NATURAL GAS STRATEGIC PLAN

AND

MULTI-YEAR PROGRAM CROSSCUT PLAN FY 1994-1999

DECEMBER 1993

MASTER

MB

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U.S. DEPARTMENT OF ENERGY

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ABBREVIATIONS

ARCS	Advanced Radiant Combustion Systems
DOE	Department of Energy
DSM	Demand-Side Management
EE	Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
Energy Efficiency	Office of Energy Efficiency and Renewable Energy
Energy Research	Office of Energy Research
EPA	Environmental Protection Agency
EPACT	Energy Policy Act of 1992
ER	Office of Energy Research
ES&H	Environment, Safety and Health
FE	Office of Fossil Energy
FERC	Federal Energy Regulatory Commission
Fossil Energy	Office of Fossil Energy
FY	Fiscal Year
GRI	Gas Research Institute
HV	Hybrid Vehicle
IRP	Integrated Resource Planning
IS	Office of Intelligence and National Security
MWD	Measurement-While-Drilling
NORM	Naturally Occurring Radioactive Materials
PO	Office of Policy, Planning and Program Evaluation
RD&D	Research, Development and Demonstration
U.S.	United States

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

When President Clinton's choice for Secretary of Energy, Hazel R. O'Leary, appeared before Congress for her confirmation hearing in January 1993, she stated that while the Nation must maximize energy conservation, efficiency and the use of alternative energy resources, we must also *"...provide flexibility and response to crises through adequate and reliable supplies of traditional energy sources...and balance [the Nation's] needs so that energy, the environment, and our economic issues are woven together in a tapestry that creates something that supports this Nation."*

The United States (U.S.) Department of Energy's (DOE) fiscal year (FY) 1994 budget request allocates funding for traditional fuel sources: coal, petroleum, and natural gas -- fuels that today provide more than 85 percent of the energy consumed in the U.S. The overall program focuses funding for research, development and demonstration (RD&D) on new, innovative technology that can achieve the balance between energy supply, economic efficiency and growth, and environmental quality envisioned by the Clinton Administration.

1.2 DOE RD&D FOR FOSSIL FUELS

The RD&D programs recommended for funding have been designed against the following specific set of DOE strategic goals:

- Affordable electricity supplied by advanced power generation technologies that support both economic growth and environmental improvement;
- Economically competitive sources of supplemental liquid transportation fuels to reduce the alarming growth in oil imports;
- Greater production and use of natural gas; and
- Continued support of a strong human resource capability in critical crosscutting science and technology fields.

The FY 1994 budget request for these programs is \$506.4 million, as summarized in the following table.

Fossil Energy RD&D Areas	Fiscal Year Funding (\$ in millions)		
	FY 1992 Actual	FY 1993 Appropriated	FY 1994 Request
Coal RD&D	225.6	188.7	141.3
Petroleum Technology	56.5	62.4	80.9
Natural Gas RD&D ¹ (DOE-wide)	114.2	149.6	208.9 ²
Other (Includes offsets, rescissions, etc.)	95.2	86.8	75.3
Total Fossil Energy Technology RD&D	491.5	487.5	506.4

¹ Includes Fuel Cells RD&D

² FY 1994 Appropriation is \$203.8 million

The programs within these funding levels reflect the recognition that even with aggressive energy conservation and the expanded use of alternative fuels, more than 80 percent of the Nation's primary energy demand likely will be the supplied by fossil fuels through at least the year 2010.

1.3 DOE RD&D PROGRAM FOR NATURAL GAS

The competitive cost and clean burning characteristics of natural gas give it a large and continuing expanding role in the total energy outlook for the United States. To expand the use of natural gas, DOE is researching, developing, and demonstrating clean, affordable technologies that will decrease the costs of producing, storing, and using gas; increase the reliability of gas supply; and use gas more efficiently. Technologies that can improve the production, storage, delivery, and use of natural gas are the recipients of significant funding increases in DOE's proposed FY 1994 budget. This reflects the commitment of President Clinton and Secretary O'Leary to expanding efforts to increase the Nation's use of natural gas to meet both environmental and energy goals.

It is important to recognize that the RD&D programs described in this plan represent all natural gas funding within DOE. Natural gas efforts are carried out within the Offices of Fossil Energy (FE or Fossil Energy); Energy Efficiency and Renewable Energy (EE or Energy Efficiency); Energy Research (ER or Energy Research); Policy, Planning and Program Evaluation (PO); Intelligence and National Security (IS); and the Energy Information Administration (EIA). Increases in funding are proposed for each of these efforts. A more complete picture of DOE-wide natural gas funding follows.

Natural Gas Program (DOE-Wide)	Fiscal Year Funding (\$ in millions)	
	FY 1993 Appropriated	FY 1994 Appropriated
Resource and Extraction (FE/ER)	19.9	23.8
Delivery and Storage (FE/IS)	0.1	1.1
Utilization (FE/EE/ER)	125.3	172.0
• Combustion Systems (FE/EE/ER)	12.6	20.7
• Heat Pumps (EE)	5.0	8.2
• Heat Engines (FE/EE)	26.6	49.3
• Natural Gas Vehicles (EE)	14.8	24.1
• Fuel Cells (FE/EE)	54.9	58.2
• Gas-to-Liquids (FE)	4.0	3.6
• Other (FE/EE)	7.4	7.9
Environmental/Regulatory Impact (FE/ER)	4.3	6.9
Total DOE Natural Gas RD&D Funding	149.6	203.8

All programs will comply with applicable Federal, State, and local laws and regulations, and Federal policies and mandates. Examples of these are: Energy Policy Act of 1992 (EPACT); Clean Air Act Amendments of 1990; National Environmental Policy Act; Secretary of Energy Notice SEN-25A-91; Alternative Motor Fuels Act of 1988; Resource Conservation and Recovery Act; and Clean Water Act.

1.4 NATURAL GAS STRATEGIC PLAN AND MULTI-YEAR PROGRAM CROSSCUT PLAN

DOE has established a Natural Gas Coordinating Committee to ensure that all natural gas programs are conducted with a single strategic focus and without unnecessary duplication. This group prepared the FY 1993 update of the DOE *Natural Gas Strategic Plan and Multi-Year Crosscut Program Plan* (FY 1993-1998), which was first produced a year ago as a "working draft" for industry comment. This revised version incorporates these external comments and the results and recommendations of such developments as Order No. 636 of the Federal Energy Regulatory Commission (FERC), the FERC/DOE Natural Gas Deliverability Task Force Report; the National Petroleum Council's 1992 natural gas study, *The Potential for Natural Gas in the United States*; relevant provisions of the EPACT, and new policy guidance from the Clinton Administration. Exhibit 1-1 provides a detailed "Roadmap" to the present *Natural Gas Strategic Plan and Multi-Year Program Crosscut Plan*.

