the materials	Incorporate materials technology improvements into limited quantities

Activity	FY 1998	FY 1999	FY 2000
		needs assessment study, develop a research plan for materials technologies to support power electronics and electric machines.	of prototype AIPM devices; assess performance against technical targets for increased power density and lower production costs. Transfer advanced capacitor technology to AIPM developer.
	Developed novel capacitor technologies using advanced materials application techniques that permit integration of capacitor functions with power modules. Evaluated advanced nanostructure chip capacitors for application in power circuits. (General Motors, Ford, Chrysler, ORNL, SNL, Navy, DoD) (PNGV: $4,410) ($4,410)	Complete automated process development for fabricating nanostructure capacitors. Transition nanostructure technology to semiconductor/capacitor developers and begin higher energy density capacitor R&D. Develop metal oxide chemical vapor deposition (MOCVD) process to fabricate capacitors for power electronics. Integrate nanostructure and MOCVD capacitors into a power electronic module and assess performance against power electronic technical targets. (General Motors, Ford, Chrysler, ORNL, SNL, Navy, DoD) (PNGV: $6,875) ($6,875)	(General Motors, Ford, Chrysler, ORNL, SNL, Navy, DoD) (PNGV: $9,000) ($9,000)
Hybrid Systems R&D (Cont'd)	HEAVY VEHICLE PROPULSION SYSTEMS: No activities. ($0)	HEAVY VEHICLE PROPULSION SYSTEMS: No activities. ($0)	HEAVY VEHICLE PROPULSION SYSTEMS: Support a four-year, heavily cost shared (greater than 50%) program to accelerate the time-to-market for heavy vehicle hybrid technology by 5 to 10 years.

III. Performance Summary: VEHICLE TECHNOLOGIES R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
			Using the urban service truck and transit bus as platforms, develop hybrid/electric propulsion systems as a replacement for transmissions (new production and retrofit). Support competitive industry teams focusing on cost reductions of the critical components specific to their systems, and taking full advantage of the pre-competitive technology programs in advanced power electronics and high power energy storage. Activities funded in this area will be coordinated with the Advanced Vehicle Program activities funded by the Department of Transportation. ($8,000)
	$55,336	$42,140	$48,900
Fuel Cell R&D	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Fuel Cell R&D: SYSTEMS: Focused systems development activities on validation of fuel cell technologies meeting automotive requirements. Building	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Fuel Cell R&D: SYSTEMS: Conduct R&D on fuel cell stack, fuel processor, and balance-of-plant components for a fuel-flexible fuel cell power system	 SYSTEMS: Complete development and begin testing of an advanced integrated 50-kW fuel cell power system capable of operation on

Activity	FY 1998	FY 1999	FY 2000
Fuel Cell R&D (Cont'd)	on the success of the fuel reformer/storage and stack component R&D, fabricated integrated 30-50 kilowatt (kW) fuel cell laboratory systems which operate on hydrogen and methanol. Demonstrated stack efficiencies of 60% and fuel processor efficiencies of 75%. Tested and evaluated these propulsion systems under simulated driving cycles.	that is vehicle-ready; capable of operating on natural gas, methanol, ethanol, and gasoline; and demonstrating a total system efficiency of 40% at 25% of peak power, 250 watts per liter (W/l) system power density, 250 watts per kilogram (W/kg) specific power, $150 per kilowatt (kW) cost and more than 2,000 hours durability.	conventional and alternative fuels to achieve year 2000 targets of 250 W/l system power density, 250 W/kg specific power, near-zero emissions, 40% efficiency at 25% power, $150/kW cost and more than 2,000 hours durability. System will be the first time a proton-exchange-membrane (PEM) fuel cell stack, fuel processor, sensors, controls, and thermal and air management systems are integrated at the automotive scale using conventional fuels, and will demonstrate steady state operation and limited transient response capability (the ability to rapidly respond to changes in demand for power).
	Identified critical needs for continued, more focused component development needed to address technical barriers, such as start-up and transient response, power management, thermal management, and reliability. Used propulsion system test results to update system models so that trade-offs among subsystems could be evaluated and priorities could be established for component R&D.	Integrate components to improve understanding of vehicle system technical barriers, such as cold start-up and transient response, power management, thermal management, durability, and reliability. Use test results to update system models, facilitate subsystem design analysis, and prioritize component R&D. (International Fuel Cells, Plug Power, Energy Partners, Allied	Build 10-kW integrated fuel cell system for characterization of unresolved fuel processing and systems control issues affecting start-up and transient response, operation at temperature extremes and freeze-thaw cycles. Update and validate existing system model using data from the system tests. Initiate a rigorous systems cost

Activity	FY 1998	FY 1999	FY 2000
Fuel Cell R&D (Cont'd)	(International Fuel Cells, Plug Power, ANL) (PNGV: $4,067) ($4,067)	Signal, ANL) (PNGV: $5,776) ($5,776)	analysis for high volume manufacturing of fuel cell systems. Integrate cost analysis findings into existing system model for determination of lowest cost system configuration. (International Fuel Cells, Plug Power, Energy Partners, Allied Signal, ANL) (PNGV: $7,600) ($7,600)
	STACK SUBSYSTEMS COMPONENTS: Fuel cell system components must meet technical challenges such as size and weight reduction, manufacturing cost reduction, quick start-up and transient response, and durability. Focused development on low cost, high performance components for proton-exchange-membrane (PEM) fuel cells. Produced improved fuel cell catalysts which are able to tolerate 50 parts per million (ppm) carbon monoxide (CO) from the hydrogen-rich fuel processing stream without performance degradation. Developed membrane-electrode assemblies employing low platinum loadings or non-noble catalyst formulations for reformate systems. Investigated	STACK SUBSYSTEMS COMPONENTS: Develop further improved fuel cell catalysts which are able to tolerate 100 ppm carbon monoxide from the hydrogen-rich fuel processing stream without performance degradation. Establish stability and durability of catalysts through long-term testing. Build and test fuel cell stack subsystems operating on reformate (a hydrogen-rich gas derived from other fuels), which incorporate new, low cost, lightweight bipolar plates and high carbon monoxide-tolerant catalysts.	STACK SUBSYSTEMS COMPONENTS: Emphasize low cost, high performance components which are needed to meet the PEM fuel cell system year 2000 cost target of $100/kW. Complete development of 50-kW reformate-capable fuel cell stack subsystem that meets year 2000 performance and cost targets. It will include controls, sensors, thermal and air management systems. Use long-term tests to demonstrate durability of stack components and small stack subsystems. Demonstrate advanced CO-tolerant (100 ppm) electrodes and membrane electrode assemblies (MEAs) operating at higher voltage (0.7-0.8 V) to enable high

III. Performance Summary: VEHICLE TECHNOLOGIES R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Fuel Cell R&D (Cont'd)	alternative bipolar plates that are low cost and lightweight, such as conductive plastics separator plates.		efficiency. Demonstrate durability of advanced electrodes tolerant to more than 100 ppm CO in stacks, to maintain high performance during transient operation. Test polymer membranes at higher fuel cell operating temperatures (120-150°C), in order to increase CO tolerance and facilitate heat rejection. Initiate development of high volume pilot plant manufacturing processes for MEAs to meet MEA cost target of $10/kW. Initiate development of reformate-capable fuel cell stack subsystem to meet more challenging targets associated with the 2004 PNGV goal.
	Investigated low cost, high volume manufacturing processes to produce advanced bipolar plates, membrane electrode assemblies, and other fuel cell components having reproducible performance and leading to a fuel cell stack subsystem having a power density of 350 watts/liter (W/l).	Continue development of low cost, high volume manufacturing processes for fuel cell components, leading to a fuel cell stack subsystem (including air, heat and water management devices) having a power density of 350 W/l.	Complete development of lightweight, low cost composite bipolar plate; initiate demonstration of high volume manufacturing processes in pilot plant operation to meet plate cost target of $10/kW.
	Produced a new methanol-		

Activity	FY 1998	FY 1999	FY 2000
Fuel Cell R&D (Cont'd)	impermeable membrane to facilitate the development of direct methanol fuel cells, eliminating the need for a fuel reformer. Conducted independent testing and evaluation of new components and systems, to identify and assess promising new technologies and/or technical approaches. (AlliedSignal, Foster-Miller, Energy Partners, Spectracorp, Electrochem, IGT, 3M, A.D. Little, Vairex, Meruit, LANL, ANL, LBNL, NREL) (PNGV: $10,407) ($10,407) FUEL PROCESSOR/STORAGE: In cooperation with the DOE Hydrogen Program, focused R&D on development and testing of low cost, lightweight hydrogen storage systems for on-board vehicle use. Due to the lack of a hydrogen infrastructure, developed hydrogen	In collaboration with DARPA, continue R&D for direct methanol fuel cells to decrease precious metal catalyst loading. Continue independent testing and evaluation of new components and stack subsystems. Test advanced compressors and expanders which achieve 80% and 90% efficiency, respectively (AlliedSignal, Plug Power, International Fuel Cells, Foster-Miller, Energy Partners, Spectracorp, Electrochem, IGT, 3M, A.D. Little, Vairex, Meruit, LANL, ANL, LBNL, NREL) (PNGV: $13,490) ($13,490) FUEL PROCESSOR/STORAGE: Complete fabrication and safety testing of hydrogen storage tanks, for on-board vehicle use, having an available energy density of 700 watt-hours per liter (Wh/l).	In collaboration with DARPA, develop small direct methanol fuel cell stack with improved power density. Based on testing of current compressor/expander technologies, select most promising; initiate development of advanced, high efficiency compressor/expander to meet 2004 system level targets. (AlliedSignal, Plug Power, International Fuel Cells, Energy Partners, IGT, 3M, LANL, ANL, LBNL, NREL, TBD) (PNGV: $12,400) ($12,400) FUEL PROCESSOR/STORAGE: Assess innovative concepts for hydrogen storage in collaboration with DOE Hydrogen program.

Activity	FY 1998	FY 1999	FY 2000
Fuel Cell R&D (Cont'd)	producing fuel processors. Building on previous R&D breakthroughs, initiated development of a 50-kW fuel-flexible processor capable of rapid start-up (less than 3 minutes) and fast response processing of natural gas, methanol, ethanol, and gasoline. The fully integrated system, including all components (reactors, heat exchangers, fuel purification system, controls and sensors) is sufficiently compact for testbed vehicle installation.	Continue development of the compact, lightweight, 50-kW fuel-flexible fuel processor that will be fully automated and ready for integration with the fuel cell stack subsystem. Develop a low pressure, low temperature fuel-flexible fuel processor with automotive controls, eliminating the need for a compressor when integrated with a low pressure fuel cell, while improving start-up time and overall system efficiency.	Complete development of and evaluate the 50-kW fuel-flexible fuel processor capable of processing methanol, ethanol, natural gas and gasoline. Integrate it with advanced shift reactor, fuel vaporizer and CO clean-up systems to achieve year 2000 PNGV technical targets: 75% efficiency, 600 W/l, 600 W/kg, less than $30/kW, less than 2 minutes start-up, 2,000 hours durability and less than Tier II emissions. Initiate advanced fuel-flexible fuel processor development meeting year 2004 PNGV technical targets of 80% efficiency, 750 W/l, 750 W/kg, less than $10/kW, less than 1 minute start-up, 5,000 hours durability and less than Tier II emissions.
	Addressed remaining key barriers: removal of carbon monoxide (CO) from the fuel stream (critical because even minute levels of CO (50 ppm) can poison the fuel cell stack catalyst); system thermal integration; and cost reduction. Evaluated preferential oxidation, hydrogen filters, and adsorption/desorption techniques to lower CO levels to less than 10 ppm.	Build advanced CO clean-up prototypes to lower CO to less than 10 ppm. Select most promising of advanced preferential oxidizers, hydrogen filters, and adsorption/desorption devices, and integrate into fuel processor.	Transfer successful laboratory CO cleanup technology to potential manufacturers, for development of production designs and processes to enable the integrated fuel-flexible fuel processor to achieve less than 10 ppm CO under steady state operation and less than 500 ppm during transients.

Activity	FY 1998	FY 1999	FY 2000
Fuel Cell R&D (Cont=d)	Using microtechnology, developed compact, efficient heat exchangers and fuel pre-heaters to provide better integrated thermal management, improving system efficiency and power density. (LANL, ANL, PNNL, LBNL, Hydrogen Burner, Epyx (A.D. Little), Thiokol, Thermo Power) (PNGV: $8,140) ($8,140)	Complete testing of a microchannel vaporizer for fuel processing. (Hydrogen Burner, Epyx (A.D. Little), Thiokol, Thermo Power, PNNL, ANL, LANL) (PNGV: $14,235) ($14,235)	Continue development of novel microchannel fuel processor components to meet stringent size requirements. Develop advanced catalysts for fuel-flexible fuel processing to achieve reductions in operating temperature and pressure, thereby decreasing cost, start-up time and transient response. Initiate development of fuel processing catalysts and processing methods, to enable transition from pellets to monolithic structures which are required for low cost, high volume manufacturing. Develop low-concentration, fast response carbon-monoxide detector, for detecting CO concentrations as low as 10 ppm or as high as 200 ppm in the gas mixture entering the fuel cell stack. (Hydrogen Burner, Epyx (A.D. Little), ANL, LANL, PNNL, TBD) (PNGV: $21,380) ($21,380)

Activity	FY 1998	FY 1999	FY 2000
Fuel Cell R&D (Cont=d)			
	$22,614	$33,501	$41,380
Advanced Combustion Engine R&D	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Vehicle Systems R&D HYBRID DIRECT INJECTION ENGINE: Completed the hybrid vehicle gas turbine engine technology support and ceramic turbine engine demonstration projects. As a result of program restructuring started in FY 1996, concluded both projects with prior year (FY 1997) funding. Based on PNGV technology selection decision, no additional turbine-related hybrid power unit R&D was funded. ($0)	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Vehicle Systems R&D HYBRID DIRECT INJECTION ENGINE: Focus the heat engine program on component technology for direct injection engines, including lean-burn spark ignition direct injection (SIDI), to achieve projected emissions requirements of 0.05g/mile nitrogen oxides, .01g/mile particulates) in an advanced, high efficiency engine. Develop fuel delivery systems (pumps, injectors) for high compression ratio SIDI engines utilizing low sulfur fuel. Apply optical engine measurements to benchmark and compare conventional SIDI engines, to help determine characteristics and necessary design features for an	HYBRID DIRECT INJECTION ENGINE: Conduct R&D which supports development of spark ignition direct injection (SIDI) technology for use in hybrid and conventional propulsion systems. Focus research activities on technologies that will enable SIDI engines to meet projected emission standards while achieving at least 35% thermal efficiency. Develop exhaust gas sensors and perform combustion modeling through existing Cooperative Research and Development Agreements (CRADAs) among the three automotive PNGV partners and DOE=s national laboratories.

Activity	FY 1998	FY 1999	FY 2000
Advanced Combustion Engine R&D (Cont'd)		optimized SIDI engine. Investigate basic fundamentals of SIDI stratified charge combustion, determining the importance of in-cylinder mixing, flame quench, and flame propagation in the formation of nitrogen oxides and carbon. Conduct single cylinder testing using technology developed under Combustion and Aftertreatment R&D program activities. (Engine manufacturer(s) and suppliers, ORNL, ANL, universities, USCAR) (PNGV: $6,915) ($6,915)	This collaborative research will help accelerate the transfer of technology from the laboratories to the factory floor. Develop and evaluate direct fuel injection systems using industry suppliers. Provide injectors, high pressure fuel pumps and associated hardware and software with improved durability, reduced fouling, and enhanced spray formation to laboratories for testing and evaluation. Continue development of other innovative concepts for SIDI engines, e.g., real time emission sensors, reduction of parasitic losses, and finer control of ignition and combustion variables. Conduct laboratory R&D to gain an improved understanding of in-cylinder combustion and emission-forming phenomena in SIDI engines. Use optical engines and computer modeling to study mixture preparation and combustion dynamics. In parallel, use simulation vessels and conventional SIDI engines to perform a parametric study of emission-

Activity	FY 1998	FY 1999	FY 2000
Advanced Combustion Engine R&D (Cont'd)			influencing parameters, and to characterize particulate emission size, mass and distribution. Focus university research on computer modeling of fundamental combustion processes and quantifying the effects of controllable variables. (SNL, ORNL, ANL, LANL, LLNL, USCAR, suppliers, universities) (PNGV: $12,000) ($12,000)
	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Advanced Combustion Engine R&D:	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Advanced Combustion Engine R&D:	
	COMBUSTION AND AFTERTREATMENT R&D: Continued support for advanced automotive piston engine technologies required to achieve a factor of three improvement in vehicle fuel economy, as well as nearer term conventional vehicle improvements.	COMBUSTION AND AFTERTREATMENT R&D: Conduct R&D which will enable passenger cars with fuel efficient compression ignition direct injection (CIDI) engines to meet projected Federal and State emissions requirements.	COMBUSTION AND AFTERTREATMENT R&D: Conduct R&D which will enable passenger cars and light trucks to utilize fuel efficient compression-ignition, direct-injection (CIDI) engines while meeting projected Federal and State emissions requirements.
	Combustion: Developed optical access measurement and numerical modeling of fluid flow and chemistry; analysis of fuel-air	Combustion: Apply newly developed optical access techniques for single-cylinder combustion research, to directly measure injection spray patterns and	Combustion: Enhance the understanding of the diesel combustion process by using laser

Activity	FY 1998	FY 1999	FY 2000
Advanced Combustion Engine R&D (Cont'd)	mixture formation; and analysis of combustion in compression-ignition engines. Continued refinement of models, which include fuel injection simulation. Validated against experimental data.	combustion processes using laser visualization. Characterize inlet and in-cylinder flows, and effects of wall heat transfer and exhaust gas recirculation (EGR). Initiate optical measurements with numerical models to validate and refine model for optimization of light-duty CIDI fuel injection, sensor, and EGR systems. Initiate development of advanced EGR concepts.	diagnostics and high-speed photography to visualize the formation of oxides of nitrogen (NOx) and particulate matter (PM) in optically accessible light- and heavy-duty diesel engines, and in an ultra-high-pressure combustion vessel. Use the experimental data in the development of computer models, which simulate fuel injection spray, combustion, and emissions formation. Investigate efficiency and emissions characteristics of advanced combustion concepts such as Homogeneous Charge Compression Ignition and other methods to reduce in-cylinder emissions formation. The Office of Science will collaborate on this research effort primarily by providing research facilities.
	Emission Controls: Continued development of diagnostic tool to identify sources of unburned hydrocarbons in engine exhaust. Continued development of lean-NOx catalyst and other exhaust aftertreatments.	Emission Controls: Initiate development of cost effective ($5/kilowatt (kW) versus current $15/kW) control and aftertreatment system for passenger cars to reduce gaseous and particulate emissions. Develop preliminary designs for NOx catalyst and plasma-assisted catalyst systems for PNGV candidate 55-kW CIDI engine.	Emission Controls: Focus exhaust aftertreatment research on the reduction of NOx and particulates that remain in the exhaust stream after in-cylinder combustion. Explore several technologies, including lean NOx catalyst, non-thermal plasma, particulate filter,