The overall goal of the Natural Gas RD&D Program is to improve the Nation's ability to supply, store, transport, distribute, and utilize gas in an economically efficient and environmentally beneficial manner. In support of DOE's missions are programs that will: improve the confidence in the continued availability of a long-term gas supply (*Resource and Extraction Area*); provide more cost-effective and competitive means to use natural gas in both new and existing markets (*Utilization Area*); develop improved and less costly means of delivering and storing gas (*Delivery and Storage Area*); and develop and ensure availability of low cost environmental compliance technology, and reduce regulatory barriers to efficient market operations by promoting coordinated, efficient, and innovative Federal and State regulations (*Environmental/Regulatory Impact Area*). Each program area has its own unique mission that contributes to the goals and mission of the overall Natural Gas Program.

The Natural Gas Program has been encouraging closer partnerships with other Federal agencies, State and local governments, and industry, as well as promoting increased cost-sharing and industry-driven programs. DOE cooperates with FERC on regulatory issues that have an impact on gas delivery and utilization and corresponding RD&D programs. DOE frequently provides comments and analysis on regulations proposed by the U.S. Environmental Protection Agency (EPA) that may affect gas supply and utilization. DOE program staff also serve on State and Federal interagency workgroups involving gas production, transportation, storage, distribution, and utilization. DOE, Department of the Interior, and EPA work cooperatively with organizations, such as the Interstate Oil and Gas Compact Commission, to improve State programs regulating the environmental aspects of gas exploration and production, and to ascertain the effect that State regulatory programs have on gas resource recovery.

Cooperation with industry and States will continue to be in the form of joint RD&D projects and technology transfer. These projects will be cost-shared in a way that will give industry and the States greater involvement in program activities. This will encourage increased participation by industry and States and allow them more freedom in managing projects. The industry cost-sharing of gas RD&D averages 25 to 30 percent, and increases to 50 percent as RD&D efforts move from the research to the demonstration phase.

DOE will work with gas industry organizations and private companies. Currently, DOE is involved with the Gas Research Institute (GRI), a major source of private sector RD&D funding. GRI conducts a comprehensive program addressing natural gas issues, and has wide industry participation in its programs through technical advisory groups. These groups, comprised of industry experts, provide advice on industry needs, priorities, and cost-sharing for particular projects. Cooperation is maintained between DOE and GRI regarding their respective programs in support of gas technology RD&D and commercialization. This exchange of information avoids redundancy, benefits program synergism, secures appropriate cofunding of projects, and leverages funding for DOE, GRI, and individual gas industry companies.

1.5 PROGRAM GOALS

DOE's Natural Gas Program has been restructured using the "systems approach" to address technology and regulatory constraints and opportunities from the wellhead to the burnertip. The program activities are designed to reduce RD&D costs for industries, thus reducing their technical risk in developing a new technology and entering the marketplace. The development and dissemination of technical information and analytical capabilities can provide cost-effective benefits to industry that might not otherwise occur. Exhibit 1-2 provides an overall summary of the program area missions. Program area specific goals and representative activities are summarized in Exhibits 1-3 through 1-10. Exhibit 1-11 describes the crosscutting program areas. The following is a brief description of the program areas.

Resource and Extraction: The Offices of Fossil Energy and Energy Research will continue applied and fundamental RD&D in the Resource and Extraction Program Area. The program will enlarge and stabilize the domestic gas supply reserve base for a period adequate to increase public confidence in the long-term availability of affordable gas and to support increased use of gas. Resource and Extraction projects have been integrated into the following areas: (1) resource and reserves assessment; (2) drilling, completion, and stimulation; (3) fracture technology; (4) secondary gas recovery; (5) low quality gas upgrading; (6) recovery from low permeability formations; and (7) fundamental geosciences research. Technologies resulting from the RD&D efforts will provide industry, government, and academia with efficient, cost-effective systems for recovery of future domestic gas supplies.

Utilization: The Offices involved in the utilization program are Energy Efficiency, Fossil Energy, and Energy Research. The primary focus of the RD&D efforts is to develop advanced high efficiency, low pollution technologies for natural gas use and to overcome obstacles to their adoption. Projects are divided into seven areas: (1) combustion systems; (2) heat pumps; (3) heat engines; (4) natural gas vehicles; (5) fuel cells; (6) gas-to-liquids; and (7) other activities [e.g., gas integrated resource planning (IRP), demand-side management (DSM), materials development, and electric and hybrid vehicles]. The utilization projects will provide competitive, energy efficient, cost-effective means of gas use in both new and existing markets. Many of the projects are cost-shared and cosponsored by external customers.

Delivery and Storage: The principal Office responsible for delivery and storage RD&D is Fossil Energy. Other Offices include IS and EIA. The natural gas delivery and storage program represents a new initiative for FY 1994. The program is divided into two areas of storage and delivery. An integral element of the program is aimed at increasing end user confidence in natural gas deliverability. This will be accomplished by fostering more efficient use of gas storage; demonstrating the reliability of peak-load deliverability of natural gas; and assisting in the development of an information system for natural gas data that is accurate, reliable, and timely. The program will develop technologies which will lead to cost-effective expansion of storage capacity and enhanced deliverability.

Environmental/Regulatory Impact: The Offices involved in the Environmental/Regulatory Impact Area are Fossil Energy, Energy Research, and PO. Programs will identify and promote research and assessments to foster environmentally sound gas resources development and utilization. This will be achieved by reducing regulatory barriers to efficient market operations; promoting sound, consistent, and efficient regulations based on improved scientific information; and ensuring the availability of low cost environmental compliance technology to industry. The programs will increase the marketability of natural gas, and lead to improved technologies that will enable industry to reduce the burden of compliance and meet the increased growth in gas use.

Exhibit 1-1. Roadmap to Natural Gas Plan

DOE Natural Gas Strategic Plan and Multi-Year Program Crosscut Plan, FY 1994-1999

Background re: Natural Gas

History

- Natural gas has long been less significant in fossil fuel supply than oil and coal.
 - Not as readily portable or storable
 - Perceived as a resource in very limited supply
 - Legislation/regulation restricted use of natural gas

Natural Gas Consumption Projections

- 1986-1992 3.1Tcf, increased 21%
- 1992 17.9Tcf, increased 3% over 1991
 - +13% non-utility power generation
 - +6% industrial processes
 - +2% residential and commercial
 - -1% electric utilities
- 1993 18.4Tcf, estimated 3% increase over 1992
- 2010 22.0Tcf, estimated to rise about 25% over 1992, primarily from consumption in power generation

Drivers of Natural Gas Policy

Recent Developments/Trends

- Developments over the last decade drive the increased use of natural gas:
 - Deregulation of wellhead prices, open access transportation, and unbundling of natural gas services; 75% of natural gas transactions are now conducted at spot market prices, and 87% is transported as third-party gas
 - Recognition that domestic natural gas reserves are large, far greater than had been believed
 - Recognition that substitution of natural gas for oil-based fuels or coal would reduce noxious emissions and reduce oil imports
 - Increased use of natural gas as an electric power generation source

Government Regulations and Public Policy

- Influences the utilization of natural gas:
 - RCRA
 - CWA
 - EPACT
 - CAAA
 - NEPA
 - Alternative Motor Fuels Act of 1988 (AMFA)
 - FERC Orders 436, 636
 - Executive Orders 12844, 12862
 - Administrative guidance

Barriers

- Natural gas history has resulted in major, interrelated barriers to achieving a rapid increase in natural gas use:
 - Overly restrictive and/or duplicative Federal and State statutes and regulations that impede extraction, storage, distribution, and use
 - Lack of fully developed physical and market infrastructure for transporting, storing, distributing, and using natural gas
 - Insufficient market incentives for private industry to aggressively develop natural gas technology
 - Public and industry perceptions of unreliability of natural gas supply and unpredictable prices

Actions Required

Market forces and government policies can bring about the desired maturation of the physical and market

DOE Mission, and Goals and Strategies for Natural Gas

DOE Mission

- Encourage economic growth and job creation
- Promote energy efficiency
- Protect human health and environment
- Enhance energy security

DOE Goals re: Natural Gas

- Improve the Nation's ability to supply, store, transport, distribute, and utilize natural gas in an economically efficient and environmentally beneficial manner
 - Use a systems approach that addresses technology and regulatory constraints from wellhead to burner-tip

Primary DOE Natural Gas Strategies

Accelerate development of a mature market-oriented system through regulatory reform

Develop gas technology choices that generate electric power, fuel vehicles, fuel industrial processes, cool and heat buildings, and reduce emissions of pollutants from gas production and use.

- Support RD&D, commercialization, and deployment of clean, affordable gas technologies

Support natural gas technology and information transfer

Support natural gas production from conventional and unconventional sources

Natural Gas Strategic Programs (See sheet A)

DOE Vision for Natural Gas

Vision — By 2030:

- Natural gas has reached its potential in:
 - Electricity generation
 - Transportation
 - Industrial processes
 - Space heating and cooling
- Supply availability and market demand are in balance because of integrated applications:
 - Advanced technologies
 - Risk management tools
 - Resource planning programs
- Reform of regulations has resulted in competitive markets which determine the most cost-efficient applications of natural gas.
 - Complementary Federal, State, local regulations.
 - Buyers and sellers have equal access to markets.
 - Advanced technologies in place for extraction, storage, processing, distribution, and use
- U.S. has become the world leader in natural gas technology and products

Exhibit 1-1. Roadmap to Natural Gas

	Resource and Extraction Area	Utilization Area
Near-Term (by year 2000)	<ol style="list-style-type: none"> Assess domestic resources/reserves, and complete development of a portfolio of methodologies for increasing recovery of resources in order to reduce exploration and production costs and to upgrade low-quality gas. 	<ol style="list-style-type: none"> Complete program leading to commercialization of ultra-high-efficiency, environmentally superior, cost-competitive gas turbine utility and industrial applications. Complete program leading to commercialization of economically competitive environmentally acceptable process for conversion of light hydrocarbons to fuels that will be competitive with oil. Complete program leading to commercialization of molten carbonate and solid oxide fuel cell power plants for dispersed applications in residential, commercial, industrial, and transportation markets (U.S. and overseas), cost-competitive with other power technologies. Complete a collaborative program between the industry and the gas utilities leading to market penetration by 1996 of a cost-competitive, first-generation advanced cycle absorption heat pump using ammonia water as the working fluid for light commercial applications. Complete program leading to commercialization by 1996 by industry of a cost-competitive cycle absorption chiller, with lithium bromide as the working fluid, for large commercial applications. Complete an industry cost-shared program that achieves a major cost reduction of solid oxide fuel cell and modifications for cogeneration systems by 1998.
Mid-Term (by year 2010)	<ol style="list-style-type: none"> Enable industry to supplement U.S. conventional production and gas imports with sufficient supply from nonconventional resources. 	<ol style="list-style-type: none"> Achieve commercialization by industry of molten carbonate and solid oxide fuel cell power plants for new and repowering central power plants in U.S. and overseas non-utility generation markets. Achieve commercialization of advanced cycle systems developed in the near-term program, with efficiency improvements and greatly reduced emissions. Improve energy efficiency in industrial processes to increase productivity in processes using natural gas. In conjunction with industry and GRAC, develop efficient, thermally activated heat pumps for use with natural gas to heat and cool buildings. Support the development of an infrastructure to promote natural gas as a significant fuel, reducing vulnerability to oil supply disruptions.

Natural Gas Plan (Continued) - Sheet A

Delivery and Storage Area

Environmental/Regulatory Impact Area

Commercial offering by environmentally friendly systems for

Commercial offering by and for direct transportation of oil prices.

Commercialization by hydrogen fuel cell systems in public utility competitive with

With industry, GRI, it introduction in operation, with for residential

Commercialization in advanced bromide/water commercial

Program that use phosphoric acid in building

Use of molten salt power plants for industrial applications and utility

Use of gas turbine that have reduced

Industrial processes and using natural gas.

Develop highly efficient systems that use

Infrastructure to transportation by disruptions.

- ① Identify and evaluate the feasibility of alternative technologies suitable for gas storage and delivery applications.
- ② Identify strategic market areas for new and growing natural gas use, projected gas demand, and the storage capacity/delivery required in these areas. Assess potential geologic formations for their development as storage reservoirs in these market areas.
- ③ Investigate field development strategies for new and expanding gas storage fields.
- ④ Identify communication system technology leading to development of a national electronic gas deliverability system.

- ① Demonstrate new storage and delivery technologies to optimize the economics of gas storage and delivery.
- ② Evaluate and demonstrate techniques to control gas migration from the storage area, address constraints associated with aquifer storage, and reduce investment costs.
- ③ Support the development of a national electronic deliverability system to support new and growing gas markets.

- ① Identify, analyze, and recommend the removal of impediments to cost-effective gas utilization.
- ② Provide industry with the tools to comply with environmental requirements in order to maintain and increase economic gas production. Reduce the cost of compliance with current and future requirements. Provide a sound scientific basis for regulation and mitigation measures.
- ③ Enhance the capability to analyze the cost and energy impacts of proposed environmental laws and regulations on the gas industry. Obtain improved Federal and State regulations affecting gas production, transportation, distribution, and utilization networks.
- ④ Maintain relationships with foreign governments and international organizations to continue the exchange of information and to expand trade and investment opportunities.

- ① Contribute to the evaluation of environmental science and externalities for all fuel cycles in order to achieve the optimal total fuel-cycle cost mix for different energy uses affecting natural gas.

Exhibit 1-2. Natural Gas RD&D Program and Area Missions

Exhibit 1-3. Resource and Extraction Area Mission and Goals

Resource and Extraction

Ensure an adequate supply of natural gas by developing improved cost effective supply technologies and systems. Increase public confidence in the long-term availability of natural gas.