III. Performance Summary: VEHICLE TECHNOLOGIES R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Advanced Combustion Engine R&D (Cont'd)		Initiate non-combustible gas sensor development for closed-loop control.	and NOx and particulate traps. Initiate development of advanced exhaust gas recirculation (EGR) components for improved cylinder-to-cylinder distribution and control under transient operating conditions. Complete component-level testing required to achieve intermediate emissions targets for PNGV passenger vehicle application. Initiate collaborative exploratory R&D effort with emission control manufacturers to develop more advanced catalysts and components. Develop emission control components which can meet the higher horsepower and more demanding duty cycle required for light truck applications.
	Engine Integration: Continued development of CIDI technology, including activities on fuel injection, alternative fuel capability and other enabling technology elements. Continued projects in partnership with DOE laboratories, universities, industry.	Engine Integration: Benchmark prototype components and control strategies, and compare to state-of-the-art, multi-cylinder CIDI engines. Continue projects in partnership with DOE laboratories, universities, and industry.	Engine Integration: Demonstrate low cost CIDI fuel injection system with improvements in rate control, opening and closing events, and reduced leakage at higher pressures. Continue projects in partnership with DOE laboratories, universities, and industry.
	(ANL, ORNL, PNNL, SNL, Ford, GM, Chrysler, Princeton, Penn State University, Wayne State	(ANL, ORNL, PNNL, SNL, Ford, GM, Chrysler, catalyst manufacturers and other Tier I suppliers, Wayne State University,	(SNL, LANL, LLNL, ORNL, PNNL, ANL, Ford, GM, Chrysler,

Activity	FY 1998	FY 1999	FY 2000
Advanced Combustion Engine R&D (Cont'd)	University, University of Wisconsin, University of Illinois, MIT, Drexel, Florida A&M) (PNGV: $7,348) ($7,348) TRANSFER FROM: ADVANCED HEAVY VEHICLE TECHNOLOGIES/Heavy Vehicle Systems R&D LIGHT TRUCK ENGINE: Implemented initial stages of a planned program to devolve the technologies under development in the LE-55 heavy duty engine program to diesel engines of the size and duty cycle appropriate for light trucks (100-275 horsepower). Completed the first phase of a 50% cost-shared program to define the critical path to achieving a 35% fuel efficiency improvement in light trucks, compared to conventional gasoline-fueled vehicles. Initiated the second phase to develop critical technologies to increase engine mean effective pressure, reduce friction, and improve exhaust energy utilization. Identified technologies needed to meet the additional	University of Wisconsin, TBD) (PNGV: $12,830) ($12,830) TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Heavy Vehicle Systems R&D LIGHT TRUCK ENGINE: Continue a program of diesel engine R&D for light trucks, pickups, vans, and sport utility vehicles, using competitive industry teams led by domestic diesel engine manufacturers. Maintain at least a 50% industry cost share. Include technologies that will enable the high efficiency diesel engine to meet market and regulatory demands for performance, noise, cost, and emissions. Specific technologies of interest include: components to increase engine mean effective pressure, reduce friction, and improve exhaust energy utilization; advanced control systems; fuel injection equipment; high efficiency turbochargers; ring/piston designs; sensors; lubricants; engine thermal	Caterpillar, Cummins and Detroit Diesel, catalyst manufacturers, Tier 1 suppliers, Wayne State University, University of Wisconsin, TBD/RFP) (PNGV: $16,300) ($19,800) LIGHT TRUCK ENGINE: Optimize a laboratory test engine for emissions, performance, cost, and noise; integrate the optimized system (200-250 horsepower) into a light truck (pickup, van, or sport utility vehicle). Select exhaust aftertreatment, fuel injection, air handling, and exhaust energy recovery systems that will enable the high efficiency diesel engine to meet market and regulatory demands. With at least two of the three teams having demonstrated success in meeting the efficiency goal, focus on achieving the very low emission requirements. Continue focus of third team, which is also expected to meet the efficiency goal, on development of

Activity	FY 1998	FY 1999	FY 2000
Advanced Combustion Engine R&D (Cont'd)	challenge of more stringent performance and emissions standards for vehicles under 8,500 pounds gross vehicle weight rating. Supported an industry-wide cooperative effort between the major U.S. vehicle manufacturers and the U.S. diesel engine manufacturers. In partnerships with industry, investigated efficiency and emissions at ultra-high combustion pressures, using facilities at the national laboratories and universities. Performed fundamental combustion research by utilizing laser diagnostic and computer modeling techniques. Investigated the formation of oxides of nitrogen and particulates in the combustion chambers of engines fueled by conventional diesel and alternative fuels, and how they are affected by such parameters as fuel injection, combustion chamber geometry, temperature and density. (ORNL, SNL, Univ. of Wisconsin, LANL, Caterpillar, Inc., Cummins Engine Co., Detroit Diesel Corp., Univ. of Illinois, Texaco, NOxTech)	management; and utilization of advanced materials (including lightweight components). Focus base technology R&D on combustion optimization and exhaust aftertreatment research. Perform combustion optimization research in an optically accessible diesel engine and an ultra high pressure combustion vessel, using laser diagnostics and high speed photography. Use experimental data in the development of computer models which simulate the diesel combustion process. The Office of Energy Research will enhance this research effort by funding the DOE 2000 Diesel Combustion Collaboratory Pilot Project. Focus exhaust aftertreatment projects on the treatment of nitrogen oxides and particulates that remain in the exhaust stream after the in-cylinder combustion event. In cooperation with the automotive program (Combustion and Aftertreatment R&D), explore several options, including a catalyst,	emissions and advanced combustion technologies that will set new low levels for oxides of nitrogen (NOx) and particulate emissions. Automotive and Truck combustion and aftertreatment activities and funding are combined, and described in, the Combustion and Aftertreatment R&D prorgram. Automotive and Truck combustion and aftertreatment activities and funding are combined, and described in, the Combustion and Aftertreatment R&D program. (SNL, LANL, LLNL, ORNL,

III. Performance Summary: VEHICLE TECHNOLOGIES R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Advanced Combustion Engine R&D (Cont'd)	($10,970)	non-thermal plasma, and combinations of the two together with particulate and NOx traps. (SNL, LANL, ORNL, ANL, PNNL, LLNL, Caterpillar Inc., Cummins Engine Co., NOxTech, Detroit Diesel Corp., Univ. of Wisconsin) ($17,930)	PNNL, ANL, Caterpillar Inc., Cummins Engine Co., Detroit Diesel Corp., NOxTech) ($18,500)
	HEAVY TRUCK ENGINE: No activities. ($0)	HEAVY TRUCK ENGINE: No activities. ($0)	HEAVY TRUCK ENGINE: Award competitive contracts to develop engine technologies for heavy duty trucks which will reduce emissions to EPA 2002 standards while maintaining or improving their high thermal efficiency. The DOJ/EPA Consent Decree with the diesel manufacturers accelerated the enactment of the EPA Heavy-Duty emissions regulations from 2004 to 2002. Efficiency will be sacrificed unless new emission control strategies are developed to meet these regulations. Utilizing emission reduction technologies developed in the Combustion and Aftertreatment R&D program, evaluate in-cylinder and

III. Performance Summary: VEHICLE TECHNOLOGIES R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Advanced Combustion Engine R&D (Cont'd)			aftertreatment systems for controlling emissions from Class 7 and 8 trucks. Once emission standards are demonstrated while maintaining or improving efficiency, shift focus to developing technologies that will improve engine thermal efficiency to 55% from the current 45%, while reducing emissions to near-zero levels. (TBD-RFP) ($5,500)
	$18,318	$37,675	$55,800
Cooperative Automotive Research for Advanced Technologies	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES AND TRANSPORTATION MATERIALS TECHNOLOGIES: Established the Cooperative Automotive Research for Advanced Technologies (CARAT) program to provide greater opportunity for small businesses and universities to accelerate progress on inventions needed for advanced vehicle technologies. Awarded 26 cooperative agreements in the areas	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES AND TRANSPORTATION MATERIALS TECHNOLOGIES: Continue Phase 1 R&D activities resulting from the initial solicitation in 5 technology areas. Begin to identify projects with the greatest potential to progress to the Phase 2 engineering prototype stage. Initiate a second solicitation with new topics for Phase 1 projects. (ANL, small businesses,	The FY 2000 request builds on the FY 1999 appropriation to support innovative Phase 1 and 2 projects, and will accelerate potential technology breakthroughs needed to make advanced automobiles commercially viable. Award limited, competitive, Phase 2 engineering prototype development contracts which require greater

Activity	FY 1998	FY 1999	FY 2000
Cooperative Automotive Research for Advanced Technologies (Cont=d)	of fuel cells, compression ignition direct injection engines, advanced battery systems, thermal management, and advanced motors. CARAT consolidates small business/university projects and focuses them on the highest priority R&D goals. (ANL, small businesses, universities) (PNGV: $2,776) ($2,776)	universities) (PNGV: $1,500) ($1,500)	resources than the Phase 1 concept feasibility phase. Phase 2 will include complete hardware development, test and evaluation of components, and a preliminary economic analysis to determine high volume, low-cost fabrication targets. Conduct the first annual CARAT forum for participants to demonstrate results for vehicle manufacturers and suppliers, and to facilitate business partnerships with them. In Phase 3, these partnerships will result in the development of preproduction prototypes by companies with the financial and technical resources to bring the CARAT technologies to market. Award additional Phase 1 projects on new topics. (ANL, small businesses, universities) (PNGV: $6,000) ($6,000)
	Initiated the Graduate Automotive Technology Education (GATE) program, to facilitate the development of multi-disciplinary graduate engineering programs for educating tomorrow=s automotive engineers in advanced vehicle	Encourage universities to partner with relevant industries which can provide cost-sharing, internships for students, topics for research, shared facilities and equipment, and jobs for graduating students. Complete	Complete first academic year fellowship funding and intitate second year funding of existing fellowships. (ANL, universities) (PNGV: $1,000) ($1,000)

Activity	FY 1998	FY 1999	FY 2000
Cooperative Automotive Research for Advanced Technologies (Cont=d)	technologies. Awarded competitive cooperative agreements at nine universities to develop technology-specific curricula and fellowships concentrating on fuel cells, advanced energy storage, lightweight and propulsion materials, direct injection engines, and hybrid electric drivetrain and control systems at selected universities. The program ensures a more highly qualified technical workforce in the future, while simultaneously addressing technology barriers today. (ANL, universities) (PNGV: $500) ($500)	curriculum development and offer a limited number of fellowships at universities for talented engineering students who desire to pursue graduate degrees in selected advanced vehicle technology areas. (ANL, universities) (PNGV: $800) ($800)	
	$3,276	$2,300	$7,000
Electric Vehicles R&D	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Electric Vehicles R&D: ADVANCED BATTERY DEVELOPMENT: Supported R&D on advanced batteries for electric vehicles with the United States Advanced Battery	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Electric Vehicles R&D: ADVANCED BATTERY DEVELOPMENT: Support R&D on long-term advanced batteries for electric vehicles with the USABC, with an average	ADVANCED BATTERY DEVELOPMENT: Complete support for R&D on long-term advanced batteries for electric vehicles under Phase II of the

III. Performance Summary: VEHICLE TECHNOLOGIES R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
	Consortium (USABC), with an average industry cost share for Phase II of 55% in FY 1998.	industry cost share of 55% in FY 1999.	Department of Energy's Cooperative Agreement with the USABC, with an average industry cost share of 55%. Initiate support for R&D on long-term, lithium-based advanced batteries for electric vehicles under Phase III of the USABC program, with an average industry cost share of 65% in FY 2000.
Electric Vehicles R&D (Cont'd)	Mid-term Battery R&D: Continued test and evaluation program for 13-volt, 90 ampere-hour nickel metal hydride (NiMH) battery modules from pilot line production, and performed cost-reduction technology programs. Conducted performance and life testing and evaluation of 6-volt, 100 ampere-hour nickel metal hydride modules. Completed delivery of laboratory test results to USABC and DOE for detailed evaluation, to establish that progress is being made toward the program goals.	Mid-term Battery R&D: Complete test and evaluation program for pilot line NiMH battery modules. Conclude two cost-reduction technology programs for NiMH batteries. Achieve cost reduction targets to meet USABC goals. Conduct performance and life testing and evaluation of 340-volt, 100 ampere-hour nickel metal hydride battery packs, and lithium-based battery cells and modules. Validate battery pack performance against USABC mid-term battery goals. Support the commercial introduction of nickel metal hydride batteries into electric vehicles.	Mid-term Battery R&D: No additional nickel metal hydride development program planned. Complete performance and life testing and evaluation of lithium-based battery modules and mini-packs. Work with the Society of Automotive Engineers, as well as European and Japanese entities, in codifying recommended practices for testing and evaluation of advanced batteries.
	Continued environment, safety, and health (ES&H) work on the	Complete nickel metal hydride ES&H assessment activities.	Assess recycling issues, abuse tolerance, and shipping

III. Performance Summary: VEHICLE TECHNOLOGIES R&D (Cont=d)

Activity	FY 1998	FY 1999	FY 2000
Electric Vehicles R&D (Cont=d)	USABC's nickel metal hydride and lithium-based battery technologies, to ensure that these new battery systems will be in compliance with regulatory requirements when commercialized. Completed Adraft@ international lithium electric vehicle (EV) battery shipping regulations for consideration by the United Nations.	Continue ES&H assessment activities on lithium-based advanced battery technology issues through the Advanced Battery Readiness Working Groups, to ensure compliance with regulatory requirements when commercialized. Work with national and international organizations to adopt DOE Adraft@ international lithium EV battery shipping regulations.	requirements for lithium-based advanced EV battery technology, through the Advanced Battery Readiness Working Groups. Coordinate these activities with the Department of Transportation=s, National Highway Traffic Safety Administration, and the Environmental Protection Agency.
	Long-term Battery R&D: Supported work on the long-term, advanced lithium-based battery with one major development team. Evaluated first generation prototype batteries (modules) in DOE laboratories. Focused technology development on design and manufacturing improvements to reduce costs, and to improve battery performance and life. (ANL, INEEL, LBNL, NREL, SNL, USABC, 3M/Hydro-Quebec) ($14,582)	Long-term Battery R&D: Using USABC long-term battery commercialization goals as performance metrics, evaluate second and third generation lithium-polymer battery modules and packs in DOE laboratories and automotive industry prototype vehicles. Evaluate option of developing ambient-temperature, lithium-based, long-term battery technologies, including comparison of projected results to the advanced USABC lithium polymer baseline technology. Focus technology development on enhanced processing quality control to improve battery performance. (ANL, INEEL, LBNL, NREL,	Long-term Battery R&D: Validate fourth and fifth generation lithium-polymer battery packs in automotive industry prototype vehicles. Complete extended testing of USABC long-term, lithium-polymer batteries to determine life and safety under accident conditions. Initiate development of ambient-temperature, lithium-based, long-term battery technologies and validate results against the advanced USABC lithium polymer baseline technology. Focus technology development on enhanced manufacturing processes which control fabrication variables to improve battery performance, life, and abuse tolerance, and to reduce

Activity	FY 1998	FY 1999	FY 2000
		SNL, USABC, 3M/Hydro-Quebec) ($5,855)	costs. (ANL, INEEL, LBNL, NREL, SNL, USABC, 3M/Hydro-Quebec) ($7,800)
Electric Vehicles R&D (Cont=d)	EXPLORATORY TECHNOLOGY RESEARCH: Continued research that strives to solve the most difficult problems facing the various vehicle electrochemical power source systems under development by USABC and the Partnership for a New Generation of Vehicles (PNGV) contractors. Identified new electrochemical power sources for electric and hybrid vehicles that can meet long-term electric vehicle performance and/or cost goals, and can meet the power and lifetime requirements for high power (hybrid vehicle) applications. Improved each power source system by better defining the life-limiting processes that are poorly understood; developing better models and analytic tools, and applying them to solve critical problems; using advanced analytic techniques on corrosion processes; and developing and optimizing high performance electrochemical components, such	EXPLORATORY TECHNOLOGY RESEARCH: Focus exploratory technology research on developing low cost components and processes necessary for mass production of battery technology that can meet USABC performance and cost targets. Develop new electrodes, separators, components, and analytical techniques for investigating phenomenological processes. Develop improved understanding of life-limiting and performance-limiting processes. Improve user-friendly models and analytic tools to guide the development of lithium-based battery systems. Develop lithium batteries with greater stability, and aqueous batteries with improved performance-durability/cost ratios. Characterize and assess thermal behavior of lithium-based systems under dynamic loads**C**especially high power pulse charges and discharges. Measure transport	EXPLORATORY TECHNOLOGY RESEARCH: Refocus research and development efforts to emphasize application-oriented measurement and diagnostic techniques. More closely link activities and interests of industrial developers with program activities, to achieve more rapid progression of technology into competitive products for the marketplace. Develop and characterize new anode materials with high capacities, and cathodes with thermal stability at temperatures greater than 125^{o}C; select and characterize the best combinations of carbon anode, organic electrolyte/lithium salt, and lithiated metal oxide cathode to achieve a low cost, abuse tolerant lithium-ion electrochemical system. Develop improved non-flammable lithium-ion electrolytes for abuse tolerant EV batteries. Increase the conductivity of polymer electrolytes by a factor of ten while doubling the energy and power densities of the

Activity	FY 1998	FY 1999	FY 2000
	as electrodes, electrolytes, and current collectors. (ANL, LBNL, LANL) ($3,236)	properties of non-aqueous electrolytes by nuclear magnetic resonance (NMR) techniques to facilitate the development of highly conductive electrolytes. (ANL, LANL, LBNL) ($2,965)	lithium- based system. Focus on developing diagnostic methods to identify the fundamental causes of the lithium battery's decrease in performance as a function of cycle life, calendar life, and thermal cycling. Refine existing models and data bases to support development of improved lithium rechargeable batteries by the EV battery developers. Investigate new battery electrochemistries capable of major improvements in performance, life, cost, and abuse tolerance. (ANL, LANL, LBNL) ($3,200)
Electric Vehicles R&D (Cont'd)			
	$17,818	$8,820	$11,000
Heavy Vehicle Systems R&D	TRANSFER FROM: ADVANCED HEAVY VEHICLE TECHNOLOGIES/Heavy Vehicle Systems R&D:	TRANSFER FROM: ADVANCED HEAVY VEHICLE TECHNOLOGIES/Heavy Vehicle Systems R&D:	
	Delineated potential cost-effective methodologies to reduce parasitic energy losses endemic in the operation of heavy vehicles. Further evaluated the effects of proposed energy saving approaches	Develop, with trucking industry participation, comprehensive multi-year program plans (MYPPs) to address potentially effective methodologies to reduce parasitic energy losses, and establish	Implement a program based on prior year planning that will reduce aerodynamic drag of heavy trucks, to reduce fuel use by about 18%. Determine acceptable redesign of trailers with computational fluid

Activity	FY 1998	FY 1999	FY 2000
Heavy Vehicle Systems R&D (Cont'd)	in the areas of aerodynamics, rolling resistance, and auxiliary systems, which account for 52%, 28%, and 20%, respectively, of the non-engine energy losses in heavy vehicle operations. Employing a fully integrated systems approach, further developed sensoring, weight reduction, safety and operational characteristics of fuel systems for heavy commercial and multi-purpose vehicles. Applied systems integration analysis to increase the energy efficiency, safety, and cost effectiveness of transit, intercity, and school bus vehicles. (ANL, MIT, WVU, American Association of Railroads) ($1,700)	priorities for a focused R&D agenda to develop cost effective, energy efficient heavy vehicle systems designs. Hold workshops to identify research needs in the areas of (1) thermal management approaches to reduce energy losses in heavy vehicle radiators and the application of nanosize particles as new, more effective coolant materials, and (2) rolling resistance, e.g., brake design and materials, tire designs and new inflation methods and monitoring, new transmission and gear materials, etc. Assemble teams to expand R&D efforts in the three top areas identified in the MYPPs. Assess this fully integrated systems engineering approach, developed for the analysis and amelioration of parasitic energy losses in heavy duty trucks, for broader application to transit, intercity, and school buses. (ANL, MIT, WVU, American Association of Railroads) ($1,500)	dynamics and advanced modeling and simulation. Confirm and validate designs with wind tunnel tests. Begin planning over-the-road vehicle demonstrations with the trucking industry. Analyze new concepts such as air circulation control for aero drag reduction. Investigate regenerative shock absorbers, to determine if a significant amount of electrical energy can be generated on trucks and passenger vehicles, and if the energy can be harnessed cost-effectively. Complete proof-of-principle studies for these applications. With industry, State, and trade associations, address the reduction of unnecessary idling of heavy truck engines to achieve fuel savings of 1% in surface transport, a cost savings of $2 billion a year and reduction of exhaust gases by up to 1%. (ANL, ORNL, MIT, LLNL, NASA, SNL) ($4,000)
	$1,700	$1,500	$4,000

III. Performance Summary: VEHICLE TECHNOLOGIES R&D (Cont=d)

Activity	FY 1998	FY 1999	FY 2000
Vehicle Technologies R&D Total	**$119,062**	**$125,936**	**$168,080**

TRANSPORTATION TECHNOLOGIES
TRANSPORTATION SECTOR
(dollars in thousands)

FUELS UTILIZATION R&D

I. Mission Supporting Goals and Objectives

I. A. Program Strategy

The mission of the Fuels Utilization R&D program is to undertake, with partners in the energy and transportation industries, research and development which will result in competitive, high performance, low emission fuel options for transportation vehicles.