- Assess domestic resources/reserves, develop gas data sets and atlases for primary regions of U.S.
- Develop better and cost-effective drilling, completion, and stimulation technologies; and reservoir characterization methods
- Develop technologies for detection, mapping, and prediction of naturally fractured gas reservoirs
- Develop methods for low quality gas upgrading at reduced cost
- Develop and demonstrate efficient development strategies for low permeability gas formations; and technologies for increasing gas recovery from known reservoirs
- Develop more effective gas production technologies for methane recovery from coalseams
- Increase understanding of origin, migration, and entrapment of natural gas

Exhibit 1-4. Resource and Extraction Area Goals and Activities

Mission: Ensure an adequate supply of natural gas by developing improved, cost-effective supply technologies and systems. Increase public confidence in the long-term availability of natural gas.	
Goal: Assess domestic resources/reserves, and develop gas data sets and atlases for primary regions of U.S.	<ul style="list-style-type: none"> • Continue development of a natural gas atlas series and database system in conjunction with GRI; • Compile comprehensive reservoir play descriptions and quantitative summaries of play characteristics, cumulative production, reserves, original gas-in-place, and other engineering and geologic data; and • Develop a computerized directory that identifies existing gas databases or information centers containing data relevant to production and utilization of natural gas.
Goal: Develop better and cost-effective drilling, completion, and stimulation technologies; and reservoir characterization methods	<ul style="list-style-type: none"> • Develop technology sufficient to accelerate widespread utilization and acceptance of drilling, completion, and stimulation products that reduce cost and minimize formation damage in low permeability gas formations; • Develop products that will improve efficiency of vertical, directional, and horizontally drilled wells in low permeability formations and perform system studies of air drilling technology to understand the full impact of technology development on low permeability gas formations; • Accelerate the development of improvements in measurement-while-drilling (MWD) technology in the area of near-bit sensors; and assist industry to develop an integrated air percussion MWD system for air drilling in difficult formations; and • Evaluate target reservoirs for development of minimum formation damage drilling products; and develop slim hole drilling products to reduce risk associated with the execution of completion technology.
Goal: Develop technologies for detection, mapping, and prediction of naturally fractured gas reservoirs	<ul style="list-style-type: none"> • Provide a laboratory/field facility, in collaboration with GRI, to measure geometries and mechanical behavior of fractures induced during hydrofracturing experiments; and conduct fracturing diagnostics research, and verify the performance of hydraulic fracturing models; • Increase the efficiency of natural gas recovery from low permeability reservoirs by developing improved techniques to detect and characterize natural fracture systems; • Improve understanding of the relationship between formation characteristics in low permeability gas sandstones, and the well-specific engineering design and production performance; • Develop an understanding of fracturing fluid performance under conditions representative of downhole fracturing process; and • Improve current practices and the specification of new or improved fluids for cost-effective stimulation of low permeability gas sandstones.
Goal: Develop methods for low quality gas upgrading at reduced cost	<ul style="list-style-type: none"> • Complete the resource estimate of low quality natural gas that might be recovered through advanced gas upgrading technologies; • Conduct advanced natural gas upgrading research at both laboratory and field demonstration scales to verify promising technologies; and perform process and economic evaluations of technologies that can upgrade low quality natural gas to pipeline specifications; • Develop new separation concepts with significant efficiency improvements and cost reductions through research on novel membrane applications and adsorption fundamentals, and on thermodynamics and chemistry of natural gas mixtures; and

Exhibit 1-4. Resource and Extraction Area Goals and Activities (Continued)

<ul style="list-style-type: none"> Identify advanced and potentially economic low quality gas separation technologies (e.g., membrane adsorption), assess their feasibility and, if an economic technology is identified, develop and test a prototype system.
Goal: Develop and demonstrate efficient development strategies for low permeability gas formations, and technologies for increasing gas recovery from known reservoirs
<ul style="list-style-type: none"> Integrate geologic and resource studies, field demonstrations, wells-of-opportunity tests, and supporting RD&D into a comprehensive strategy for efficient development of low permeability reservoirs; Estimate the reserve base of low permeability in the central Rocky Mountain basins, including sandstones and coals; and build the geologic database/foundation for industry use to develop low permeability reservoirs when economic extraction technology is available; Test new applications of horizontal well technology to enhance production; Extrapolate results from successful field experiments in the Piceance Basin, and verify the technology, by conducting demonstration tests at a representative site; Develop a portfolio of technologies and methodologies, in coordination with GRI, with near-term potential for increasing natural gas recovery from known fields; and Develop improved sandstone reservoir definition, stimulation, and reservoir management techniques for secondary gas recovery.
Goal: Develop more effective gas production technologies for methane recovery from coalseams
<ul style="list-style-type: none"> Develop more effective technologies and methodologies to recover gas from coalseams and associated gas-bearing strata; Develop technical and economic strategies to store and use coalseam gas; Develop deviated slim hole drilling technology for thin coalseams; and Initiate resource and reserve studies of shallow multiple coalseam gas strata.
Goal: Increase understanding of origin, migration, and entrapment of natural gas
<ul style="list-style-type: none"> Conduct fundamental studies on the origin, migration, and understanding of geologic factors controlling and limiting the recovery of natural gas; Develop basic understanding of fluid flow in porous and fractured rocks through laboratory, field, and modeling studies; Develop new and improved high resolution geophysical techniques and approaches for imaging subsurface fluid-bearing reservoirs; and Provide new concepts and information on rock fractures and their failure under in-situ conditions to improve drilling methods.

Exhibit 1-5. Utilization Area Mission and Goals

Exhibit 1-6. Utilization Area Goals and Activities

Mission: Develop and demonstrate technologies to use natural gas cleanly and more efficiently. Provide competitive, cost-effective means of using natural gas in both new and existing markets.	
Goal:	Conduct cost-shared RD&D leading to development of ultra-high efficient, environmentally superior, cost-competitive gas turbine systems
<ul style="list-style-type: none"> • Develop more efficient gas turbine systems for both utility and industrial electric power generation, including cogeneration; • Develop high efficiency and low nitrogen oxides industrial gas turbines to meet future power generation needs; and reduce emissions to levels significantly lower than the current standards; • Provide a technology base that gas turbine manufacturers can utilize to commercialize advanced gas turbine systems with improved efficiencies and reduced emissions; and • Complete studies on advanced high temperature gas turbine systems capable of operating on natural gas and a wide range of gaseous coal and biomass derived fuels. 	
Goal:	Support development of fuel cells for power generation, transportation, and building applications
<ul style="list-style-type: none"> • Support technology base development of fuel cell systems, and develop fuel cells for use in electric utility, industrial, and commercial sectors; • Demonstrate and commercially introduce high efficiency, gas-fueled fuel cells for powerplants at competitive costs; and establish commercial availability of advanced, ultra-high efficiency, integrated fuel cell systems; • Continue activities for basic and applied research on materials, processes, and components applicable to fuel cell systems to achieve steady progress in improving these technologies; • Develop and evaluate fuel cell systems in the U.S. transportation sector, and utilize natural gas in compressed or liquid form in fuel cell vehicles; • Develop advanced fuel processing systems to reform methanol, ethanol, natural gas, and other hydrocarbons into hydrogen for use in transportation fuel cell systems, and to develop better systems for onboard hydrogen storage; • Develop fuel cell power generation systems that are cost-effective and highly efficient in supplying electric and thermal needs of buildings; and • Assist and participate in activities designed to lower costs, improve reliability, and achieve expeditious commercialization of residential and commercial fuel cell systems. 	
Goal:	In conjunction with industry, develop highly efficient, thermally activated heat pumps
<ul style="list-style-type: none"> • Develop highly efficient, thermally activated heat pumps that use natural gas to heat and cool buildings; and focus RD&D efforts on technologies for residential and commercial market segments; • Introduce into the market residential natural gas heat pumps and advanced "triple effect" absorption gas-fired chillers with improved heating coefficient of performance; • Develop advanced residential commercial rooftop heat pumps and further improve large commercial chillers; and achieve the commercial introduction of a high efficiency absorption chiller for large commercial buildings; and • Achieve the commercial introduction of the Nation's first gas-fired residential absorption heat pump through laboratory development and joint venture commercialization with a major equipment manufacturer. 	
Goal:	Support development of cost-competitive, environmentally acceptable processes for direct conversion of light hydrocarbons to transportation fuels
<ul style="list-style-type: none"> • Demonstrate technology for economical conversion of methane and other light hydrocarbon gases to liquids that can be used as light transportation fuels or chemical feedstocks; 	

Exhibit 1-6. Utilization Area Goals and Activities (Continued)

<ul style="list-style-type: none"> • Conduct theoretical and experimental investigations in catalytic, noncatalytic, and biological conversion processes for generating fundamental information and concepts on chemical reactions during conversion; • Develop the scientific and engineering knowledge base for industry use in manufacturing hydrocarbon fuels and chemicals from process derived gases; and • Accomplish innovative improvements over the state-of-the-art conversion technologies through staged development from laboratory scale to bench scale and finally to the proof-of-concept scale.
Goal: Support development of more efficient combustion systems and advanced materials
<ul style="list-style-type: none"> • Conduct applied research to provide combustion process knowledge to develop three-dimensional fluid dynamic simulation models that can be used for advanced combustion systems design; • Demonstrate an advanced, toxic emission free burner system utilizing refinery process gas; and develop a measurement system, and quantify the level of emissions from a typical refinery using process gas; • Demonstrate how advanced laser diagnostics technology can be used to quantify emission species and provide in-situ combustion control in natural gas burner systems; • Develop advanced structural materials with improved high temperature, wear resistant, noncorroding characteristics that open up new opportunities for potential new applications; and • Develop primary processing methods for reliable and cost-effective fabrication of continuous fiber ceramic composite components that will lead to new industrial applications.
Goal: Support development of an infrastructure to promote gas as a significant transportation fuel
<ul style="list-style-type: none"> • Encourage the development and widespread use of natural gas as a transportation fuel, and the production of natural gas-powered motor vehicles; • Accelerate the Federal fleet conversion program and procure Federal passenger automobiles and light duty trucks, in conjunction with the General Services Administration, and place them into service in Federal fleets; and test alternative fuel transit buses in support of Federal, State, and local programs; • Develop next generation engines and fuel systems for alternative fuels; and establish a database that can be used to estimate alternative fuel vehicle exhaust emissions; • Coordinate Federal agency alternative fuel vehicle education and training programs; and promote agency awards for alternative fuel vehicle goal achievement; and • Conduct joint planning with industry on developing a refueling infrastructure for alternative fuel vehicles.
Goal: Support development of alternative fuel vehicle engine technologies
<ul style="list-style-type: none"> • Develop light and heavy duty, multi-fuel capable engine technologies, in partnership with U.S. automakers, designed to meet future emissions standards with improved fuel economy; • Develop and test ceramic gas turbine components for high efficiency, low emission, and alternative fuel, light duty engines; and develop an advanced propulsion (hybrid) technologies for alternative fuel, heavy duty trucks and buses; • Support U.S. auto industry in developing and marketing advanced emission control technologies; and develop an industrial technology base in advanced materials for engines to optimize the use of alternative fuels in vehicles; and • Assist U.S. industry in developing and demonstrating the viability of an hybrid vehicle (HV) technology base for design, production, and future use of HVs as a competitive transportation alternative.

Exhibit 1-6. Utilization Area Goals and Activities (Continued)

Goal: Conduct cost-shared RD&D to increase energy efficiency and productivity in industrial processes using natural gas
<ul style="list-style-type: none"> • Develop advanced burner systems that will transfer energy to industrial processes more efficiently than conventional burners with greatly decreased emissions; • Demonstrate technical feasibility of advanced radiant combustion systems (ARCS) through pilot testing; identify a host site for technology demonstration; and install and demonstrate the ARCS in an industrial facility; • Develop a commercially viable rapid glass refiner and design for application to advanced glass melters and conventional furnace retrofit; • Develop high pressure heat exchange systems for natural gas/steam reforming that will have improved conversion ratios and greater throughput; and • Design, integrate, and test ceramic components for critical locations of stationary gas turbines in cogeneration systems in order to achieve considerable fuel savings and reduced emissions.
Goal: Conduct fundamental chemical and engineering research related to natural gas
<ul style="list-style-type: none"> • Conduct fundamental investigations on chemistry relating to catalysis of methane, and the factors affecting combustion of methane in flames, industrial combustors, and internal combustion engines; • Characterize the reactive pathways of radical intermediates in the oxidation and coupling reactions of methane on catalytic surfaces, and develop predictive theories for heterogeneous catalysis; • Develop general theories, principles, and methods of measurement for characterizing the reactions of prototypical combustion species at surfaces, temperatures, and pressures characteristic of combustion systems; and • Conduct studies for improved analysis of natural gas flows in pipelines and heat exchangers with high heat fluxes.
Goal: Demonstrate natural gas production from municipal solid waste
<ul style="list-style-type: none"> • Demonstrate conversion of both municipal solid waste and other organic wastes into methane; • Design, build, and operate a community scale anaerobic digestion system for combined digestion of municipal solid waste and sewage sludge; and • Conduct studies to understand gas migration and emissions from landfills, and develop techniques for increased gas production from organic matter in landfills.
Goal: Conduct studies in support of gas integrated resource planning and gas demand-side management
<ul style="list-style-type: none"> • Develop a comprehensive primer on gas integrated resource planning for use by State public utility commissions and gas utility staff for informed technical decisionmaking; • Determine regulatory, structural, and geographic factors affecting the level of DSM activities by gas utilities; and conduct a comparative analysis of IRP and DSM programs submitted by major gas utilities; • Prepare a status report on the potential efficiency and costs of residential gas technologies for gas utility DSM programs; and assess the possibility and range of savings in gas DSM programs; and • Examine integration of gas efficiency options into existing gas IRP models and methods used to evaluate DSM program options, and analyze fuel substitution policies and technical issues.

Exhibit 1-6. Utilization Area Goals and Activities (Continued)**Goal: Participate in and support international technology transfer activities**

- Support activities of the International Energy Agency Center for Gas Technology Information, and promote widespread commercialization of gas-related technologies and international cooperation;
- Support and participate in the Center activities for gas technology information exchange and dissemination;
- Proactively promote the transfer of gas-related technologies by providing information on the effectiveness of new gas technologies in specific applications; and
- Participate in workshops and training courses designed to inform potential users of the capabilities of new technologies.