The strategic approach is to identify and develop new fuel options that will allow advanced Partnership for a New Generation of Vehicles (PNGV) and other future vehicles to meet increasingly challenging performance and emissions targets. Emissions reductions in vehicles over the past two decades have been significant, but further gains are required. The current state of technology suggests that changes in fuel formulation, and the use of fuels other than petroleum, can have a major positive impact on achieving further improvements in emissions reductions.

The Fuels Utilization R&D Program identifies, develops, and tests new fuel formulations for use in advanced automotive and truck engines; these fuels are needed to simultaneously achieve high fuel economy and low emissions.

Two major areas are being addressed: Advanced Petroleum Based Fuels and Alternative Fuels. Applied research in these two areas will lead to the development of advanced fuels for new technology engines with high fuel economy, and the development of vehicles which can cost-effectively utilize alternative fuels while meeting all consumer expectations.

Key Milestones

2004 Complete development of a new fuel formulation for advanced direct injected engines that can use the existing fueling infrastructure, and which enables vehicle operation with both high fuel use efficiency and very low emissions.

2004 Complete development of cost-effective systems, for application in Class 3-8 truck platforms, that will enable the practical use of natural gas as a preferred vehicle fuel option.

Appropriate Federal Role: The Government has an important role in realizing new fuel options. Current fuel price market signals mitigate against private sector investment in alternatives to conventional fuels. Also, the government can facilitate cooperative work among the fuel

producers, catalyst developers, and vehicle manufacturers on the multiple technology development paths necessary to achieve the desired vehicle-fuel systems at minimal cost.

I. B. Program Benefits

Metric	2000	2010	2020
Primary Energy Displaced (quadrillion Btu)	Benefits for Fuels Utilization R&D		
Primary Oil Displaced (million barrels per day)	are included in the benefits for		
Energy Cost Savings ($ billion)	Vehicle Technologies R&D		
Carbon Reductions (million metric tons)			

I. C. Performance Measures

Advanced Petroleum Based Fuels

Activity Summary: The Advanced Petroleum Based Fuels activity is a collaborative effort conducted in partnership with energy companies, engine/vehicle manufacturers, and emission controls companies. It is focused on developing new fuel formulations that will allow extremely fuel efficient engines to be developed that can also be very low polluters. This work supports an initiative of the Office of Science and Technology Policy (OSTP), which has an objective of assuring that clean fuels are available to achieve emissions goals. The current compositions of fuels are not suitable for advanced high fuel economy engines, since they have poor physical properties (e.g., cetane number) and contain high levels of sulfur and aromatics. R&D is being conducted to reformulate gasoline and diesel fuels, optimizing them so that significant oil displacement benefits from high efficiency vehicles, being developed primarily through the Partnership for a New Generation of Vehicles (PNGV), can be realized by 2010. For example, initial testing at Southwest Research Institute has shown that the addition of dimethoxymethane (DMM) in low-sulfur diesel fuel can reduce particulate emissions significantly. Direct injection engines being developed for high efficiency automotive, light truck, and heavy duty truck applications will not meet proposed 2004 emissions standards without improvements to fuels. Current impurities (e.g., sulfur) and other constituents cause combustion inefficiencies and aftertreatment catalyst poisoning, which leads to excessive NOx and particulate emissions. Fuel cell engines being developed for PNGV automotive applications will be more efficient and less costly if gasoline can be optimized to make onboard fuel processors simpler. In addition to fuels R&D, efforts will be made to assess the effect of fuel changes on the production and distribution infrastructure. Currently, projects are being developed to determine toxicity effects from different fuels used in advanced engines, and to investigate oxygenate and lube oil impacts on particulate emissions.

Partners: Test programs are conducted at DOE's national laboratories and independent laboratories (e.g., the Southwest Research Institute) in partnership with energy companies, exhaust aftertreatment manufacturers, and domestic automobile and truck engine manufacturers. Although

I. Mission Supporting Goals and Objectives: FUELS UTILIZATION R&D (Cont'd)

major auto companies are not receiving Federal funds, they are carrying out test programs complementary to the DOE-sponsored laboratory programs. Data will be shared publicly to determine technology status and develop future plans. Commitments from catalyst, auto, engine, emission controls, and energy companies are being made to support generation of technology R&D roadmaps which address priorities and milestones.

Documents which address fuel development and testing, for both direct injection and fuel cell engines, are currently being developed, to complete initial planning described in Section 3.7 of the Office of Advanced Automotive Technologies R&D Plan (March 1998, DOE/ORD/2065). The roadmaps are being developed jointly with auto/truck industrial partners and energy companies.

Goal: In FY 2000, an important program goal is to determine the maximum emissions reduction achievable with an advanced petroleum- based fuel. This determination will be based on the analysis of tailpipe emissions from vehicles incorporating advanced emission controls strategies. Year 2000 targets of 0.3 g/mi NOx and 0.025 g/mi particulate have been established for compression ignition direct injection (CIDI) engines. By 2004, in collaboration with the vehicle manufacturing industry, its suppliers, and the fuels industry, the goal is to develop and validate advanced fuels which enable direct-injected and fuel cell engines to meet Tier II emission standards proposed by the Environmental Protection Agency.

FY 1998 Accomplishments
- Initiated testing of natural gas derived fuels blended with petroleum-based fuels.
- Operated a diesel engine in flexible-fuel mode.
- Completed Phase I testing of advanced petroleum-based fuels.

FY 1999 Planned Accomplishments
- Complete test and evaluation of an advanced compression ignition direct injection (CIDI) engine, representative of PNGV size, using conventional fuels blended with alternative fuels to reduce NOx and particulate emissions.

FY 2000 Planned Accomplishments
- Develop techniques for sampling and measuring fine particulate matter.
- Complete initial screening of fuels for fuel cells.
- Select advanced liquid fuels for PNGV concept vehicles.

I. Mission Supporting Goals and Objectives: FUELS UTILIZATION R&D (Cont'd)

FY 2001 - FY 2004 Planned Accomplishments

- Based on accumulated data base, start final evaluation and engine optimization of advanced engines operating on new fuel formulations. (FY 2001)
- Select advanced fuels for fuel cell vehicle. (FY 2002)
- Demonstrate operation of a heavy duty direct injection test engine, operating on advanced fuel formulations, that achieves 55% efficiency and meets all emissions regulations. (FY 2004)

Alternative Fuels

Activity Summary: The Alternative Fuels activity has both near- and long-term elements. The near-term activity is a collaborative effort in partnership with the natural gas industry, heavy duty engine/vehicle manufacturers, and natural gas storage tank manufacturers. It is focused on supporting the use of natural gas in a cost-effective manner. The long-term activity is to evaluate fuels derived from natural gas, such as dimethyl ether (DME), for compression ignition direct injection (CIDI) engines. Natural gas promises to be as cost effective as conventional fuel in some applications. However, the barriers associated with the use of natural gas include: (1) current natural gas engines operate at lower efficiency levels than conventional fueled engines, (2) unacceptable incremental cost of current onboard storage techniques for natural gas, and inconvenience to the operator during refueling, (3) lack of available fuel; and (4) excessive costs of natural gas fueling facilities. The program seeks to overcome these barriers by supporting development of high efficiency natural gas engines, reduced-cost onboard storage techniques that are user friendly, and low-cost fueling station designs. Research and development is focused on cost-effective applications of this fuel option, specifically for Class 3-6 inner city and Class 7-8 inter-city trucks where natural gas is available and the duty cycles of the vehicles do not require long-range travel. Natural gas derived fuels, such as dimethyl ether (DME) and methanol, will be evaluated in advanced PNGV automotive engines and direct injection engines for light trucks.

Partners: Industrial partners perform research and development on utilization of natural gas through cost-shared programs, contracts, and cooperative agreements. Particular emphasis is placed on achieving proposed emissions standards and fuel efficiency goals, reducing cost, improving reliability, and maintaining safety. Current partners include Johns Hopkins University, the Institute of Gas Technology, the Gas Research Institute, the State of California, Southwest Research Institute, Lucas Aerospace, Lincoln Composites, and Power Tech Labs. National laboratories also have a major role in this program, performing fundamental research, testing and evaluation. In addition, cost-shared projects exist with the Coordinating Research Council and the California Air Resources Board.

A multi-year plan for natural gas use in transportation vehicles was published as part of the overall DOE Natural Gas Multi-Year Program Plan, dated December 1997. This plan identifies the technology barriers to natural gas use in the transportation sector and presents a technical approach to overcoming them. Budget requirements are also identified.

I. Mission Supporting Goals and Objectives: FUELS UTILIZATION R&D (Cont'd)

Goal: In FY 2000, the goal of the Alternative Fuels program is to achieve 42% peak thermal efficiency in a heavy duty natural gas engine. By 2004, the goals are to develop: a cost-effective natural gas vehicle system for typical Class 3-6 inner city trucks and Class 7-8 inter-city applications; and a detailed proven design concept for a cost-effective natural gas fueling station.

Pre-FY 1998 Accomplishments
- Demonstrated a compressed natural gas automobile having a 300-mile range, with power and emissions comparable to a conventional gasoline-powered vehicle.
- Achieved reliable compression ignition in a heavy duty, high efficiency, direct injected natural gas engine.

FY 1998 Accomplishments
- Developed a natural gas light duty vehicle to meet California's ultra-low emission vehicle (ULEV) standards, with a range of 300 miles, and a unique integrated storage system.
- Completed development of a lower cost, lighter weight natural gas cylinder for onboard storage.
- Successfully operated a heavy duty engine on natural gas with direct injection.

FY 1999 Planned Accomplishments
- Demonstrate 40% energy conversion efficiency in a heavy duty engine operating on natural gas.
- Complete development of a prototype fuel injection system for an automotive application using DME.

FY 2000 Planned Accomplishments
- Complete efficiency and emissions evaluations of natural gas in direct injection engines.
- Complete evaluation of DME in PNGV and light truck applications.
- Begin development of materials and lubricants necessary to meet automotive and light truck durability and performance requirements while operating on DME.
- Initiate assessment of the impacts of fuel changes on fuel production, infrastructure, and environment.

FY 2001 - FY 2004 Planned Accomplishments
- Assess infrastructure requirements and cost impact for producing optimum natural gas or natural gas derived fuels for direct injection and/or fuel cell engines, in support of PNGV and light truck programs. (FY 2001)
- Complete NGV2 and other appropriate industry standards tests of newly developed low cost liquefied natural gas (LNG) storage systems and compressed natural gas (CNG) onboard storage tanks. (FY 2001)
- Demonstrate heavy duty truck operation at 45% efficiency operating on natural gas. (FY 2002)
- Design and demonstrate a liquefied/compressed natural gas (L/CNG) station that can fuel any type of natural gas vehicle, with a 50% reduction in price. (FY 2003)

I. Mission Supporting Goals and Objectives: FUELS UTILIZATION R&D (Cont'd)

- Design and demonstrate a fully integrated compressed natural gas vehicle system in a medium duty truck, incorporating a high efficiency engine and low-cost fueling system. (FY 2004)
- Demonstrate operation of a heavy duty Class 8 truck that operates on natural gas and is fully competitive with its diesel fuel counterpart in cost and performance. (FY 2004)

II. A. Funding Table: FUELS UTILIZATION R&D

Program Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Request	$ Change	% Change
Advanced Petroleum Based Fuels	$ 2,900	$ 6,615	$ 12,400	$+5,785	+87.5%
Alternative Fuels	14,124	11,170	11,100	-70	-0.6%
Total, Fuels Utilization R&D	$ 17,024	$ 17,785	$ 23,500	$+5,715	+32.1%

II. B. Laboratory and Facility Funding Table: FUELS UTILIZATION R&D

Program Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Request	$ Change	% Change
Argonne National Lab (East)	$ 1,157	$ 1,661	$ 1,400	$ -261	-15.7%
Brookhaven National Lab	2,000	300	3,500	+3,200	+1066.7%
Idaho National Engineering and Environmental Lab	0	200	0	-200	-100.0%
Lawrence Livermore National Lab	0	855	0	-855	-100.0%
National Renewable Energy Lab	5,196	4,175	6,000	+1,825	+43.7%
Oak Ridge National Lab	3,265	2,750	4,185	+1,435	+52.2%
Sandia National Laboratories	825	920	1,300	+380	+41.3%
All Other	4,581	6,924	7,115	+191	+2.8%
Total, Fuels Utilization R&D	$ 17,024	$ 17,785	$23,500	$+5,715	+32.1%

III. Performance Summary: (New BA in thousands of dollars)

Activity	FY 1998	FY 1999	FY 2000
Fuels Utilization R&D			
Advanced Petroleum Based Fuels	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Automotive Alternative Fuels R&D and ADVANCED HEAVY VEHICLE TECHNOLOGIES/Heavy Vehicle Alternative Fuels R&D: Automobile/Light Truck: Completed Phase I testing of petroleum based fuels, using a PNGV-type direct injection (DI) engine, to characterize effects of fuel formulations on emissions. (Southwest Research Institute (SWRI)) (PNGV: $500) ($500)	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Automotive Alternative Fuels R&D and ADVANCED HEAVY VEHICLE TECHNOLOGIES/Heavy Vehicle Alternative Fuels R&D: Automobile/Light Truck: Initiate Phase II, optimization of various blends of petroleum-based fuels, using a PNGV direct injection (DI) engine, to determine emissions reductions benefits from fuels being investigated. Initiate projects between PNGV and the transportation fuels producers to enhance the performance of compression ignition direct injection (CIDI) and fuel cell engines through fuel reformulations. Projects will include optimizing oxygenate type and concentration for emissions reduction, determining the chemical characterization and toxicity of these oxygenate blends, and determining the lube oil impact on particulate emissions. Initiate	Automobile/Light Truck: Optimize fuel blends to enable PNGV and truck engines to meet projected emission standards concurrently with fuel economy targets. Test fuel blends in the best available engines to assess their performance, economics, and emission impacts; utilize the data from this effort to assess the air quality impacts of these fuels with regard to particulates and potential for ozone formation. Continue fundamental combustion research on alternative fuel/conventional diesel fuel/gasoline blends, including studies to determine why oxygenates reduce particulate emissions and what effect they have on toxicity. Initiate an assessment

III. Performance Summary: FUELS UTILIZATION R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Advanced Petroleum Based Fuels (Cont'd)		combustion studies to determine the effect of oxygenates on emissions. Develop chemical kinetic models of diesel fuels and diesel fuel blends. Initiate identification of major contaminants in advanced petroleum based fuels and blends, and their impacts on fuel processor catalysts and fuel cell performance. Identify constituents in advanced petroleum-based fuels and blends that degrade or improve fuel processor efficiency. (NREL, ORNL, ANL, SWRI, SNL, LLNL, LANL) (PNGV: $3,915) ($3,915)	of the impacts of fuel changes on fuel production and distribution infrastructure, and on the environment. Determine tolerance levels of the contaminants in advanced petroleum-based fuels identified in FY 1999. Investigate methods to mitigate effects of these contaminants on fuel cell processor catalysts and fuel cells. Begin testing of fuels in fuel processors to optimize use of the constituents. (ORNL, ANL, SWRI, SNL, LLNL, LANL) (PNGV: $7,000) ($7,000)
	Heavy Trucks: Conducted combustion research on conventional diesel fuel/alternative fuel blends, including a blend with Fisher-Tropsch diesel from natural gas. Initiated a flexible fuel engine concept that incorporates the emissions and efficiency goals of Low Emission (LE)-55 program. Studied the capability of advanced technologies, including variable valve timing, to expand the fuel tolerance of the diesel engine and enable greater fuel flexibility.	Heavy Trucks: Initiate development of lube oils which form low particulate emissions. With industrial partners, continue fundamental combustion studies on alternative fuel/conventional diesel fuel blends, to determine their effects on NOx and particulate emissions formation in a diesel engine. In an optically accessible engine, initiate experimental combustion research with alternative blends, including Fisher- Tropsch diesel provided by the Office of Fossil Energy. Examine fuel	Heavy Trucks: Test and evaluate advanced lube oils for their effects on particulate formation for both heavy and light duty applications. Continue to conduct experimental combustion research using an optically accessible engine to determine the effects of Fischer-Tropsch diesel, oxygenate additives and fuel blends on NOx and particulate formation in-cylinder. Perform detailed chemical and physical analyses of fuel blends to determine their potential toxicity,

III. Performance Summary: FUELS UTILIZATION R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Advanced Petroleum Based Fuels (Cont'd)	(NREL, ORNL, SNL, ANL) ($2,400)	injection spray characteristics, and study formation of NOx and soot, using advanced petroleum-based fuels in a combustion bomb. Conduct a cooperative program with DOE's Office of Science to evaluate the health impacts of diesel engine particulate emissions associated with combusting alternative fuel blends. Initiate testing of heavy duty engines with near term aftertreatment systems, to study the effect of fuel sulfur on aftertreatment efficiency and durability. (NREL, ORNL, SNL, ANL) ($2,700)	and their compatibility with materials used in existing engine components and seals. Initiate testing of advanced petroleum based fuels in diesel engines equipped with near term aftertreatment systems, to assess the full emissions reduction benefits that these fuels enable. (NREL, ORNL, SNL, ANL) ($5,400)
	$2,900	$6,615	$12,400
Alternative Fuels	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Automotive Alternative Fuels R&D and ADVANCED HEAVY VEHICLE TECHNOLOGIES/ Heavy Vehicle Alternative Fuels R&D:	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Automotive Alternative Fuels R&D and ADVANCED HEAVY VEHICLE TECHNOLOGIES/ Heavy Vehicle Alternative Fuels R&D:	
	Automobile/Light Truck: Completed the Phase III fabrication and field evaluation of a second generation advanced natural gas	Automobile/Light Truck: Conduct R&D on technologies that will reduce cost, increase range, increase fuel economy and achieve projected	Automobile/Light Truck: Evaluate natural gas derived fuels, such as DME and methanol, in PNGV and light truck direct injection (DI)

III. Performance Summary: FUELS UTILIZATION R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Alternative Fuels (Cont'd)	light-duty vehicle. Completed a lower cost and lighter weight natural gas cylinder project using conventional materials, which have metal liners reinforced with hoop-wrapped continuous filaments (usually fiberglass) in a resin matrix. Completed certification testing of conformable shaped compressed natural gas tanks. Evaluated potential dimethyl ether (DME) fuel storage systems; developed a prototype DME fuel injection (FI) system for use in an automotive diesel cycle engine. Initiated development of a backup pump design for a DME FI system. Evaluated commercially available lubricants to determine their adequacy for the DME FI system. Completed evaluation of data, and disseminated results, from ethanol and propane vehicle test program. Evaluated cold-start techniques for alcohol fueled engines. Conducted a study to determine the best approach for a high efficiency ethanol vehicle powered by lean-burn spark ignition or four stroke direct injection, and formulated a plan to utilize ethanol in a high efficiency vehicle. (NREL,	emissions standards for alternative fuel vehicles. Complete development of lower cost tank material, and cost effective tank manufacturing techniques, for storage of compressed natural gas in type 4 tanks, made with plastic liners and full-wrapped continuous fiberglass and/or carbon fibers in a resin matrix. Complete development of an optimized prototype DME FI system to be used in an automotive PNGV CIDI engine. Initiate testing of a DME FI system, and analysis of DME fuel production, distribution and dispensing requirements. Initiate the C-1 research program to develop technology for the conversion of methanol into transportation fuels and chemicals. (NREL, ORNL, ANL) (PNGV: $2,500) ($2,500)	engines, to determine their ability to meet emission standards and fuel economy targets. Based on test results, develop alternative fuel injection and delivery systems for optimized DI engines. Test and evaluate fuel-related components and lubricants to meet automotive and light truck durability and performance requirements. (NREL, ORNL, ANL) (PNGV: $500) ($500)

III. Performance Summary: FUELS UTILIZATION R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Alternative Fuels (Cont'd)	ORNL, ANL) (PNGV: $3,649) ($3,649) Medium Trucks: Awarded contracts to initiate the natural gas enhanced engine efficiency program. Successfully conducted burst test of low pressure tanks, to allow on-road testing to begin in medium trucks. Conducted a cooperative program with DOE's Office of Science to evaluate the health impacts of particulates from engines using alternative fuels. Developed and tested advanced fuel storage systems for medium duty vehicles. Continued advanced development of alternative fueled engine/vehicle systems, with the goal of bringing newly developed natural gas and propane technologies to a production-ready status. Continued operation of the West Virginia University Transportable Chassis Dynamometer and Emissions Test Facility, utilizing its capabilities as a development tool. (NREL, ORNL, SNL, ANL, BNL) ($6,310)	Medium Trucks: Continue the natural gas enhanced engine efficiency program, with the goal of reaching the technology targets of the LE-55 engine. Complete on-road test of a conformable natural gas tank in a medium truck. Develop smart sensor technology to enable the monitoring of natural gas tank structural integrity on a continuous basis, utilizing technology developed for the Department of Defense. Conduct research activities on natural gas tank technologies that fully integrate the fuel dispenser, tank, and engine systems. Develop compressor technology to support adsorbent natural gas storage. Continue operation of the West Virginia University Transportable Chassis Dynamometer and Emissions Test Facility. Examine the chemical interactions between ozone and particulates generated in urban atmospheres. (NREL, ORNL, SNL, ANL, BNL) ($4,700)	Medium Trucks: Initiate testing of a 40% efficient engine operating on natural gas. Initiate development of a natural gas fueled hybrid electric power system for a Class 6 truck application. Incorporate smart sensor technology into compressed natural gas tank design and begin prototype construction of tanks for testing in a medium truck. Continue operation of the West Virginia University Transportable Chassis Dynamometer and Emissions Test Facility. (NREL, ORNL, SNL, ANL, BNL) ($4,300)

III. Performance Summary: FUELS UTILIZATION R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Alternative Fuels (Cont'd)	Heavy Trucks: Performed fundamental combustion studies of natural gas. Designed and began development of a three-way catalyst for natural gas engines. Continued development of advanced natural gas engines, with the goal of raising efficiency levels to that of their petroleum-based diesel fuel counterparts. Identified heavy vehicle emissions inventory, and composition of heavy vehicle volatile organic compound (VOC) emissions, from alternative and conventional diesel fuels. Conducted cost-shared research, in cooperation with the Coordinating Research Council (CRC), to extend the previous light duty vehicle emissions impacts to heavy vehicles. Conducted preliminary urban airshed modeling, emphasizing the relative impacts of heavy vehicles operating on alternative fuels and conventional diesel fuel. Performed reliability assessment studies of the liquefied natural gas storage systems for heavy vehicles. (NREL, ORNL, SNL, ANL, BNL) ($3,765) Fueling Infrastructure: Completed an infrastructure study focused on the cost and reliability of natural gas	Heavy Trucks: Evaluate projected heavy vehicle emissions inventories for NOx, VOCs, toxins, and particulates. Using modeling and other techniques, examine the potential future atmospheric impacts of heavy vehicle emissions on urban air quality and climate change. Initiate development of advanced liquefied natural gas storage and fuel delivery systems which could support direct injection natural gas engine technology. Continue development of direct injection technology for natural gas in a heavy duty engine. (NREL, ORNL, SNL, ANL, BNL) ($3,270)	Heavy Trucks: Examine issues related to the EPA's ozone, PM 2.5, and regional haze regulations. Using field studies and real-world emissions testing, evaluate the contribution of heavy vehicle emissions to these problems. Compare the results from ambient field studies with vehicle emissions inventories, in an attempt to reconcile the differences. Compare the toxicity of particulates from gasoline and diesel engines. Continue developing advanced liquefied natural gas storage and fuel delivery systems in support of direct injection natural gas engine technology. Continue development of direct injection technology for natural gas use in a diesel cycle engine. (NREL, ORNL, SNL, ANL, BNL) ($4,300)

III. <u>Performance Summary</u>: FUELS UTILIZATION R&D (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Alternative Fuels (Cont'd)	fueling facilities. Initiated development of high efficiency, low-cost advanced natural gas compressors. (NREL, ORNL, SNL, ANL, BNL) (PNGV: $400) ($400)	Fueling Infrastructure: Complete development of high efficiency, low-cost natural gas compressor. Initiate feasibility study of a combined CNG/LNG fueling facility. (NREL, ORNL, SNL, ANL, BNL) (PNGV: $500) ($700)	Fueling Infrastructure: Initiate design of a combined CNG/LNG fueling facility. (NREL, ORNL, SNL, ANL, BNL) ($2,000)
	$14,124	$11,170	$11,100
Fuels Utilization R&D Total	**$17,024**	**$17,785**	**$23,500**

TRANSPORTATION TECHNOLOGIES
TRANSPORTATION SECTOR
(dollars in thousands)

MATERIALS TECHNOLOGIES

I. Mission Supporting Goals and Objectives

I. A. Program Strategy

The mission of the Materials Technologies program is to support development of cost-effective materials and materials manufacturing processes which are required in order to achieve successful commercial introduction of fuel efficient, low emission transportation vehicles. Research, development, testing and analysis are conducted to provide advanced materials with the necessary properties, and the processes needed to produce them, at the costs and volumes required by vehicle producers.

Lightweight materials and advanced propulsion materials will enable vehicle fuel economy and emission goals to be realized in commercially viable automobiles and trucks. Government-industry partnerships are in place to facilitate validation and implementation of cost-effective advanced materials technologies.

The Materials Technologies program has two closely coordinated elements: propulsion materials technology and lightweight materials technology. Goals of the program include: (1) development and validation of lightweight materials technologies that will enable reductions in automobile weight of 40 percent (relative to 1994 baseline) and in heavy truck weight of 30 percent (relative to 1998 baseline) by 2004; and (2) development and validation of enabling propulsion materials technologies for integration into advanced propulsion systems.

These goals are aligned with those of the Vehicle Technologies R&D program and, as described in that section of the budget, are directly supportive of the *Energy Resources* and the *Science and Technologies* business lines of the DOE Strategic Plan (1997). Advancement in the materials development areas is critical to success of the overall DOE transportation R&D effort. For example, up to 30 percent of the improvement required to triple vehicle fuel economy, and to attain much of the cost, safety, and recyclability targets of the Partnership for a New Generation of Vehicles (PNGV), depends on lightweight materials development, as does achieving a 10 to 18 percent reduction in fuel use by heavy duty trucks. New materials are also essential to the viability of the advanced propulsion systems under development for both cars and trucks. In addition to enabling increased vehicle efficiency because of lighter weight, incorporation of advanced lightweight materials into vehicles has synergistic beneficial effects for reducing fuel consumption; for example, in allowing reduced engine sizes for automobiles, or in the area of high strength weight reduction materials for commercial trucks, which would enable increased payloads.

I. Mission Supporting Goals and Objectives: MATERIALS TECHNOLOGIES (Cont'd)

The strategic approach to meeting these goals involves partnering with industry, with a high degree of cost sharing, to identify and remove the technical barriers to the viability of the highest payoff materials technologies. Most of the R&D activities to be conducted through 2004 are in direct support of government/industry partnerships. Many also utilize the expertise of national laboratories and universities, as well as that in industry. A major principle of the approach is that the program will not address technology R&D that industry is already conducting or is likely to conduct on its own. Continuous coordination with industry is required to: (1) understand industry's R&D needs and agenda; and (2) establish and maintain a mutual agreement on the appropriate portfolio of cooperative, high-risk research.

Key Milestones

2000 Validate lightweight materials technologies to enable a 50 percent weight reduction in automobile body and chassis components, and a 20 percent weight reduction in heavy vehicles.

2004 Validate materials technologies to enable a cost-competitive 40 percent reduction in automobile total weight (including body, chassis, powertrain, and fuel system); and validate lightweight materials technologies to enable a 30 percent reduction in total heavy vehicle weight.

Appropriate Federal Role: The primary government research and development role is to support long-range, high-risk activities where breakthroughs offer large potential payoffs to the nation, but are not reflected in current market pricing. This support includes funding, as well as access to unique R&D capabilities within the Federal laboratory system. With fuel prices at historic lows, transportation exemplifies a sector where a lack of market demand, combined with realistic requirements for private sector return on investment, provide industry with limited incentive to undertake high-risk research on its own to achieve breakthrough improvements in fuel use efficiency. Such breakthrough improvements would contribute to achieving national goals of reduced petroleum dependence and decreased emissions while having a positive economic impact.

The Materials Technologies program includes maintenance and usage of the Oak Ridge National Laboratory's world-class High Temperature Materials Laboratory (HTML), which has unique capabilities to support the transportation materials development effort; the facility also supports other materials efforts, other transportation R&D efforts relating to materials, and the training of technologists in cutting-edge materials characterization research.

I. Mission Supporting Goals and Objectives: MATERIALS TECHNOLOGIES (Cont'd)

I. B. Program Benefits

The following metrics are associated with lightweight materials and light vehicles only:

Metric	2010	2020
Primary Energy Displaced (quadrillion Btus)	0.01	0.05
Primary Oil Displaced (million barrels per day)	0.01	0.04
Energy Cost Savings (billion)	0.16	0.58
Carbon Reductions (million metric tons)	0.24	0.99

By 2020, the 32 million PNGV vehicles in use will have achieved part of their energy and oil savings from use of lighter weight materials.

Benefits for the Propulsion Materials Technology Program are included with the benefits cited in the Vehicle Technologies R&D section of the budget.

I. C. Performance Measures

Propulsion Materials Technology

Activity Summary: Propulsion materials R&D focuses on developing enabling materials for propulsion components and subsystems needed to achieve higher engine efficiencies, lower emissions, improved alternative fuel capabilities, and lower specific weight and volume, without compromising other factors such as cost, safety, and recyclability. This activity covers all types of advanced materials—metals, ceramics, composites, and novel material systems such as 'smart' materials. Planning and work are conducted in close coordination with the associated engine/power source development efforts. Developing and validating appropriately scaled manufacturing technologies is an important part of the R&D. Work addresses materials critical to the advanced propulsion systems/components under development for automobiles (PNGV) and for diesel engines for light trucks, vans, sport utility vehicles, and heavy trucks. For example, automotive materials development efforts are critical to achieving the following propulsion component targets: reduction of NOx and particulate emissions (to .05 g/mile and .01 g/mile, respectively) from direct injection engines, and increased specific power of power electronics to 25 kW/kg (a 3-times improvement) at a cost of $7/kilowatt.

The five-year propulsion materials technology development effort is described in the Office of Advanced Automotive Technologies R&D Plan (March 1998, DOE/ORO/2065) and in the Office of Heavy Vehicles Technologies (OHVT) Multi-year Program Plan for 1998-2002 (July 1997). The goals in the plans are consistent with the overall vehicle goals of Vehicle Technologies R&D and with the Office of Transportation

I. Mission Supporting Goals and Objectives: MATERIALS TECHNOLOGIES (Cont'd)

Technologies Strategic Plan. The efforts are planned in collaboration with industry and national laboratories, and are consistent with government/industry technology roadmaps, such as those developed for PNGV with the United States Council for Automotive Research (USCAR), and the OHVT Technology Roadmap developed with the heavy vehicle and engine manufacturers. Laboratory activities are addressed in annual operating plans.

Partners: DOE's propulsion materials technology development efforts are conducted in partnership with a variety of participants, including national laboratories, universities, and vehicle manufacturers and their suppliers. Propulsion materials development, because of its close integration with the engine development and power device development efforts, is conducted with many of the same partners involved in developing fuel cells, engines, and power electronics.

Goal: Provide enabling materials technologies required for higher efficiency, low-emission, advanced propulsion systems, with particular emphasis on materials for advanced diesel engines, fuel cells, and power electronics. Complete identification and functional proof of concept for selected advanced materials and manufacturing technologies by 2000, and demonstration of cost competitiveness by 2004.

Pre-FY 1998 Accomplishments

- Developed an intelligent system for induction heating and hardening that has been applied by industry in producing drive train components, to reduce the uncertainty in depth of hardening by a factor of five.
- Developed life prediction methodology for in-situ toughened silicon nitride to the point that accurate results can be achieved for most fracture modes.

FY 1998 Accomplishments

- Completed the transition from focus on gas turbine ceramics to enabling materials for compression ignition direct injection (CIDI) engines, fuel cells, and power electronics for hybrid vehicle applications.
- Successfully completed 500-hour thermal fatigue durability testing of thick thermal barrier coatings for piston-crown insulation, proving the concept to reduce heat loss through the pistons and allowing lower cost piston materials.
- Established facilities for evaluating material performance under high thermal gradients, including thermal shock and cyclic oxidation of thermal barrier coatings; and added radiography, tomography, and temperature measurement inside running engines to neutron-based characterization capabilities.

FY 1999 Planned Accomplishments

- Initiate fabrication and testing of advanced carbon foam heat sinks for thermal management of power electronics, with an increase in effective heat transfer by up to 4 orders of magnitude, a factor of 10 reduction in heat exchanger volume, and 20 to 25 percent of the cost reduction necessary to meet the target of $7/kW for the power electronics system.

I. Mission Supporting Goals and Objectives: MATERIALS TECHNOLOGIES (Cont'd)

- Develop cost-effective technologies to manufacture thick thermal barrier coated pistons for the 55 percent efficient (LE-55) engine (Vehicle Technologies R&D) to enable use of lower cost alloys for pistons; demonstrate over 2,000 hours durability.
- Demonstrate an intelligent grinding process for ceramic engine components; demonstrate manufacturing of products such as engine valves and fuel injector components with this process.

FY 2000 Planned Accomplishments

- Complete fabrication and testing of high temperature, low loss capacitors with a factor of 10 volume reduction for power electronics.
- Demonstrate feasibility of near-frictionless carbon coatings in advanced fuel cell air compressors to reduce wear and increase efficiency.
- Develop material for a regenerative exhaust filter to reduce diesel engine particulate emissions to less than 0.025 grams per mile.

FY 2001 - FY 2004 Planned Accomplishments

- Complete testing of continuous sintering methods for diesel engine components. (FY 2001)
- Develop high-volume manufacturing procedures for nonthermal plasma catalyst materials and microwave regenerated diesel exhaust filters to reduce diesel engine NOx and particulate emissions. (FY 2003)
- Complete development of key materials components such as the ceramic capacitor for the integrated power electronics module and catalyst material for the integrated diesel exhaust system, and deliver to automotive suppliers with the integrated systems. (FY 2004)

Lightweight Materials Technology

Activity Summary: Lightweight materials R&D focuses on development and validation of advanced lightweight materials that can significantly reduce vehicle body and chassis weight without compromising other vehicle attributes such as safety, performance, recyclability, and cost. The single greatest barrier to use of lightweight materials is their high cost; the priority development activity is aimed at reducing costs through development of new materials, forming technologies, and appropriately scaled manufacturing processes. Five areas of research are pursued: cost reduction, manufacturability, design data and test methodologies, joining, and recycling and repair. Priority lightweight materials include aluminum, magnesium, titanium, and composites such as metal-matrix and carbon-fiber. Work is focused on automotive applications, supporting PNGV goals, and the heavy truck; however, as lightweight materials become cost-competitive, they will be considered for applications on all vehicle platforms.

As with propulsion materials development, the lightweight technology development effort is described in the Office of Advanced Automotive Technologies R&D Plan (March 1998, DOE/ORO/2065) and in the Office of Heavy Vehicles Technologies (OHVT) Multi-year Program Plan for 1998-2002 (July 1997). The efforts are planned in collaboration with industry and national laboratories, and are consistent with government/industry technology roadmaps such as those developed for PNGV with USCAR, and the OHVT Technology Roadmap developed with the heavy vehicle manufacturers and materials suppliers. Yearly program plans establish research priorities and hardware deliverables supporting technical goals provided in the roadmaps.