Exhibit 1-7. Delivery and Storage Area Mission and Goals

Exhibit 1-8. Delivery and Storage Area Goals and Activities

Mission: Develop technologies and methodologies that will foster more efficient use of gas storage. Demonstrate reliability of peak-load deliverability of natural gas. Develop an accurate, reliable, and timely natural gas data system.	
Goal:	Identify and evaluate the feasibility of alternative technologies for gas storage and delivery; and demonstrate new storage and delivery technologies
	<ul style="list-style-type: none"> Identify and improve system aspects of gas delivery from the storage reservoir to the burnertip that will lead to improved storage/delivery technologies; Develop new and cost-effective gas storage alternatives and improve existing gas storage systems; and conduct proof-of-concept research for alternative storage methods (e.g., gas storage in low permeability and thin-bedded salt formations, nonreservoir rock, and surface facilities); Increase industry's understanding and commitment to develop new storage capacity; and Demonstrate the ability of gas storage to bridge the potential deliverability gap between gas supplies and strategic markets, and to assure end users of adequate gas supplies.
Goal:	Identify strategic market areas for new and growing gas usage
	<ul style="list-style-type: none"> Identify, evaluate, and rank underground reservoirs for their potential as new storage pools or for expansion of existing capacity; Conduct research that will lead to the development of storage capacity in new and growing market areas; Develop systems to meet specific gas delivery needs for power generation; and Promote contraseasonal markets through improved storage to lessen imbalance in pipelines.
Goal:	Investigate field development strategies for new and expanding gas storage fields
	<ul style="list-style-type: none"> Develop an information system that will provide the capability to evaluate domestic storage capacity and deliverability on a site specific basis; Document and assess the use of new technologies to develop and manage gas storage and the role of storage in meeting variable demand patterns; Develop a personal computer based system to evaluate changes and efficiency gains related to development and use of gas storage facilities in the natural gas delivery system; and Investigate and determine cost-effective gas storage field development strategies.
Goal:	Develop a National Deliverability Capacity Model
	<ul style="list-style-type: none"> Develop a personal computer based system to analyze domestic gas deliverability; Evaluate the current capability, and investigate the impact of projected changes in gas supply and demand patterns (e.g., planned pipeline expansion) on the capability of the delivery system to meet domestic requirements; and Provide the capability to evaluate seasonal and peak-day supply and consumption and other issues, and to model and simulate regional gas production and end use deliverability to new markets.
Goal:	Develop a national electronic gas deliverability system for improved information gathering and dissemination
	<ul style="list-style-type: none"> Increase consumer confidence in the availability and reliability of gas supplies by providing more accurate and timely production data;

Exhibit 1-8. Delivery and Storage Area Goals and Activities (Continued)

- Conduct an assessment of the requirements necessary to upgrade the individual State data collection and dissemination systems; provide assistance to States to accomplish the upgrading of systems; and initiate demonstration programs;
- Provide the basis to establish a national electronic communication network that will provide real time information on gas flows and pressures from critical locations at production and storage facilities, pipelines, local distribution companies, and major end users;
- Complete development of the EMERGE natural gas database and geographic information system, incorporating production and consumption data and a network flow model; and
- Enhance the capability of DOE to assess the impact of natural gas emergencies, and to provide information for development of Federal and State response strategies.

Goal: Develop and demonstrate cost-effective technologies for reservoir management and control of gas migration from storage fields

- Develop technologies that will reduce costs associated with revitalization of existing gas storage wells;
- Identify and verify technologies to improve injection and withdrawal of gas from new and existing fields;
- Demonstrate cost-effective techniques to minimize gas migration from storage fields;
- Conduct field tests to verify effectiveness of horizontal wells, surfactants/foams, or other technologies to reduce costs associated with gas migration; and
- Reduce costs associated with the management of underground gas storage fields, and provide cost-effective reservoir management tools to the industry.

Exhibit 1-9. Environmental/Regulatory Impact Area Mission and Goals

Exhibit 1-10. Environmental/Regulatory Impact Area Goals and Activities

Mission: Reduce regulatory barriers to efficient market operation. Promote consistent, efficient, science-based regulations. Ensure availability of low cost environmental technologies.	
Goal: Identify, analyze, and recommend removal of impediments to cost-effective gas utilization	<ul style="list-style-type: none"> • Develop an environmental regulatory impact data analysis system to identify and evaluate the principal environmental concerns requiring DOE supported research; • Assess trends in industry operational methods, and extraction and processing technologies; • Identify and assess Federal and State environmental regulatory trends for gas exploration and production; and • Develop environmental data management systems for risk-based regulations; and assess industry environmental compliance practices, and the impact of current and proposed environmental regulations.
Goal: Enhance capability to analyze impacts of proposed environmental regulations on the gas industry	<ul style="list-style-type: none"> • Increase awareness of how environmental compliance costs and access restrictions affect gas resource recovery; • Support activities to create a balance between costs and benefits in environmental legislative and regulatory processes; • Conduct studies to identify costly and inefficient environmental regulations; and assess the financial impacts associated with environmental compliance and mitigation on the gas supply industry; and • Assess the economic and energy supply impacts of existing and anticipated Federal and State offshore and coastal discharge regulations.
Goal: Improve Federal and State regulations affecting gas production, transportation, distribution, and utilization	<ul style="list-style-type: none"> • In cooperation with States and others, identify and address environmental challenges to sustained or increased gas production, transportation, distribution, and utilization; • Adopt improved criteria for environmental regulations based on such factors as risk assessment and cost/benefit analysis; • Cooperate with industry, States, and others to facilitate cost-effective, risk-based environmental regulations and information exchange; and • Support dialogue among interested parties to identify and resolve environmental barriers to natural gas supply and utilization.
Goal: Develop technical data on environmental risks posed by gas exploration and production; and provide scientific basis for regulation and mitigation measures	<ul style="list-style-type: none"> • Develop and utilize sound risk assessment approaches to help maximize production/resource recovery, and to reduce the cost of effective environmental protection; • Identify and evaluate environmental and human health risk assessment approaches for gas exploration, production, and processing; • Develop statistical methods to identify significant impacts of gas drilling and production platforms on benthic communities; • Identify and develop environmental impact mitigation methods and technologies (e.g., wetlands mitigation banking) for gas operations in environmentally sensitive areas; and

Exhibit 1-10. Environmental/Regulatory Impact Area Goals and Activities (Continued)

<ul style="list-style-type: none"> • Develop an approach to population risk assessment for naturally occurring radioactive materials (NORM) discharged to coastal and offshore environments; and characterize NORM in gas production equipment and vessels.
Goal: Develop and demonstrate technologies to improve environmental performance and to reduce environmental compliance costs
<ul style="list-style-type: none"> • Identify alternative methods of increasing incremental gas production by developing alternative technologies to meet desired levels of environmental protection, to reduce environmental regulatory compliance costs, and to minimize waste generation; • Conduct field tests of alternative technologies to assess their cost effectiveness, collect technical data, facilitate subsequent technology transfer; • Develop and transfer low cost remote sensing technology that measures air emissions from gas productions operations; • Provide small and independent operators with technology to prevent NORM scale in gas production operations, and to develop and transfer technology on decontamination/disposal alternatives for NORM.
Goal: Conduct environmental outreach and technology transfer
<ul style="list-style-type: none"> • Increase the availability of information on environmental aspects of natural gas exploration, production, processing, transportation, and storage to industry and government decisionmakers; • Use existing forums and technology transfer mechanisms to support efforts by industry, government, and others to exchange technical information on environmental aspects of natural gas production and utilization; and • Seek greater recognition of efforts by industry, Government, and others to address environmental problems in a balanced and cost-effective manner.
Goal: Conduct scientific studies to assess global warming aspects of natural gas production and utilization
<ul style="list-style-type: none"> • Quantify methane emissions to the atmosphere from rice paddy fields, boreal peat bogs, and ruminants; and determine factors controlling the emission levels; • Assess the environmental impact from increased combustion of natural gas; and conduct field studies on the chemical, physical, and dynamical processes associated with transformations of nitrogen oxides from the burning of natural gas; • Complete laboratory studies that address the key photochemical processes involving nitrogen oxides; and • Develop global atmospheric chemistry models that will integrate key processes and perturbations of the atmospheric climate system.