I. Mission Supporting Goals and Objectives: MATERIALS TECHNOLOGIES (Cont'd)

Partners: DOE's lightweight materials technology efforts are conducted in partnership with automobile and truck manufacturers, materials suppliers, national laboratories, universities, and other non-profit technology organizations. Materials development for trucks is conducted directly with materials suppliers, with involvement of truck manufacturers in planning and review of activities. Automotive materials work is conducted directly with materials suppliers in part, but primarily through a cooperative agreement with the United States Advanced Materials Partnership (USAMP) under USCAR, and with technical and priority guidance from the PNGV Materials Technical Team. Prominent partners also include such organizations as the Aluminum Association, International Magnesium Association, and International Titanium Association. Laboratories include ANL, PNNL, ORNL, SNL, INEEL, LANL, LLNL, LBNL, and Ames Laboratory. PNNL manages the Northwest Alliance for Transportation Technologies (NATT), drawing on the expertise and developments in the northwest. ANL oversees recycling efforts, while ORNL provides technical management for all other activities including the DOE cooperative agreement with USAMP.

Goals: By FY 2000, develop and validate materials technologies that, when implemented, will enable a reduction in automobile body and chassis weight by 50 percent relative to a 1994 baseline automobile, at 1.5 times the cost of using the baseline materials; and a reduction in the weight of unloaded heavy duty tractor-trailer units by 20 percent, while maintaining safety, reliability, and recyclability. By 2004, improve materials technology to enable a 50 percent reduction in the weight of automobile body and chassis components, and a 40 percent reduction in the overall vehicle weight (PNGV target), while achieving cost competitiveness with conventional materials; and to enable a 30 percent reduction in the weight of unloaded heavy duty tractor-trailer units.

Pre-1998 Accomplishments

- Developed the technology of metal compression forming for monolithic aluminum alloys for vehicle applications, enabling increased use of aluminum with a 40 percent reduction in cost compared to current production methods for aluminum parts.
- Successfully completed a 35 miles per hour crash test of a vehicle with a front end constructed of composite materials 33 percent lighter than the steel parts they replaced.

FY 1998 Accomplishments

- Demonstrated aluminum sheet processing technology (continuous sheet casting) with a 50 percent lower cost compared to conventional ingot-to-sheet processing technology.
- Demonstrated ultra-large casting technology for large aluminum components, applicable to all vehicle platforms, which will enable, for example, reduction in a heavy truck's weight by 1,250 pounds (5 percent) through substitutions of aluminum for conventional materials.

I. Mission Supporting Goals and Objectives: MATERIALS TECHNOLOGIES (Cont'd)

FY 1999 Planned Accomplishments

- Demonstrate low cost casting methods to produce structural light metal castings for automotive applications.
- Complete development of the process for casting ultra-large vehicular components; cast prototypes for laboratory testing and evaluation by original equipment manufacturers (OEMs); field test qualified components under service conditions.
- Extend the successful development of metal compression forming, for solid solution and precipitation-hardenable aluminum alloys, to metal matrix composites and magnesium alloys. Produce prototype components for testing and evaluation by OEMs.

FY 2000 Planned Accomplishments

- Demonstrate technologies that enable a high-modulus carbon reinforcing fiber that will sell for less than $5 per pound (reduced from the current $8 per pound) for use in advanced composite automotive structures, achieving comparable costs to steel and 60 percent weight savings for applicable automotive parts.
- Increase the resolving power of a newly acquired Transmission Electron Microscope by controlling spherical aberration and reducing from 1.6 to 0.7 Angstroms the smallest resolvable object, which will expedite the investigation of catalysts and exhaust gases.
- Validate lightweight technologies to enable a 50 percent reduction in automobile body and chassis weight.
- In conjunction with the heavy vehicle industry, define and test the design, methodological, materials, process, and forming approaches required to cost effectively achieve total heavy vehicle weight reduction of 5,000 pounds (over 20 percent); validate the maintenance of safety and vehicular performance requirements in all applicable truck classifications.

FY 2001 - FY 2004 Planned Accomplishments

- Validate crash energy absorption model for carbon fiber composite-intensive automobiles. (FY 2001)
- Validate die cast magnesium alloy automobile components costing less than $1.65 per pound (cost parity with steel and/or aluminum parts), with satisfactory creep performance at high temperature and 33 percent weight savings relative to aluminum. (FY 2003)
- Validate, through test and analysis, lightweight technologies which enable a 50 percent reduction in automobile body and chassis weight with no cost penalty. (FY 2004)
- In conjunction with the heavy vehicle industry, validate technology to enable a 30 percent reduction in total heavy vehicle weight. (FY 2004)

II. A. Funding Table: MATERIALS TECHNOLOGIES

Program Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Request	$ Change	% Change
Propulsion Materials Technology	$ 11,155	$ 8,210	$ 9,050	$ 840	+10.2%
Lightweight Materials Technology	17,615	23,825	16,950	-6,875	-28.9%
High Temperature Materials Laboratory	5,100	5,440	7,000	+1,560	+28.7%
Total, Materials Technologies	$ 33,870	$ 37,475	$ 33,000	$ -4,475	-11.9%

II. B. Laboratory and Facility Funding Table: MATERIALS TECHNOLOGIES

Program Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Request	$ Change	% Change
Ames Lab	$ 65	$ 100	$ 65	$ -35	-35.0%
Argonne National Lab (East)	598	1,810	744	-1,066	-58.9%
Idaho National Engineering and Environmental Lab	450	0	2,000	+2,000	>999%
Lawrence Berkeley National Lab	200	260	0	-260	-100.0%
Lawrence Livermore National Lab	850	500	1,000	+500	+100.0%
Los Alamos National Laboratory	500	435	805	+370	+85.1%
National Renewable Energy Lab	0	0	0	0	0%
Oak Ridge National Lab	22,671	20,940	21,743	+803	+3.8%
Pacific Northwest National Lab	2,390	4,255	1,205	-3,050	-71.7%
Sandia National Laboratories	750	910	650	-260	-28.6%
All Other	5,396	8,265	4,788	-3,477	-42.1%
Total, Materials Technologies	$ 33,870	$ 37,475	$ 33,000	$ -4,475	-11.9%

III. Performance Summary: (New BA in thousands of dollars)

Activity	FY 1998	FY 1999	FY 2000
Materials Technologies Propulsion Materials Technology	TRANSFER FROM: TRANSPORTATION MATERIALS TECHNOLOGIES/Automotive Materials Technology AUTOMOTIVE PROPULSION MATERIALS: Concluded R&D on automotive gas turbine ceramic materials and processes. Effected transition of these laboratory in-house and contracted ceramics projects to a broader advanced materials R&D program that supports targeted improvements in fuel efficiency and automotive manufacturing cost for the remaining Partnership for a New Generation of Vehicles (PNGV) candidate propulsion systems: compression ignition direct injection (CIDI) engine, fuel cell, and complementary propulsion electronics and electric machines. Prepared in conjunction with the Office of Industrial Technologies (OIT), for an orderly transfer of those automotive gas turbine ceramic technology projects needed for continued support of the	TRANSFER FROM: TRANSPORTATION MATERIALS TECHNOLOGIES/Automotive Materials Technology AUTOMOTIVE PROPULSION MATERIALS: Conduct enabling R&D of advanced materials in support of, and in close coordination with, PNGV candidate propulsion systems development. Projects supported typically include new classes of materials and/or unique processing methods at the laboratory stage of development. The propulsion systems include advanced energy conversion, vehicle power control and transmission, and emission control concepts and components for the remaining engine candidates: CIDI engines and fuel cells, with associated electro-mechanical power trains. Completed testing of novel material for fuel cell bipolar plate. This bipolar plate material technology transferred from the laboratory to industry for further development.	AUTOMOTIVE PROPULSION MATERIALS: Continue R&D of advanced materials for PNGV propulsion technologies, focusing on: materials/devices to increase fuel efficiency and reduce emissions from advanced diesel engines suitable for automotive applications; low cost, lightweight materials/components for fuel cells; and materials to reduce size and enhance performance of power electronics modules. Projects supported typically include new classes of materials and/or unique processing methods at the laboratory stage of development. Develop near-frictionless carbon coatings for advanced diesel engine components and fuel cell air compressors, to decrease wear and increase efficiency.

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Propulsion Materials Technology (Cont'd)	industrial gas turbine program. Assumed responsibility for and continued development of low cost bipolar plate materials for fuel cells. Broadened non-gas turbine ceramics and other propulsion materials R&D efforts, such as ultra low friction coatings, microwave-regenerated particulate trap matrices, and advanced materials for power capacitors and electronic substrates. (ORNL, AlliedSignal Ceramics, Kyocera Industrial Ceramics, Univ. of Dayton Research Institute, Univ. of Michigan, NASA Lewis, ANL, LANL, Nixdorf, ONR) (PNGV: $6,285) ($6,285)	Initiate development of ceramic paper filter to trap carbon particulates and hydrocarbons from diesel exhaust. (ORNL, ANL, LANL, SNL, Industrial Ceramic Solutions) (PNGV: $2,965) ($2,965)	Continue development of ceramic paper for regenerative diesel exhaust filter to meet PNGV particulate emissions targets. Identify optimum pore size and structure for carbon foam heat sinks which can enable improved thermal management of power electronics. Fabricate and test new ceramic materials for capacitors with a factor of 10 volume reduction, and higher operating temperatures for power electronics. (ORNL, LANL, SNL, ANL, Industrial Ceramic Solutions) (PNGV: $3,000) ($3,000)
	TRANSFER FROM: TRANSPORTATION MATERIALS TECHNOLOGIES/Heavy Vehicle Materials Technology	TRANSFER FROM: TRANSPORTATION MATERIALS TECHNOLOGIES/Heavy Vehicle Materials Technology	
Propulsion Materials	HEAVY VEHICLE PROPULSION MATERIALS: Developed advanced materials technologies needed for the achievement of 55% efficiency in diesel engines (LE-55) for heavy vehicles, while simultaneously reducing emissions of environmental pollutants to meet	HEAVY VEHICLE PROPULSION MATERIALS: Work in partnership with the diesel engine companies and suppliers to develop enabling materials technology needed for low emission, higher efficiency diesel engines. Continue tests to verify 2,000 hour durability of thick thermal barrier coating	HEAVY VEHICLE PROPULSION MATERIALS: Pursue development of materials technologies that enable advanced, efficient, clean diesel engines suitable for application to sport utility vehicles (SUVs), vans, and trucks. Complete the identification of opportunities for advanced

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Technology (Cont'd)	increasingly stringent standards. Expanded the application of the materials technologies under development to include diesel engines for multipurpose vehicles (100-275 horsepower) that account for a rapidly growing market segment (pickups, vans, and sport utility vehicles). Continued R&D on cost effective, high toughness silicon nitride for diesel components. Developed alumina matrix, self-lubricating ceramics for low cost/low emission valve guides. Completed ceramic machining activities. Continued low expansion materials development and catalyst characterization using the High Temperature Materials Laboratory electron microscopes. Continued life prediction verification of engine valve materials. Continued support of low cost sintering and non-destructive testing. Continued diesel component manufacturing technology projects with industry, including development of titanium aluminide, that support diesel engine objectives. (Caterpillar, Cummins, Detroit Diesel, North Carolina A&T, NIST, Univ. of	using component thermal fatigue rig, and continue engine testing to verify the 10,000 hour durability required for highway truck application of LE-55 technology. Through 50% cost-shared agreements with the three leading U.S. diesel companies: (1) develop and initiate a plan to fabricate a zirconia toughened mullite cylinder head insert for advanced diesel engines, using composite fabrication and low cost processing; (2) pursue projects on fuel system materials, materials for NOx and particulate reduction, and advanced air handling materials; and (3) initiate development of "smart materials" for fuel injection systems. Jointly with industry and standard setting organizations, conduct non-destructive evaluation (NDE) of diesel engine materials; high temperature life prediction of ceramic valves; and ceramic materials testing standards activities.	materials such as intermetallic compounds, amorphous metals and alloys, nanocrystalline materials, and metal and ceramic matrix composites, along with ceramics, to be key enablers for the advanced diesel engines. Complete development of a zirconia toughened mullite cylinder head insert for advanced diesel engines, using composite fabrication and low cost processing. Complete development of materials for fuel systems, NOx and particulate reduction, advanced air handling, and higher cylinder-pressure engines needed for diesel cycle propulsion. Complete development of "smart materials" for fuel injection systems. Prepare prototypes of all components and systems for testing and evaluation in the final stage of these multiyear developmental projects with the diesel engine companies and their suppliers. Test and evaluate ceramic piezoelectric materials for rapid fuel injector actuation, NOx catalysts, plasma assisted catalysts, and thick thermal barrier coatings for pistons.
Propulsion Materials Technology (Cont'd)		In partnership with the Office of Fossil Energy's liquefaction program, support characterization	

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
	Massachusetts, ANL, ORNL). ($4,870)	of fuel processing catalysts utilizing the unique High Temperature Materials Laboratory (HTML) capabilities. (ORNL, Caterpillar, Cummins, Detroit Diesel, North Carolina A&T, ANL, NIST) ($5,245)	Identify candidate materials with high damping coefficients required for noise and vibration reduction in advanced engines. With teams of engine companies and suppliers, define the materials and manufacturing technologies required for exhaust gas recirculation and high brake mean effective pressure engine blocks and cylinder heads. Complete the testing of low cost, continuous sintering methods for cermets, ceramics, and powder metallurgy diesel engine components. Prepare a test plan for prototyping, testing, and evaluation of components. Pursue domestic and international cooperative efforts to establish testing standards facilitating specification of properties for the new candidate materials in engine component designs.
Propulsion Materials Technology (Cont'd)			Maintain cooperative materials analysis and characterization efforts utilizing the electron microscopes and user facilities at the High Temperature Materials Laboratory.

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
			(ORNL, Caterpillar, Cummins, Detroit Diesel, North Carolina A&T, ANL, NIST) ($6,050)
	$11,155	$8,210	$9,050
Lightweight Materials Technology	TRANSFER FROM: TRANSPORTATION MATERIALS TECHNOLOGIES/Automotive Materials Technology	TRANSFER FROM: TRANSPORTATION MATERIALS TECHNOLOGIES/Automotive Materials Technology	
Lightweight Materials Technology (Cont'd)	AUTOMOTIVE LIGHTWEIGHT MATERIALS: The R&D targets and priorities of the lightweight vehicle materials program have been set since 1994 through formal coordination with USCAR's United States Automotive Materials Partnership (USAMP) and the PNGV Materials Technical Team. However, in this year closer coordination began with functions of the auto materials supplier industry, most notably a technology roadmapping effort with the Aluminum Association. In addition, the Northwest Alliance for Transportation Technologies (NATT), which was formed in FY 1997, completed its initial portfolio	AUTOMOTIVE LIGHTWEIGHT MATERIALS: The roadmapping effort with the Aluminum Association is concluding. Discussions are being held with other organizations representing the auto materials supply industry, including the American Iron and Steel Institute (AISI), the International Magnesium Association (IMA), the International Titanium Association (ITA) and the American Plastics Council (APC). Interactions with the USCAR's Vehicle Recycling Partnership (VRP) are increasing as a result of planned expansion of efforts in recycling.	AUTOMOTIVE LIGHTWEIGHT MATERIALS: Formal coordination with the USAMP, the PNGV Materials Tech Team and the Aluminum Association will continue, and will likely be expanded to the AISI, IMA, ITA, APC and VRP.

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
	of projects which have been incorporated into this R&D element.		
Lightweight Materials Technology (Cont'd)	Metals: Some of the projects begun in FY 1994 through FY 1997 on aluminum concluded. One showed that continuously-cast aluminum sheet can have properties equivalent to standard ingot-cast and rolled sheet, but at reduced costs. Another demonstrated turn-around times for production of casting dies (molds) of less than ten weeks instead of the typical 40 to 50 weeks. Still another developed an alloy that only needs heat treatment typical of an auto paint bake cycle to develop adequate properties. An initial effort on lowering the cost of producing raw magnesium was terminated and another began. Approaches for producing raw titanium metal at less than $5/lb were assessed, and one was funded for further development.	Metals: Most of the remaining 1994-1997 projects on aluminum are concluding. These include projects on warm forming of aluminum sheet and on continuously-cast aluminum sheet. Assessments are showing that aluminum sheet at $1.25/lb is possible. Further work aimed at $1.05/lb by 2004 is being initiated. A project aimed at producing magnesium in automotive quantities for $1.25/lb began. A detailed plan for R&D to develop approaches for recycling the lightweight metal from future autos is being developed. The area of titanium is being assessed to confirm if efforts on titanium should be expanded. Two of three previous projects on steel were terminated.	Metals: Work aimed at $1.05/lb aluminum sheet will begin. All work on aluminum in the cast light metals project will end, but work on cast magnesium will continue. Production of thin-wall automotive components with at least 15% ductility will be demonstrated. At least a doubling of the useful life of dies used for molding aluminum or magnesium castings will be shown. Initial efforts on tailor-welded blanks of aluminum will end and new efforts will begin. Advanced work on achieving cost-competitive titanium components will commence. Work on recycling lightweight metals in future autos will be expanded.
	Composites: Most previous work from 1994-1997 on fiber glass-reinforced composites capable of 25% weight reduction ended and the transition to carbon fiber-reinforced composites capable of 50-60%	Composites: Rapid production of composite components is being confirmed by resin-impregnation of truck bed and truck tailgate preforms, thus concluding all prior efforts on glass fiber-reinforced	Composites: Work on carbon fiber-reinforced composites, begun in FY 1998 and 1999, will continue. Technology verifications for alternate precursors used to produce low-cost carbon fiber are planned.

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Lightweight Materials Technology (Cont'd)	weight reductions began. Achieved production of a chopped fiber-glass truck bed preform in less than four minutes. Due to this success, work on the alternative slurry molding process was terminated. Demonstrated that microwave energy could significantly cut the time for converting precursor fibers to carbon fibers, compared to normal thermal decomposition. Processes for producing lower cost precursors were identified. Previous studies of durability and crashworthiness of composites were redirected from glass-fiber to carbon-fiber composites. (ORNL, PNNL, Ames Lab, SNL, INEEL, LANL, LLNL, LBNL, Univ. of Texas-Austin, Alcoa, Chrysler, Ford, GM, Reynolds Aluminum, Commonwealth Aluminum, Ravenswood Aluminum, Textron, Rockwell, Knight & Packer, Budd Corp., Amcast, Georgia Tech, Purdue Univ. Applicator System, Oakland Univ., Concurrent Tech., ARCO Aluminum, Thixomat) (PNGV: $14,570) ($14,570)	composites. Three projects for producing carbon fiber precursors at less than $5/lb are being initiated, as are new efforts on thermoplastics composites. Action to focus the various carbon-fiber developments is being planned and initiated in conjunction with USCAR's Automotive Composites Consortium (ACC). An initial project on recycling of automotive polymeric composites is beginning. (PNNL, ORNL, Ames Lab, SNL, INEEL, LANL, LLNL, LBNL, ALRC, University of Texas-Austin, ALCOA, Reynolds Metals, Chrysler, Ford, GM, Commonwealth Aluminum, Ravenswood Aluminum, Textron, Rockwell, Budd Company, Amcast, ARCO Aluminum, Thixomat, Georgia Tech, Oakland University, University of Michigan, Michigan Tech, Erie Press Systems, Troy Design, Imageware, AutoDie International, Wyman Gordon, Universal Energy Systems, Eck Industries, CMI International, Thompson Aluminum Casting, Stackpole, EPRI, Inland Bar Steel, Republic Engineered Steel, North	Development of a user facility for assessing and optimizing the production of carbon fiber with alternate precursors will be coordinated with other government agencies, and planning will commence. Mechanical property test methods development for adhesive joining will conclude, and efforts to develop non-adhesive joining methods will commence. A preliminary design of a carbon-fiber based vehicle structure will be completed and associated high-rate production methodology development will start. An existing preform station will be modified to allow the use of carbon fiber in making large, rapidly produced preforms. Work on warm forming of thermoplastics will continue, with the addition of a project aimed at understanding, modeling and optimizing the production process. (PNNL, ORNL, Ames Lab, SNL, INEEL, LANL, LLNL, LBNL, ALRC, University of Texas-Austin, ALCOA, Reynolds Metals, Chrysler, Ford, GM, Commonwealth Aluminum, Ravenswood Aluminum, Textron,

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
		Star Steel Co., MacSteel Co., Aeroquip Corp., Stahl Speciality, Westmorland Mechanical Testing, Delphi Energy Systems, PACCAR) (PNGV: $19,690) ($19,690)	Rockwell, Budd Company, Amcast, ARCO Aluminum, Thixomat, Georgia Tech, Oakland University, University of Michigan, Michigan Tech, Erie Press Systems, Troy Design, Imageware, AutoDie International, Wyman Gordon, Universal Energy Systems, Eck Industries, CMI International, Thompson Aluminum Casting, Stackpole, EPRI, Inland Bar Steel, Republic Engineered Steel, North Star Steel Co., MacSteel Co., Aeroquip Corp., Stahl Speciality, Westmorland Mechanical Testing, Delphi Energy Systems, PACCAR) (PNGV: $14,000) ($14,000)
Lightweight Materials Technology (Cont'd)	TRANSFER FROM: TRANSPORTATION MATERIALS TECHNOLOGIES/Heavy Vehicle Materials Technology HEAVY VEHICLE HIGH STRENGTH WEIGHT REDUCTION MATERIALS: Cast selected large, high-strength, lightweight vehicular components by a high rate process, to establish parameters needed to design equipment and to prepare for	TRANSFER FROM: TRANSPORTATION MATERIALS TECHNOLOGIES/Heavy Vehicle Materials Technology HEAVY VEHICLE HIGH STRENGTH WEIGHT REDUCTION MATERIALS: Complete design and procurement of equipment for large-component castings project. Cast prototype	HEAVY VEHICLE HIGH STRENGTH WEIGHT REDUCTION MATERIALS: Complete design, and order dies and platens, for prototype aluminum casting which exceeds the

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
	industrial production runs in the large-component casting project.	ultra-large, thin-walled aluminum vehicle components.	component size produced by the ultra-large caster. Design and test smaller components. With trucking industry partner, select prototype large truck component to be used later for initial casting tests.
Lightweight Materials Technology (Cont'd)	Fabricated and tested selected prototype components employing carbon-based materials for heavy vehicle applications, based on improved stiffness, durability and lighter weight.	In conjunction with the Office of Fossil Energy, characterize and test precursor fibers, and other forms of coal-derived carbon, for lightweighting of heavy vehicle components, such as structural insulation, tires and under-run bars and energy absorbent foams for safety applications.	Continue development of strong, durable, low cost lightweight carbon fiber-based materials for truck components.
	Completed development and characterization of advanced metal compression forming process for high strength, aluminum-based lightweight materials for heavy vehicle engine and structural applications. Continued development and characterization of lightweight metallic components for application in advanced diesel engines. (American Trucking Associations, truck OEMs, Alcoa, Thompson Aluminum Casting, Cummins Engine Co., Amoco, Detroit Diesel Corp., Caterpillar Tractor, ORNL, PNNL, WVU, MIT) ($3,045)	In cooperation with the heavy vehicle industry, the Northwest Alliance for Transportation Technologies, Oak Ridge National Laboratory's National Transportation Research Center, and DOE's Offices of Industrial Technologies and Science, evaluate applications of new metal forming processes and lightweight alloys for producing heavy vehicle components, particularly structural and advanced diesel engine applications. Within the scope of the multi-year program plan, initiate	Expand to prototype scale the casting and fabrication of large, three dimensional, aluminum-based structural components for heavy and medium duty truck frames. Coordinate this activity and other truck lightweighting strategies with the Northwest Alliance for Transportation Technologies and the National Transportation Research Center at ORNL. Explore the application of equal channel angular extrusion (ECAE) to aluminum and magnesium

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Lightweight Materials Technology (Cont'd)		design and fabrication of aluminum frame, tractor, and transmission components for heavy vehicles. Continue development of metal compression forming process with aluminum and magnesium metal matrix composites. Evaluate extension of process to higher temperature materials. (American Trucking Associations, truck manufacturers, Alcoa, Thompson Aluminum Casting, Cummins, Amoco, Detroit Diesel, Caterpillar, ORNL, ANL, PNNL, WVU, MIT) ($4,135)	lightweight alloy materials for vehicle components, with the intent to achieve improved microstructure, properties, performance and control. Apply the metal compression forming technology to ultra-lightweight monolithic magnesium alloy, and magnesium-based metal matrix composite, vehicular components. (American Trucking Associations, truck manufacturers, Alcoa, Thompson Aluminum Casting, Cummins, Amoco, Detroit Diesel, Caterpillar, ORNL, ANL, INEEL, PNNL, WVU, MIT) ($2,950)
	$17,615	$23,825	$16,950
High Temperature Materials Laboratory	HIGH TEMPERATURE MATERIALS LABORATORY: Continued to focus High Temperature Materials Laboratory (HTML) support and assistance to automotive manufacturers, heavy vehicle manufacturers, diesel engine manufacturers, and the trucking industry.	HIGH TEMPERATURE MATERIALS LABORATORY: With the unique collection of instruments in the six HTML user centers, continue to provide a comprehensive set of tools for performing state-of-the-art determination of the structures and properties of materials at high temperatures. Provide increasingly sophisticated instrumentation and techniques, including	HIGH TEMPERATURE MATERIALS LABORATORY: Maintain world class, state-of-the-art technical and scientific level diagnostic and characterization capabilities for advanced materials, by continuously developing advanced analytical techniques and periodically acquiring the most modern equipment to support development of new and improved

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
		characterization of microstructures at higher resolution; infra-red imaging of processes occurring at atomically active sites; evaluation of barrier and other coatings by accurate measurements of hardness, modulus, thermal properties, wear, friction, residual stresses, and adherence; refinement of ceramic component lifetime analysis, and higher speed/higher precision machining.	materials for application in surface transportation vehicles.
High Temperature Materials Laboratory (Cont'd)		Capital Equipment: Purchase a high resolution Scanning Auger Microscope ($875), which has 10 times the brightness, and 10 times the signal, of the current instrument. Maintain existing equipment and upgrade the Differential Scanning Calorimeter.	Capital Equipment: Purchase and accept delivery of a one-of-a-kind (in the U.S.) high resolution (0.7 vs 1.6 Angstrom) Transmission Electron Microscope ($1,700), which will greatly enhance the ability to detect, image, and quantify chemical species that control the structural, microstructural, electronic, and other physical properties of the full range of vehicular materials. The specific, near-term application of the microscope to the full characterization (chemical composition and internal structure, occupied atom sites, particle sizes, shapes, surface morphology and

Activity	FY 1998	FY 1999	FY 2000
			defects, internal and surface adherent impurity species, and active sites of catalysis) of lean burn NOx catalysts is critical for the development of optimized catalysts required by advanced spark ignition and diesel vehicles. A 32% cost share is anticipated from industry users of the current microscope. The cost of the microscope constitutes a one-time expenditure in FY 2000.
High Temperature Materials Laboratory (Cont'd)	As part of the DOE 2000 initiative, applied the remote operation technique, developed for the electron microscope, to other instruments. Increased efforts to provide users with friction and wear characterization capabilities. Demonstrated neutron radiography and tomography for large items such as engine blocks. Demonstrated remote capability (DOE 2000), via neutron resonance spectrometry, to accurately measure temperatures of components, such as pistons, in operating diesel or other internal combustion engines.	Participate in the DOE 2000 Materials Micro Characterization Collaboratory, an Office of Science initiative designed to permit creative scientists, having varying yet complementary expertise, to operate in a new environment which allows convenient, rapid, and dynamic research interactions, e.g., accurately measuring temperatures, to flow unencumbered by the limits of time and distance.	Extend the methodology developed for remote operation of the electron microscope in the DOE 2000 Materials Micro Characterization Collaboratory to include the new high resolution microscope. Through the user centers and cooperative efforts with industry, enhance the scientific data base of the expanding range of materials and help prepare the next generation of U.S. technologists for the increasingly sophisticated techniques needed to develop cost-effective materials that meet more stringent performance demands, including enhanced engine energy efficiency, significantly reduced exhaust gas

III. Performance Summary: MATERIALS TECHNOLOGIES (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
High Temperature Materials Laboratory (Cont'd)	To maintain the quality of research in the expanding area of transportation energy efficiency, fully support 16 scientific staff for the user program. (ORNL) ($5,100)	To respond to the defined national needs of energy efficiency and reduced exhaust emissions in transportation, fully support 16 scientific staff for the user program. (ORNL) ($5,440)	emissions, and substantially improved engine component durability and reliability. Maintain support of 16 scientific staff for the user programs and to manage the sophisticated experimentation in support of the transportation developments described above. (ORNL) ($7,000)
	$5,100	$5,440	$7,000
Materials Technologies Total	**$33,870**	**$37,475**	**$33,000**

TRANSPORTATION TECHNOLOGIES
TRANSPORTATION SECTOR
(dollars in thousands)

TECHNOLOGY DEPLOYMENT

I. Mission Supporting Goals and Objectives

I. A. Program Strategy

Successful introduction and commercialization of alternative fuel vehicles (AFVs) and advanced technology vehicles with significantly improved fuel economy are necessary to achieve reductions in oil consumption and environmental emissions from transportation. The Department's deployment efforts logically follow and complement successful technology development by industry and government. The program, in coordination with partners, stakeholders, and customers, will provide the catalyst needed to establish an improved public understanding about, and resulting market demand for, alternative fuel vehicles, advanced technology vehicles, and new fuels; and to establish a strong and far-reaching fuel and service infrastructure. The program is designed to provide support at critical periods in the transition of advanced transportation technologies from the laboratory to the marketplace, and then reduce government support as market penetration improves.

The Deployment program puts DOE and industry developed alternative fuel and advanced vehicle technologies to work for energy security and clean air by creating and supporting initiatives which get those technologies out of the lab and onto the road.

The mission of the Technology Deployment program is to accelerate the adoption and use of alternative fuel and advanced technology vehicles to help meet energy and environmental goals. With fleets paving the way for higher volume, lower cost vehicle production, and the installation of refueling capability, the strategic objective is to make alternative fuel vehicles and advanced technology vehicles the preferred choice of many individual private vehicle purchasers. Over the next five years, the program will result in significant increases in the number of alternative fuel vehicles, reductions in petroleum consumption compared to baseline projections, and reductions in environmental emissions from transportation. The program's overall goal is to support the introduction and use of over 4 million AFVs over the next five years, a significant increase over the 500,000 AFVs operating in 1998. These AFVs will displace, by 2004, at least 200,000 barrels per day of petroleum, reduce carbon emissions by 3 million metric tons per year, and reduce annual energy costs (i.e., oil costs) by approximately $1 billion per year.

The Deployment program supports the use of new transportation technologies that will enable dramatic changes necessary to deal with rising dependence on oil imports and the increasing impact of transportation on air quality. A transportation system that uses a more diverse fuel supply, and less oil overall, will increase competition and provide greater resiliency in the face of external disruptions. The Department's Comprehensive National Energy Strategy (April 1998) documents the need for deployment activities to complement research and development

I. Mission Supporting Goals and Objectives: TECHNOLOGY DEPLOYMENT (Cont'd)

efforts: *"Promoting the acquisition of newly developed alternative fuel transportation technologies for government and private fleets, through efforts such as the Clean Cities program, encourages more widespread use of alternative fuels. Federal funding, leveraged by significant private investment, can create an infrastructure of corridors in which alternative fuel vehicles can readily find refueling stations, spurring the use of alternative transportation fuels in key regions."* (page 20). This approach is also endorsed by the President's Committee of Advisors on Science and Technology, in its November 1997 recommendations: *"Government investment in R&D is crucial, but needs to be supplemented by standards, incentives, information, and education programs."* (page 3-9).

The approach to meeting the program goals is to promote both alternative fuel use and advanced vehicles that have significantly improved fuel economy. The alternative fuel efforts are designed around the multiple goals of the Energy Policy Act of 1992 (EPACT), which supported and renewed the Alternative Motor Fuels Act of 1988. Alternative fuels of interest include electricity, ethanol, hydrogen, methanol, natural gas, biodiesel and propane. Relative to petroleum fuel substitution, the basic EPACT goal is to promote the development and use of domestic replacement fuels to substitute for imported petroleum motor fuels to the maximum extent practicable. Within the context of the basic program goal, DOE focuses its program on those replacement fuels which will have the greatest impact on: reducing oil dependency, improving the nation's economy, and reducing criteria pollutants and greenhouse gas emissions. The Department promotes the increased use of alternative fuels in vehicles, and also the increased use of non-petroleum fuels (e.g., ethanol, biodiesel, oxygenates) blended into conventional gasoline and diesel fuels. Both uses of non-petroleum fuels can help promote the goals of EPACT as "replacement fuels" for petroleum-based fuels.

Appropriate Federal Role: With oil prices at record lows, current market conditions are not conducive to widespread use of, and investment in, alternative fuels and fuel efficient vehicles. In addition, Federal policies do not provide adequate tools to address many of the technical and market barriers to increased use of these vehicles, even though it would be in the national long-term self interest. Until market and/or policy conditions change, the Federal deployment programs will lay the foundations for future use by focusing on proven niche markets where alternative fuel vehicles and advanced vehicles can successfully compete.

- For the next five years, alternative fuels and alternative fuel vehicles will be the primary focus. With over 40 models of alternative fuel vehicles available, the technical risk is low. However, Federal efforts, such as the successful Clean Cities program, are needed to support the growth of refueling infrastructure and consumer acceptance of AFVs. To help build consumer confidence in these technologies and encourage private sector investment in supporting infrastructure, the program will:

    -- forge partnerships with fleet owners, fuel providers, vehicle manufacturers, and State and local governments;

    -- provide current, accurate, reliable information on all types of alternative fuels and vehicles;

    -- perform rigorous, structured programs to test and evaluate cars and trucks that use alternative fuels and advanced technologies;

I. <u>Mission Supporting Goals and Objectives</u>: TECHNOLOGY DEPLOYMENT (Cont'd)

-- implement the requirements of the Energy Policy Act;

-- promote consumer acceptance of advanced technology cars and trucks with significantly improved fuel economy; and

-- encourage the increased blending of non-petroleum fuels into conventional gasoline, reformulated gasoline, and new formulations of diesel fuel.

- Acquisition of AFVs by the Federal fleet remains an important part of the technology deployment program; the current Federal fleet has over 20,000 AFVs. The program will continue to encourage the use of AFVs in the Federal fleet to help agencies meet and exceed all Energy Policy Act and Executive Order requirements.

- During this same period, advanced technology vehicles capable of significantly improved fuel economy will be entering the final development phases; some will already be available commercially. The program will support educational efforts, testing and evaluation, and deployment planning for these technologies. The Clean Cities program will help promote these advanced vehicles. In addition, the program will work with industry and universities to sponsor advanced vehicle competitions that push the technology envelope and expose numerous people to these technologies.

I. B. Program Benefits

The Department's efforts to encourage the deployment of alternative fuel and advanced technology vehicles are linked with and support State and local government initiatives. The Federal investment, together with these complementary efforts, will result in significant changes in the transportation market over the next five years. By 2004, alternative fuel vehicles will have achieved significant commercial success, and advanced technology vehicles will be poised to enter the market as increasing awareness of the benefits of fuel diversity and fuel-efficient vehicles spurs demand. In particular:

- In selected metropolitan areas, alternative fuel vehicles will be common-place and supported by extensive re-fueling infrastructure.

- Clean Cities will grow from 67 to over 100 participants but, more importantly, 15% of the Cities will reach their goals for 100% AFV use in specific market niches (e.g., taxis, shuttles, school buses, etc.).

- Alternative fuel vehicles will account for 40-50% of the transit bus orders (30% in 1998); 10-20% of school bus orders (less than 1% in 1998); and 10-20% of the covered light duty fleet orders with spillover into the medium duty market (less than 1% in 1998).

I. <u>Mission Supporting Goals and Objectives</u>: TECHNOLOGY DEPLOYMENT (Cont'd)

- Cost-shared infrastructure/corridor development will yield 10 times the number of E85 refueling stations (less than 50 in 1998), 5 times the number of EV recharging stations (500 in 1998), and 5 times the number of natural gas stations available in 1998 (1,400 in 1998).

- The blend market for renewable fuels will be 50% larger (1 billion gallons annually in 1998).