Exhibit 1-11. Natural Gas RD&D Crosscutting Program Areas

Mission: Improve the Nation's ability to supply, store, transport, distribute, and utilize natural gas in an economically efficient and environmentally beneficial manner. Encourage economic growth and job creation, promote energy efficiency, protect human health and the environment, and enhance energy security.

2.0 NATURAL GAS STRATEGIC PLAN

2.0 NATURAL GAS STRATEGIC PLAN**CONTENT'S**

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ABBREVIATIONS

Btu	British Thermal Unit
CAAA	Clean Air Act Amendments of 1990
CNG	Compressed Natural Gas
CO ₂	Carbon Dioxide
CRADA	Cooperative Research and Development Agreement
Defense	Department of Defense
DOE	Department of Energy
Energy Efficiency	Office of Energy Efficiency and Renewable Energy
EPA	Environmental Protection Agency
EPACT	Energy Policy Act of 1992
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
Fossil Energy	Office of Fossil Energy
FY	Fiscal Year
GRI	Gas Research Institute
HHV	Higher Heating Value
HVAC	Heating, Ventilation and Air Conditioning
IRP	Integrated Resource Planning
LDCs	Local Distribution Companies
LNG	Liquefied Natural Gas
NGVs	Natural Gas Vehicles
NO _x	Nitrogen Oxides
NPC	National Petroleum Council
Order 636	FERC Order No. 636
PEM	Proton Exchange Membrane
PUCs	Public Utility Commissions
Quad	10 ¹⁵ Btu
RD&D	Research, Development and Demonstration
Tcf	Trillion Cubic Feet
U.S.	United States

2.0 NATURAL GAS STRATEGIC PLAN

2.1 MISSION STATEMENT

The United States (U.S.) Department of Energy's (DOE) mission through its natural gas program is to encourage economic growth and job creation, to promote energy efficiency, to protect human health and the environment, and to enhance energy security. DOE's goal is to improve the Nation's ability to supply, store, transport, distribute, and utilize natural gas in an economically efficient and environmentally beneficial manner. Specifically, DOE will target opportunities to develop technology choices that generate electric power, fuel vehicles, cool and heat buildings, fuel industrial processes, and reduce emissions of pollutants from gas production and use.

2.2 VISION STATEMENT: 2030

By 2030, natural gas is enhancing economic growth and efficiency, and providing America with a cleaner environment and a more secure and reliable source of energy. Natural gas has reached its potential in the electric generation, industrial processes, transportation, and space heating and cooling markets. Supply availability and market demand -- enhanced by national electronic information exchanges -- are in balance because of the integrated application of advanced technologies, risk management tools, and resource planning programs.

Reform of Federal and State statutes and regulations has resulted in competitive markets which determine the most cost-effective applications of natural gas. Federal, State, and local regulatory processes are now coordinated. Buyers and sellers have equal access to all markets. Advanced technologies are in place for efficient extraction, storage, processing, distribution, and utilization. The United States has solidified a world leadership role in the development and sale of advanced technology products for producing and using natural gas.

2.3 SITUATION ANALYSIS

Current Situation

Natural gas demand continued to grow in 1993, sustaining the upward trend evident since 1986, and resulting in a closer supply and demand balance than at any time since the early 1980s. Because of its competitive cost and clean burning characteristics, gas plays a large and growing role in the total energy outlook in the United States. Regulatory, legislative, and administrative actions during 1992 and 1993 highlight the importance placed on gas in meeting the Nation's energy goals.

The relatively low wellhead prices of recent years continue to be a defining issue in the gas production industry; reducing drilling activity, but benefiting all classes of consumers. However, the average wellhead price increased by 10 percent from 1991 to \$1.80 per thousand cubic feet in 1992, ending an eight year decline in wellhead prices. The market has become increasingly competitive, reflecting the deregulation of wellhead prices, the expanded access of purchasers and suppliers to interstate pipeline capacity, and alternative market and supply areas. As much as 75 percent of natural gas transactions are conducted on the spot market. Spot market prices, as well as futures prices, are increasingly used as a reference in pricing gas flowing under longer-term supply contracts. Throughout 1992, spot market and wellhead prices varied widely, reflecting the intensity in market competitiveness, unusual weather patterns, and supply concerns associated with the effect of Hurricane Andrew on offshore production in the Gulf of Mexico. In 1992, delivered prices to all end users increased modestly in most sectors. The largest change occurred in the prices paid by electric utilities.

The supply system has maintained steady production despite declines in wellhead prices and drilling activity. Although wellhead prices declined in real terms from 1983 through 1991, producers increased production through technological advances in exploring and recovering gas resources. But lower price levels impacted drilling activity and wellhead productive capacity has declined. The major producing areas of Texas, Louisiana, Okla-

homa, and the Gulf of Mexico had reserve replacement ratios below 50 percent during 1992. The Section 29 Tax Credit, in conjunction with advanced technologies, provided incentives for development of nonconventional resources. However, the impacts of this incentive will diminish because the tax credit is restricted to wells drilled before January 1, 1993, and on gas produced before January 1, 2003. Imports from Canada [2.0 trillion cubic feet (Tcf)] continue to make an important contribution to gas supply, accounting for about 10 percent of domestic consumption in 1992.

The distribution system is continuing to expand both its pipeline and storage capacity. Increased consumption in 1992 has been supported by substantial expansion of the transmission and storage system during the past few years. As of 1991, the transmission system is estimated to have the capability to deliver 24 Tcf of gas on an annual basis. In 1992, underground storage capacity was approximately eight Tcf. Of this, four Tcf of capacity can be used to support daily operations to the gas markets. During 1992, approximately 3.4 billion cubic feet per day of additional interstate pipeline capacity was placed in service in the Lower 48 States. Additional projects are planned to service expanded markets in California, Florida, and the Northeast, and provide access to new supply areas.

Annual natural gas consumption increased by three percent in 1992, to 19.7 Tcf. This increase was driven by a six percent increase in consumption in the industrial sector and a 14 percent increase in nonutility power generation. These increases were offset by a slight decline (one percent) in gas use by electric utilities, the only sector in which consumption declined in 1992. Consumption remained relatively flat in the residential and commercial sectors due partly to mild weather. In the near-term, gas demand is expected to rise above 20 Tcf in 1993, increasing three percent from 1992. Over the longer-term, the use of gas is expected to rise by about 25 percent through the year 2010 -- driven principally by increased usage of gas for power generation. The competitive cost of natural gas, coupled with the low capital cost and improvements in efficiency of gas turbines and emission levels, makes power systems fired with gas economically and environmentally attractive.