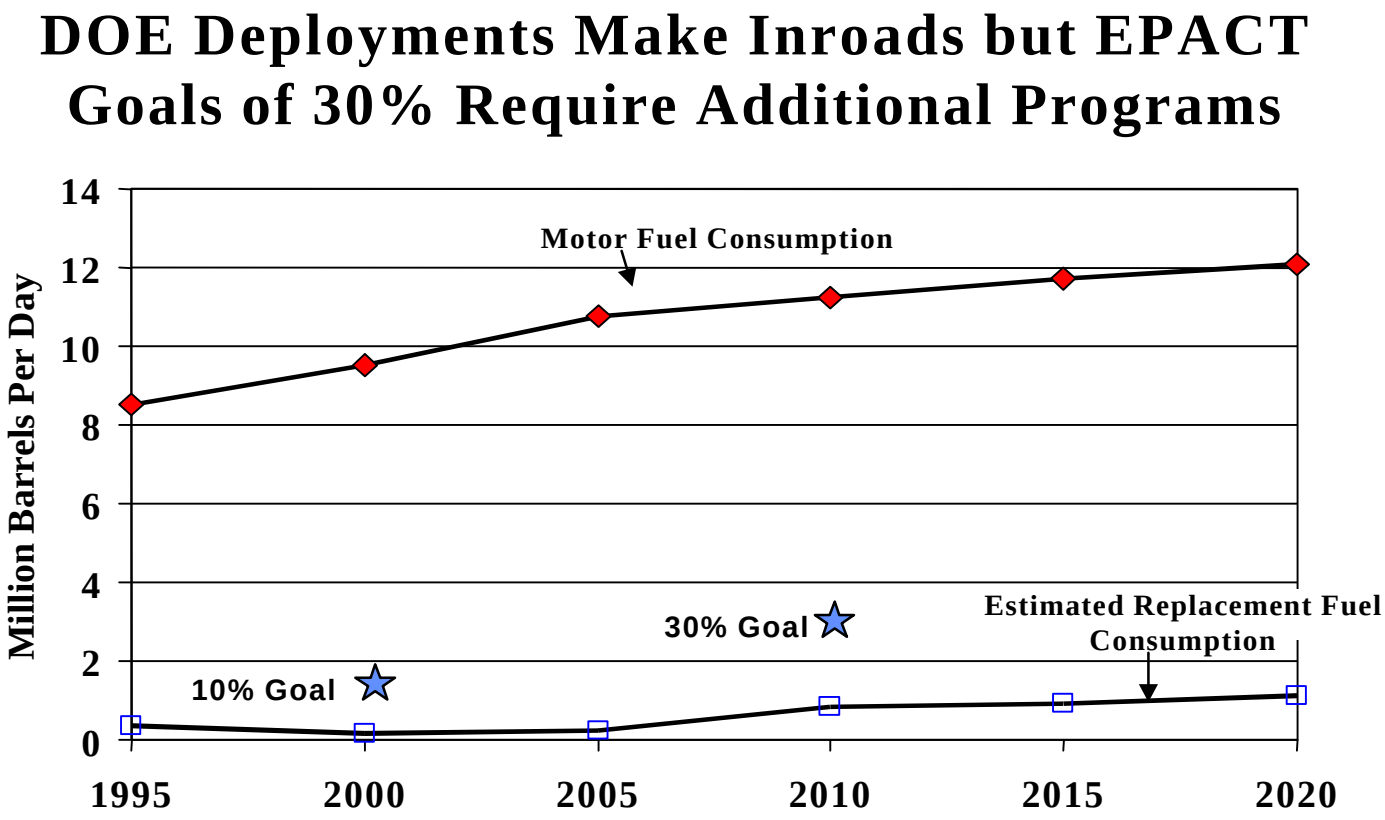
- Vehicle competitions will have demonstrated 60 and 80 mpg cars, and motivated hundreds of highly trained automotive engineers.

Using the Office of Transportation Technologies' quality metrics modeling methodology, it is estimated that about 1 million AFVs will be in operation nationally by the year 2000. If 50% of these use alternative fuels routinely, they would displace 20,000 barrels per day of petroleum, reduce carbon emissions by 0.21 million metric tons per year, and reduce annual energy costs (i.e., oil costs) by approximately $150 million per year. These estimates are summarized below:

Metric	2000	2010	2020
Primary Energy Displaced (quadrillion Btu)	0	0	0
Primary Oil Displaced (million barrels per day)	0.02	0.2	0.21
Energy Cost Savings ($ billion)	0.15	0.85	0.7
Carbon Reductions (million metric tons)	0.21	1.82	1.94

I. <u>Mission Supporting Goals and Objectives</u>: TECHNOLOGY DEPLOYMENT (Cont'd)

This significant penetration of alternative fuel vehicles, and the resulting oil displacement and cost savings, would not, however, be adequate to meet the ambitious goals set forth in the Energy Policy Act. As shown in the graph below, the EPACT Section 502(b) goal of 30 % oil displacement by the year 2010 equates to about 3.5 million barrels per day. With current funding levels and programs, this goal will not be achieved. However, OTT will work with industry, State, and local governments to identify additional programs that could be developed by the States and Federal government to further increase the use of alternative fuels.



Source: EIA AEO 1998. Replacement Fuels includes alternative fuels used in vehicles and non-petroleum fuels blended into gasoline.

I. Mission Supporting Goals and Objectives: TECHNOLOGY DEPLOYMENT (Cont'd)

I. C. Performance Measures

The Deployment program is divided into four complementary program areas: Clean Cities, Testing and Evaluation (which includes the Federal fleet program), EPACT Replacement Fuels Program, and Advanced Vehicle Competitions. Each program area and its planned accomplishments are described below.

Clean Cities

Activity Summary: Clean Cities is a voluntary Federal program designed to accelerate and expand the use of alternative fuel vehicles (AFVs) in communities throughout the country, and to provide refueling and maintenance facilities for their operation. As of January 1999, sixty seven communities have joined the Clean Cities program. Many of these local programs have links across regional and State boundaries to establish Clean Corridors with refueling infrastructure, to allow easier inter-city travel with alternative fuel vehicles. Technical information development and dissemination are now coordinated under the Clean Cities program to better reach stakeholders and consumers. The State Energy Program Special Projects for transportation are also funded through the Clean Cities program.

Partners: These programs are highly leveraged. The Clean Cities program has over 3,000 stakeholders in 67 cities. The State Energy Program Special Projects, funded by the Clean Cities program, attract 6:1 cost share, with significant State, local, and private funding. Industry co-sponsorship of the Clean Cities conference is at least 50%. In-kind cost share from industry, State, and local partners (time, overhead, space, logistics, etc.) in the Clean Cities is easily worth an additional 50-100% of the DOE deployment budget.

Goal: For FY 2000, the Technology Deployment program will use Clean Cities to focus alternative fuel efforts in proven niche markets and to expand public education and outreach activities.

Pre-FY 1998 Accomplishments

- Launched the Clean Cities program in 1993 and added 25 participants in the subsequent 18 months, bringing national attention to the role that local communities can play in deploying alternative fuel vehicles.
- Provided over $8 million in financial assistance grants to Clean Cities through the State Energy Program Special Projects, leveraging over $30 million in non-Federal investment for alternative fuel projects.
- Established the Alternative Fuels Data Center and hotline that have developed and provided to fleets and consumers objective information on alternative fuels and vehicles.

I. Mission Supporting Goals and Objectives: TECHNOLOGY DEPLOYMENT (Cont'd)

FY 1998 Accomplishments
- Expanded the Clean Cities program to 66 participating communities and focused efforts on assisting implementation of local plans for alternative fuel market development. Strengthened the infrastructure corridor program, through the States and Clean Cities, that encouraged refueling development and alternative fuel use. Launched the ethanol infrastructure development program in two Clean Cities.
- Added electric and hybrid vehicle data and information products to the Alternative Fuels Data Center and disseminated the information through Clean Cities.

FY 1999 Planned Accomplishments
- Expand the Clean Cities scope to include emphasis on fuel efficient vehicles, and expand grants to States and Clean Cities for demonstrating vehicles with significantly improved fuel economy. Link and solidify Clean Cities infrastructure and corridor investments launched in 1996 through 1998.
- Improve the value of the Fuel Economy Guide and other information products, as a means to encourage the use of fuel efficient vehicles.

FY 2000 Planned Accomplishments
- Strengthen Clean Cities focus on proven niche markets, leading to 100% penetration of alternative fuels in several niche markets in selected Clean Cities.
- Expand Clean Cities educational materials that focus on alternative fuels and advanced fuel efficient technologies.
- Create Clean Cities Buyers Clubs to help consumers and fleets obtain alternative fuel vehicles quickly and at lowest cost.
- Expand the number of Clean Cities participating in the ethanol infrastructure development program.

FY 2001 - FY 2004 Planned Accomplishments
- Continue Clean Cities corridor and infrastructure efforts to strengthen and expand availability of refueling infrastructure. Expand the number of Clean Cities that achieve 100% penetration of alternative fuel vehicles in niche markets. Create Clean Cities "Early Adopter" Club for advanced technology vehicles.

Testing and Evaluation

Activity Summary: The Department of Energy is recognized nationally and internationally for its objective testing and evaluation programs for alternative fuel vehicles, including electric vehicles. In partnership with industry, performance and emissions of near market-ready advanced technology vehicles are validated, and data is made available to engineers, government agencies, manufacturers, fleets, and consumers.

Partners: Industry partners, such as the electric utilities, contribute 50% cost share. The Federal agencies participate actively though the acquisition of significant numbers of alternative fuel vehicles, a portion of which are used to provide data on real-world use.

I. Mission Supporting Goals and Objectives: TECHNOLOGY DEPLOYMENT (Cont'd)

Goal: In FY 2000, the test and evaluation program will continue electric vehicle testing while initiating performance and emissions testing for near market-ready advanced technology vehicles. This program will also facilitate the increased use of AFVs by the Federal agencies.

Pre-FY 1998 Accomplishments
- Developed and implemented the EV America testing program, in partnership with industry, that led to the first comprehensive evaluation standards for electric vehicles.
- Conducted emissions and performance testing on thousands of light duty alternative fuel vehicles in Federal and private fleets, yielding the world's largest database of scientific information on alternative fuel vehicles.
- In partnership with other Federal agencies, facilitated the growth of the Federal AFV fleet to over 20,000 AFVs.

FY 1998 Accomplishments
- Started the first year of field test/evaluation of electric vehicles using first generation advanced batteries developed through the cooperative agreement with the U.S. Advanced Battery Consortium.
- Initiated an electric vehicle loaner program for Federal agencies to provide additional opportunities for them to evaluate and acquire electric vehicles.
- Facilitated the acquisition of over 10,000 alternative fuel vehicles by the Federal agencies, which will increase the Federal AFV fleet from about 20,000 to nearly 30,000 AFVs.

FY 1999 Planned Accomplishments
- Demonstrate state-of-the-art, fuel-efficient vehicle technologies for cars and trucks, including hybrid vehicles. Initiate a three-year test and evaluation program for medium/heavy duty hybrid vehicles.
- Continue EPACT fleet programs, adding 8,000 AFVs to the Federal fleet.

FY 2000 Planned Accomplishments
- Complete the final year of light duty electric vehicle test and evaluation; compile and report results through the Alternative Fuels Data Center and Clean Cities information network.
- During the second year of medium and heavy duty hybrid test and evaluation program, initiate cost-shared procurement and placement of vehicles with Federal and industry partners.
- Support the annual acquisition of 12,000 alternative fuel vehicles in the Federal fleet.

FY 2001 - FY 2004 Planned Accomplishments
- Launch phased test and evaluation programs for light duty hybrid vehicles, fuel cell vehicles, and medium/heavy duty natural gas vehicles as they become available from technology development programs.

I. Mission Supporting Goals and Objectives: TECHNOLOGY DEPLOYMENT (Cont'd)

EPACT Replacement Fuels Program

Activity Summary: The Department is responsible for implementing the Energy Policy Act requirements for the purchase of alternative fuel vehicles. Those requirements currently apply to Federal agencies, State governments, and alternative fuel providers (e.g., natural gas utilities). In carrying out this responsibility, the Department prepares and issues needed regulations, collects data, performs analysis, and prepares reports to Congress.

Partners: The program works closely with the Department's Offices of Policy and General Counsel, with other Federal agencies, and with the Office of Management and Budget, to ensure that analyses and regulations are appropriately reviewed prior to publication. Through informal stakeholder groups and public notices, the Department solicits and considers public comments on its proposed analyses and regulations.

Goal: For FY 2000, the program will continue to implement the Energy Policy Act mandates for AFVs, including the optional private and local fleet requirement. The program will also research and develop market-based policies and standards that can encourage the greater use of fuel-efficient vehicles and non-petroleum blends.

Pre-FY 1998 Accomplishments
- Developed and published regulations implementing the State and fuel provider alternative fuel vehicle acquisition mandates under the Energy Policy Act of 1992.
- Developed and published, in coordination with the Department's Office of Policy, a comprehensive report on the feasibility of achieving the Energy Policy Act goals.
- Developed and published a report on the potential for replacement fuels to meet the goals of the Energy Policy Act.

FY 1998 Accomplishments
- Continued implementation of EPACT fleet requirements and undertook a rulemaking to consider expanding requirements to private and local fleets.
- Moved the certification of training program to the private sector.

FY 1999 Planned Accomplishments
- Continue enforcement of EPACT fleet programs.
- Continue the rulemaking process on private and local fleets.
- Determine, through public comment and rulemaking, how to modify the EPACT replacement fuel goals, and evaluate options to promote the maximum practicable use of replacement fuels.

FY 2000 Planned Accomplishments

I. Mission Supporting Goals and Objectives: TECHNOLOGY DEPLOYMENT (Cont'd)

- Continue implementation and enforcement of existing EPACT alternative fuel vehicle programs. Complete and publish a final determination for the expansion of vehicle requirements to private and local government fleets.

FY 2001 - FY 2004 Planned Accomplishments
- Through EPACT fleet program implementation, increase the number of alternative fuel vehicles in fleets to as many as 3 million vehicles.
- Prepare and submit to Congress analyses and recommendations for additional programs and policies that may be needed to meet the EPACT replacement fuel goals.

Advanced Vehicle Competitions

Activity Summary: The Advanced Vehicle Competitions provide an unparalleled education in automotive engineering for university students, while demonstrating the performance of the critical vehicle technologies identified by the Department of Energy and its partners. Students who graduate from these vehicle competitions go on to take jobs in the auto industry, where they bring with them an unprecedented appreciation and understanding of advanced technologies. During the next several years, DOE will continue to support both the FutureCar Challenge and fuel competitions, such as the Ethanol Challenge, and will offer other opportunities to additional universities to demonstrate a specific fuel or technology.

Partners: Support for the competitions comes from the auto and fuels industries, suppliers, and State and Federal government agencies. In previous years, direct cost sharing has ranged from 50-75%, with students and universities providing additional local funding.

Goal: In FY 2000, the Department will use these unique university/industry partnerships to push the envelope of technology and develop a new generation of transportation engineers.

Pre-FY 1998 Accomplishments
- Sponsored student competitions for methanol, natural gas, propane, and hybrid vehicles that demonstrated innovative technologies to meet energy and environmental goals.
- Exposed thousands of college students to advanced transportation technologies, over 50% of these students are now working in the automotive industry putting their experience to work.

FY 1998 Accomplishments
- Initiated the Ethanol Challenge, which included 14 universities. Demonstrated improved cold start capability, fuel economy and emissions for dedicated E-85 vehicles. Demonstrated reliability and performance by traveling 600 miles from the General Motors Proving Grounds in Michigan to Washington, DC. Challenge participants were featured in the National Clean Cities Conference.
- Introduced fuel cell technology into the FutureCar competition at two universities.

I. Mission Supporting Goals and Objectives: TECHNOLOGY DEPLOYMENT (Cont'd)

- Demonstrated industry's commitment to the FutureCar competition through USCAR's donation of 10 new vehicles, as well as substantial seed and award money for the participating universities. Achieved 75 mpg in two FutureCar vehicles during the on-road fuel economy event.

FY 1999 Planned Accomplishments
- Demonstrate 65 mpg fuel efficiency with mid-sized sedans on the combined driving cycle.
- Demonstrate two on-the-road fuel cell-powered FutureCar vehicles.
- Introduce new direct injection engine technologies into the university competition.
- Demonstrate dramatic lightweighting and mass reduction in FutureCar vehicles to achieve higher fuel economy.
- Demonstrate improved energy efficiency and reduced emissions from dedicated E-85 vehicles in the second year of the Ethanol Challenge.

FY 2000 Planned Accomplishments
- Demonstrate 70 mpg in FutureCar competition vehicles.
- Open FutureCar Challenge participation to 12 new universities.

FY 2001 - FY 2004 Planned Accomplishments
- Demonstrate 80 mpg in multiple FutureCar competition vehicles.

II. A. Funding Table: TECHNOLOGY DEPLOYMENT

Program Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Request	$ Change	% Change
Clean Cities	$ 7,396	$ 7,905	$ 10,700	$+2,795	+35.4%
Testing and Evaluation	2,795	2,920	4,000	+1,080	+37.0%
EPACT Replacement Fuels Program	1,375	1,285	2,000	+715	+55.6%
Advanced Vehicle Competitions	850	840	1,000	+160	+19.0%
Total, Technology Deployment	$ 12,416	$ 12,950	$ 17,700	$+4,750	+36.7%

II. B. Laboratory and Facility Funding Table: TECHNOLOGY DEPLOYMENT

Program Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Request	$ Change	% Change
Argonne National Lab	$ 1,184	$ 275	$ 300	$+25	+9.1%
Idaho National Engineering and Environmental Lab	1,701	1,000	1,460	+460	+46.0%
National Renewable Energy Lab	3,600	2,600	2,410	-190	-7.3%
Oak Ridge National Lab	861	730	200	-530	-72.6%
All Other	5,070	8,345	13,330	+4,985	+59.7%
Total, Technology Deployment	$ 12,416	$ 12,950	$ 17,700	$+4,750	+36.7%

III. Performance Summary: (New BA in thousands of dollars)

Activity	FY 1998	FY 1999	FY 2000
Technology Deployment			
Clean Cities	TRANSFER FROM: Clean Cities Voluntary Deployment program; Infrastructure, Systems, and Safety; and Technical Information Development:	TRANSFER FROM: Clean Cities Voluntary Deployment program; Infrastructure, Systems, and Safety; and Technical Information Development:	
	Core Program: Expanded the Clean Cities program to 66 participating communities, focusing efforts to leverage specific private capital investments for greater alternative fuel market development. Continued efforts to measure the success of each Clean Cities program in carrying out its plan. Encouraged voluntary private sector efforts to complement existing rules for government fleets and help meet energy, environmental, and economic goals. Launched ethanol refueling pilot projects, in partnership with States, in two cities.	Core Program: Expand the program to 75 participating cities, and focus on alternative fuel vehicle placement in niche markets and corridors. Expand Clean Cities scope to encompass fuel efficient advanced technology vehicles. Accept one more city in the ethanol infrastructure pilot program. Add new liquefied natural gas (LNG) refueling stations and many new heavy duty LNG trucks to the west coast corridor. Promote adoption of 100% niche penetration targets in several cities.	Core Program: Continue to strengthen Clean Cities efforts to deploy alternative fuel vehicles and build alternative fuel refueling stations. Focus efforts on proven niche markets, such as taxis, airport shuttles, transit buses, school buses, delivery fleets, and others. Achieve 100% AFV use in specific niche markets in at least two cities. Create a Clean Cities Buyers Club to facilitate AFV purchases. Increase the number of refueling stations by encouraging private investments. Submit report to Congress on program effectiveness.
	Tools and Training: Developed tools and training to promote use of alternative fuel vehicles. Provided software tools and training through	Tools and Training: Identify and add capabilities to promote use of medium and heavy duty alternative fuel vehicles. Continue to offer	Tools and Training: Continue to promote use of fuel efficient advanced technology vehicles. Update tools with latest technical

III. Performance Summary: TECHNOLOGY DEPLOYMENT (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Clean Cities (Cont'd)	workshops, print media, and the Internet to enable fleet managers, community planners, and fuel providers to better identify local options for alternative fuel projects. (EPACT Section 505) (NREL)	tools through workshops, print media, and the Internet. Hold at least 30 fleet workshops to facilitate AFV use by fleets. Coordinate with DOT to provide training to Clean Cities on new transportation programs. (EPACT Section 505) (NREL)	information. Continue to offer tools through workshops, print media, and the Internet. Co-sponsor, with EPA, a regional workshop to discuss and provide information on how advanced technology vehicles can help meet local air quality goals. (EPACT Section 505) (NREL)
	Competitive Grants: Continued State grants and other public/private partnerships to competitively fund projects that support infrastructure development, vehicle use, and technology demonstration. Provided $2.665 million for 33 Special Project State Grants. Provided $0.5 million for cost-shared program with the Gas Research Institute. (EPACT Sections 302, 409) (INEEL, States)	Competitive Grants: Continue and increase State grants work from previous year; in particular, support projects that develop 100% niche market applications for AFVs. Expand projects that promote the use of fuel efficient vehicles. Provide $2.7 million for 25-30 Special Project State Grants. Start a National Parks initiative to demonstrate alternative fuel vehicles in critical locations, providing $0.25 million for 2-3 high visibility projects. (EPACT Sections 302, 409) (States)	Competitive Grants: Continue State grants and other public/private partnerships to competitively fund projects that support infrastructure development, vehicle use in niche markets, and technology demonstration. Provide $2.7 million for 25-30 Special Project State Grants. Continue the National Parks initiative, providing $1.0 million for 3-5 projects. (EPACT Sections 302, 409) (States)
	Education and Outreach: Developed and disseminated targeted technical information products to consumers and other stakeholders. Provided information	Education and Outreach: Develop and disseminate targeted case studies to consumers and other stakeholders. Use the Energy Smart Schools program to showcase	Education and Outreach: Continue technical information development, adding additional products related to near-term advanced technologies, including fuel cells. Continue to

III. Performance Summary: TECHNOLOGY DEPLOYMENT (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Clean Cities (Cont'd)	over the Internet, at conferences, and through publications. Continued publication of the congressionally required Fuel Economy Guide. (EPACT Section 405) (ANL, NREL, ORNL, GPO)	alternative fuel school buses. Sponsor 5th annual Clean Cities conference, heavily cost-shared by industry. Re-engineer the Fuel Economy Guide and develop other consumer products to promote fuel efficient, advanced technology vehicles. Work with auto dealers, associations, and others to increase the usage of the Fuel Economy Guide. (EPACT Section 405) (ANL, NREL, ORNL, GPO)	sponsor 6th annual Clean Cities conference to showcase commercially available AFVs. Continue to refine the Fuel Economy Guide to improve utilization. Research the concept for a Clean Cities "Early Adopters" Club to promote fuel efficient advanced technology vehicles. (EPACT Section 405) (ANL, NREL, ORNL, GPO)
	$7,396	$7,905	$10,700
Testing and Evaluation	TRANSFER FROM: Vehicle Field Test/Evaluation Vehicle Evaluation: Conducted vehicle testing for performance, reliability, and emissions, on a wide variety of commercially available alternative fuel and advanced technology vehicles. In partnership with electric utilities, acquired, tested, and evaluated new electric vehicles (EV) to support deployment efforts in ten EV Market Launch communities. (EPACT Sections 601 and 505) (INEEL, NREL, ANL)	TRANSFER FROM: Vehicle Field Test/Evaluation Vehicle Evaluation: Continue electric vehicle and other AFV testing and evaluation program, in partnership with industry. Initiate field testing of selected medium and heavy-duty hybrid vehicles, focusing on identifying industry partners and developing specifications for hybrid evaluation. (EPACT Sections 601 and 505) (INEEL, NREL, ANL)	Vehicle Evaluation: Complete final year of electric vehicle test and evaluation program. Continue selected AFV testing in partnership with industry. Continue second year of field testing of selected medium and heavy duty hybrid vehicles, focusing on cost-shared competitive acquisition and placement of vehicles by industry partners. (EPACT Sections 601 and 505) (INEEL, NREL, ANL)

III. Performance Summary: TECHNOLOGY DEPLOYMENT (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Testing and Evaluation (Cont'd)	Federal Fleets: Supported and evaluated electric vehicle use in the Federal fleet in response to the requirements of Executive Order 13031. Started EV loaner program to encourage EV use in Federal agencies. Added over 4,000 AFVs to Federal fleet. (EPACT Section 303) (INEEL, GSA, DOI) Infrastructure Testing: In coordination with industry, further refined systems and safety analyses of refueling, transport, and delivery infrastructure for alternative fuels, and implemented findings as appropriate. Initiated development of low cost liquefied natural gas (LNG) refueling station. (EPACT Section 502) (INEEL)	Federal Fleets: Continue to support and evaluate electric vehicle use in the Federal fleet in response to the requirements of Executive Order 13031. Expand EV loaner program to more areas and more agencies. Help add 8,000 AFVs to the Federal fleet. (EPACT Section 303) (INEEL, GSA, DOI) Infrastructure Testing: Continue infrastructure systems and safety analyses. Complete low cost refueling station validation. Partner with industry to demonstrate small-scale low cost LNG liquefaction facility along Clean Cities corridor. (EPACT Section 502) (INEEL)	Federal Fleets: Continue to support and evaluate electric vehicle use in the Federal fleet in response to the requirements of Executive Order 13031. Help Federal agencies acquire 12,000 AFVs. (EPACT Section 303) (INEEL, GSA, DOI) Infrastructure Testing: Support expanded demonstration and validation of low cost refueling and liquefaction systems. Expand deployment of LNG liquefaction technology to other corridors. (EPACT Section 502) (INEEL)
	$2,795	$2,920	$4,000
EPACT Replacement Fuels Program EPACT Replacement Fuels Program (Cont'd)	Analysis and Modeling: Using transition modeling and other analytical tools, assessed progress of EPACT fleet programs in helping to reach the Act's replacement fuel goals. Developed utilization scenarios for advanced	Analysis and Modeling: Model impact of fuel usage associated with potential private and local fleet acquisitions for AFVs. Expand modeling scenarios to include advanced hybrid vehicles, and new heavy vehicle technologies.	Analysis and Modeling: Model spillover impacts of light duty regulatory programs on medium and heavy duty fleet use of AFVs. Model the potential for use of non-petroleum fuels in blends with

III. Performance Summary: TECHNOLOGY DEPLOYMENT (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
	transportation technologies, such as hybrid and fuel cell vehicles, that draw upon Clean Cities experience and industry expertise. (EPACT Section 502) (ANL, ORNL)	(EPACT Section 502) (ANL, ORNL)	conventional fuels. (EPACT Section 502) (ANL, ORNL)
EPACT Replacement Fuels Program (Cont'd)	Regulatory Support: Continued enforcement of EPACT Federal, State, and fuel provider fleet programs. Initiated rulemaking on private and local fleets. During rulemaking, obtained additional public comment on the potential for additional fleet programs, renewable fuels, replacement fuels, and incentive programs to meet the Act's goals and reduce vulnerability to oil price shocks. Used comments as part of the rulemaking and to initiate a second technical and policy analysis of the Act's goals. (EPACT Sections 501, 502, 506, 507, and 508) (NREL, ANL, ORNL) Closed out certification of training program and transferred it to the private sector. (EPACT Section 411) (NATEF)	Regulatory Support: Continue enforcement of EPACT Federal, State, and fuel provider fleet programs. Continue rulemaking process to determine if private and local fleets should be included in the EPACT fleet requirements. Continue development of, and obtain public comment on, the second technical and policy analysis of the Act's replacement fuels goals. (EPACT Sections 501, 502, 506, 507, and 508) (NREL, ANL, ORNL)	Regulatory Support: Continue enforcement of EPACT Federal, State, and fuel provider fleet programs, and support implementation through voluntary and credit based approaches. Complete final determination on private and local government fleet program. Complete and submit the second technical and policy analysis of the Act's replacement fuels goals to the President and Congress. Depending on the rulemaking outcome, include recommendations to Congress on additional programs and policies that may be needed to meet EPACT goals. (EPACT Sections 501, 502, 506, 507, and 508) (NREL, ANL, ORNL)

III. Performance Summary: TECHNOLOGY DEPLOYMENT (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
	$1,375	$1,285	$2,000
Advanced Vehicle Competitions	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Automotive Alternative Fuels R&D: Offered new universities the opportunity to participate in the FutureCar Challenge bringing the number of university participants up to 13. U.S. automakers continued to provide vehicles, seed money, and award money. Provided the opportunity for two FutureCar universities to build fuel cell vehicles. Demonstrated 75 mpg in on-road fuel economy in two vehicles at the 1998 FutureCar Challenge; the gasoline control car achieved 37 mpg. Transitioned from the Propane Challenge to the Ethanol Vehicle Challenge, co-sponsored by GM. Over 50% of student team members graduating from FutureCar and Ethanol Challenges accepted jobs in the auto industry. (ANL, ASEE, universities) (PNGV: $850)	TRANSFER FROM: ADVANCED AUTOMOTIVE TECHNOLOGIES/Automotive Alternative Fuels R&D: Continue the FutureCar Challenge with enhanced performance targets. Provide limited advanced technologies (e.g., fuel cells) to those universities which demonstrate the best potential to use them. Demonstrate the first U.S. built fuel cell vehicle. Increase the performance goals for the second year of the Ethanol Challenge, with particular emphasis on hot/cold start capabilities, fuel economy, and emissions. DOE funding will continue to be matched at least three to one by FutureCar contributors and at least five to one by Ethanol Challenge partners. (ASEE, ANL, universities) (PNGV: $840)	
Advanced Vehicle Competitions (Cont'd)			Continue the FutureCar Challenge with the inclusion of new university participants. Expand the demonstration and use of advanced power plants, alternative and reformulated fuels, and advanced lightweight and propulsion materials technologies in competition vehicles which meet future emission standards and fuel economy targets. Fuels and vehicle industry partners, suppliers, and professional societies, as well as State and other Federal agencies, will provide matching funds. (ASEE, ANL, universities) (PNGV: $1,000)

III. Performance Summary: TECHNOLOGY DEPLOYMENT (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
	$850	$840	$1,000
Technology Deployment Total	**$12,416**	**$12,950**	**$17,700**

TRANSPORTATION TECHNOLOGIES
TRANSPORTATION SECTOR
(dollars in thousands)

MANAGEMENT AND PLANNING

I. Mission Supporting Goals and Objectives

I. A. Program Strategy

Management and Planning supports the human resource requirements as well as the Office-level analysis, assessment, evaluation, and planning functions for the Office of Transportation Technologies (OTT). The objective of this activity is to provide the integrated program direction needed to plan, manage, and oversee the research, development, and technology deployment activities funded by the transportation sector program. The analytical part of the mission is accomplished by collecting and analyzing technology and market data, using computer models to project technology potential and market share, and calculating program benefits.

The technology assessment activity estimates the impacts, benefits, and costs of advanced transportation vehicle and fuel technologies. A system of models has been created that: (1) estimates the market shares of new light duty vehicle sales for alternative fuel and advanced vehicle technologies; and (2) calculates the alternative fuel use, petroleum use reductions, and changes in criteria pollutant and global climate change emissions. These models are continually improved and updated to consider new technology developments, and to be consistent with projections prepared by the Energy Information Administration. The models are also used to estimate the impacts of individual technology programs during budget formulation and program planning.

The analysis function produces the annual Transportation Energy Data Book; assembles the best past and current data to use in updating transportation sector plans; and supports preparation and updating of Energy Efficiency and Renewable Energy and Department of Energy plans.

I. B. Performance Goals

FY 1998 Accomplishments

- Continued to improve the quality metrics methodology to incorporate different petroleum price projections.
- Worked with the Energy Information Administration to develop information on vehicle characteristics desired by buyers, for five light vehicle classes.
- Published Edition 18 of the *Transportation Energy Data Book*, with an increased emphasis on transportation petroleum dependence.

I. Mission Supporting Goals and Objectives: MANAGEMENT AND PLANNING (Cont'd)

FY 1999 Planned Accomplishments

- Expand the quality metrics methodology to deal with the issue of sustainability, improving forecasts and expectations regarding the time frame when petroleum products would need to be replaced with sustainable fuels.
- Produce Edition 19 of the *Transportation Energy Data Book*, with an emphasis on alternative fuels.

FY 2000 Planned Accomplishments

- Undertake a major effort to estimate the cost of advanced vehicle technologies, with the emphasis on the cost of vehicles capable of tripling fuel economy.
- Update all the vehicle choice model coefficients.
- Produce Edition 20 of the *Transportation Energy Data Book*, with emphasis on trends during the past 20 years.

FY 2001 - FY 2004 Planned Accomplishments

- Re-build the heavy truck model to assure that it can deal with all the advanced technologies with potential applications in this market. (FY 2001)
- Modify analytical tools to estimate impacts an additional 20 years in the future. (FY 2002)
- Add regional analytic capabilities to models. (FY 2003)
- Address the ramifications of international competition on imports and exports of advanced technologies. (FY 2004)
- Continue to produce annual editions of the *Transportation Energy Data Book*, focusing on household and fleet purchases and use, demographic differences in purchase and use, and comparisons across transportation modes. (FY 2001 - FY 2004)

II. A. Funding Table: MANAGEMENT AND PLANNING

Program Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Request	$ Change	% Change
Technology Assessment and Analysis	$ 1,600	$ 1,700	$ 2,500	$+800	+47.1%
Program Direction	6,000	6,225	7,320	+1,095	+17.6%
Total, Management and Planning	$ 7,600	$ 7,925	$ 9,820	$+1,895	+23.9%

II. B. Laboratory and Facility Funding Table: MANAGEMENT AND PLANNING

Program Activity	FY 1998 Enacted	FY 1999 Enacted	FY 2000 Request	$ Change	% Change
Argonne National Lab	$ 770	$ 900	$ 1,000	$+100	+11.1%
National Renewable Energy Lab	140	200	200	0	0.0%
Oak Ridge National Lab	340	360	360	0	0.0%
All Other	6,350	6,465	8,260	+1,795	+27.8%
Total, Management and Planning	$ 7,600	$ 7,925	$ 9,820	$+1,895	+23.9%

III. Performance Summary: (New BA in thousands of dollars)

Activity	FY 1998	FY 1999	FY 2000
Management and Planning			
Technology Assessment and Analysis	TRANSFER FROM: IMPLEMENTATION AND PROGRAM MANAGEMENT/Evaluation, Planning, and Analysis: Continued to maintain a comprehensive and accurate set of transportation data, including energy use by transportation mode and fuel type. Assembled baseline projections of future transportation demands and energy use, and estimated the petroleum savings and substitution potential, as well as the pollution and economic impacts, of transportation sector programs. Published and distributed Edition 18 of the *Transportation Energy Data Book*; expanded to include detailed information on the growth of light truck use. Assessed the energy, environmental, and economic impacts of introducing new vehicles and fuels. Estimated the oil substitution and energy saving impacts of all the technology programs for alternative funding levels; considered optional scenarios for fuel price and economic	TRANSFER FROM: IMPLEMENTATION AND PROGRAM MANAGEMENT/Evaluation, Planning, and Analysis: Continue to maintain a comprehensive and accurate set of transportation data, including energy use by transportation mode and fuel type. Assemble baseline projections of future transportation demands and energy use. Estimate the petroleum savings, oil substitution potential, emissions reduction and economic impacts of transportation sector programs. Publish and distribute Edition 19 of the *Transportation Energy Data Book*. Continue to assess the energy, environmental, and economic impacts of introducing new vehicles and fuels. Estimate the oil substitution, energy saving impacts, and emissions reduction of all the technology programs for alternative funding levels, fuel price scenarios, and economic growth scenarios. Estimate technology market penetration by operating the vehicle and fuel choice models.	Continue to improve the quality metrics methodology for estimating the impacts (oil savings, energy reduction, greenhouse gas reduction, employment and Gross Domestic Product (GDP) changes, and criteria pollutant changes) of the technologies supported by the Office of Transportation Technologies (OTT). Continue to provide data and analytic assistance to OTT program managers. Publish and distribute Edition 20 of the *Transportation Energy Data Book*. Undertake a major effort to estimate the costs of advanced vehicle technologies, with emphasis on the cost of vehicles capable of tripling fuel economy. (ANL, ORNL, NREL)

III. Performance Summary: MANAGEMENT AND PLANNING (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
Technology Assessment and Analysis (Cont'd)	growth. Estimated technology market penetration by operating the vehicle and fuel choice models that have been improved. Developed detailed technology characterizations of alternative vehicle technologies as input to the choice models. Completed the total energy cycle analysis for all alternative vehicles and fuels. (ANL, ORNL, NREL)	Develop detailed technology characterization of alternative vehicle technologies as input to the choice models. Analyze the international impacts of exporting and/or importing advanced vehicle technologies. Improve methods for estimating greenhouse gas reductions from travel demand reductions, land use planning, and telecommunications. Analyze the market for greenhouse gas reducing technologies. (ANL, ORNL, NREL)	
	$1,600	$1,700	$2,500
Program Direction	TRANSFER FROM: IMPLEMENTATION AND PROGRAM MANAGEMENT/Program Direction	TRANSFER FROM: IMPLEMENTATION AND PROGRAM MANAGEMENT/Program Direction	
	The following is a breakdown of the funding by Object Class:	The following is a breakdown of the funding by Object Class:	The following is a breakdown of the funding by Object Class:
	11.9 Personnel compensation $4,702 12.1 Civilian personnel benefits $901 21.0 Travel and transportation of persons $251 25.2 Other services $146	11.9 Personnel compensation $4,408 12.1 Civilian personnel benefits $1,102 21.0 Travel and transportation of persons $450 25.2 Other services $265	11.9 Personnel compensation $5,335 12.1 Civilian personnel benefits $1,335 21.0 Travel and transportation of persons $550 25.2 Other services $200
Program Direction	Provide funds for salaries, benefits, and travel (including normal increases in both salaries and benefits) to	Provide funds for salaries, benefits, and travel (including normal increases in both salaries and benefits) to	Provide funds for salaries, benefits, and travel (including normal increases in both salaries and benefits) to

III. Performance Summary: MANAGEMENT AND PLANNING (Cont'd)

Activity	FY 1998	FY 1999	FY 2000
(Cont'd)	support the 63 FTEs needed to conduct and monitor research, development, and other activities associated with various transportation technologies, at Headquarters (62) and in the field (1). A 3% contingency is provided under Other Services.	support 59 FTEs needed to conduct and monitor research, development, and other activities associated with various transportation technologies, at Headquarters (58) and in the field (1). A total of $265 under Other Services includes activities such as permanent change of station moves, employee training, and a small contingency.	support 56 FTEs needed to conduct and monitor research, development, and other activities associated with various transportation technologies, at Headquarters (55) and in the field (1). The FY2000 Congressional Request for Program Direction provides for staffing adjustments resulting from Workforce 21 plans. A total of $200 under Other Services includes activities such as permanent change of station moves, employee training, and a small contingency.
	$6,000	$6,225	$7,32
Management and Planning Total	**$7,600**	**$7,925**	**$9,82**