The Energy Policy Act of 1992 (EPACT) and the Federal Energy Regulatory Commission (FERC) Order No. 636 (Order 636) have substantial impli-

cations for the gas industry. EPACT provides the opportunity for increased use of gas primarily in the transportation sector and in electricity generation by nonutility generators. Yet, the legislation's focus on conservation and efficiency improvements may limit growth in some areas. EPACT exempts wholesale power generators from the Public Utility Holding Company Act, which will encourage growth in gas-powered electric generation plants. In addition, EPACT calls for DOE to conduct research, development and demonstration (RD&D) programs relating to gas production, storage, and use. It also requires the Secretary to develop RD&D and commercial application plans and reports that will be applicable to gas RD&D programs, and contains several provisions requiring or encouraging the use of alternative fuel vehicles. Finally, it promotes energy resource development on Indian reservations.

Approximately 30,000 natural gas vehicles (NGVs) were in use at the end of 1992. As of June 1993, 560 refueling stations were in operation. The tax incentives section of EPACT, that covers both vehicles and refueling stations, became effective in July 1993, and has already had an impact on the number of compressed natural gas (CNG) refueling stations estimated to be in excess of 700.

The "big-three" automakers continue to offer more vehicles that use compressed natural gas. Most are full sized sedans (Ford Crown Victoria), pickup trucks (General Motors Sierra), and passenger or cargo vans (Chrysler's Dodge Ram). All three Detroit automakers are developing vehicles to compete in the CNG vehicle market over the next 10-20 years and beyond.

Restructuring of the gas market is providing opportunities to all industry segments, yet it is increasing the complexity of transporting gas. During 1994, industry will continue to address issues to ensure maintenance of a reliable system as extensive changes in the operational structure are implemented under Order 636. Integrated resource planning (IRP) is increasingly being applied to gas distribution companies by State regulators. The impact of new IRP, combined with implementation of Order 636, will significantly increase the complexity of decisionmaking by gas distribution companies in meeting customer demand.

Environmental regulations continue to affect the availability and cost of gas to the Nation. The potential environmental damage from exploration,

development, and distribution activities limits the industry's access to certain locations and/or requires extensive environmental reviews that are both costly and time consuming. The supply sector is regulated by many environmental statutes, and reauthorization of several statutes in the next few years is expected to have significant impact on supply in some areas. Provisions of the Clean Air Act Amendments of 1990 (CAAA), requiring compliance with emission limits, offer significant opportunities for increased gas use. Gas combustion emission levels of sulfur dioxide, nitrogen oxides (NO_x), carbon monoxide, and particulates are the lowest of any fossil fuels. However, challenges remain for increased gas use if emission standards become more stringent for NO_x, carbon dioxide (CO₂), and methane greenhouse gas emissions. The States' adoption of strict environmental standards for solid and liquid wastes, and California air quality standards pose further possible constraints on both the supply and end use sectors.

DOE Position

DOE is a major funder, leader, and supporter of natural gas technology and increased gas use. The evolution to a deregulated natural gas market, resulting in structural changes that are increasing competition in all segments of the gas system, is changing the DOE's role substantially.

DOE is promoting gas technology as a catalyst for economic growth by: (1) directly supporting and accelerating demonstration, commercialization, and deployment of new technologies; (2) developing fiscal and legislative policies that promote these activities; (3) investing in education and training; and (4) supporting NGVs and deliverability information infrastructures. A strategy for technology commercialization will be developed in early 1994, after an evaluation of various assistance options. The *Global Climate Change Action Plan* recommends the acceleration of high efficiency gas technologies commercialization through joint ventures with utilities, research organizations, and technology developers.

This Administration has significantly reallocated energy research funds for fiscal year (FY) 1994. In 1991, although natural gas supplied 24 percent of the Nation's energy needs, gas RD&D was only one-tenth of one percent (0.1%) of total energy RD&D funding. Natural gas has been identified as a fuel that is both domestically available in large

quantities and is environmentally attractive. Many gas technologies considered today offer the prospect of imminent economic and environmental benefits if the associated RD&D is intensified through greater Federal support. The Federal budget should increase to support RD&D in gas-related technologies, thereby helping the Nation attain environmental and economic goals. Consequently, DOE requested \$208.9 million for FY 1994, with approximately 15.7 percent of the energy RD&D dollars allocated to natural gas. FY 1994 appropriations totalled \$203.8 million.

DOE is forging a closer working partnership among industry, Federal and State governments, and universities by: (1) involving industry in its recommendations of appropriate research and development program areas and levels of funding; (2) developing more opportunities for cooperative research and development agreements (CRADAs); and (3) providing industry and academic institutions with access to technology located at DOE's laboratories and facilities. DOE also coordinates and jointly funds gas supply RD&D with industry partners, including the Gas Research Institute (GRI) and the Electric Power Research Institute (EPRI).

For example, a new partnership developed for FY 1994 is the Advanced Computational Technology Initiative. This industry-driven program will enhance, apply, and transfer computing technologies developed within the National Laboratories to increase the ability of domestic producers to find and recover gas and oil. DOE has also increased the priority of technology transfer within its natural gas program and will complete a strategy document in 1994.

DOE's new technology policy reflects the needs of businesses as demonstrated by their willingness to cofund research or participate in the design of initiatives. The industry cost-share of gas RD&D averages 25 to 30 percent, increasing to 50 percent as RD&D efforts move from the research to the demonstration phase. Industry and government partnerships lower the risk and leverage funds for both groups. DOE encourages the use of teams or consortia of companies wherever possible.

The benefits of partnership are exemplified by the joint industry and government program for advanced gas turbines. Management of this eight year program is coordinated by both industry and government participants [DOE Offices of Energy

Efficiency and Renewable Energy (Energy Efficiency) and Fossil Energy (Fossil Energy), the U.S. Environmental Protection Agency (EPA), and the Department of Defense (Defense)]. Government and industry cost-shares are 64 and 36 percent, respectively.

DOE restructured its gas RD&D program in 1991 in response to the concerns and needs of external customers. This new strategy, called the "systems approach," addresses technology and regulatory constraints and opportunities from the wellhead to the burnertip. The focus is on the near- and mid-term impacts on industry and consumers -- reducing costs and increasing reliability of gas supply and deliverability.

The systems approach also applies to the policy and regulatory area. DOE is concerned about State and local government statutes and regulations, as well as Federal government barriers to increased production and use of gas. DOE promotes the coordination and reform of all government statutes and regulations. The future of the gas industry continues to be shaped by legislation and regulation, but regulatory policy must encourage innovation and achieve social objectives. DOE policy and regulatory initiatives focus on four key areas: (1) market efficiency; (2) market opportunities; (3) restrictions on industry activities; and (4) State and local regulatory oversight of industry.

DOE's IRP program will develop and promote the adoption of IRP concepts and techniques in conjunction with the States and utilities. DOE's approach to IRP for utility and State energy planning is to treat all options -- supply, storage, delivery, and demand-side -- on an equal and consistent basis without preconceptions or bias toward any particular options, fuel type, or form of ownership.

Natural gas has tremendous potential to contribute in the energy security area, specifically in decreasing oil consumption in the transportation sector. Almost two-thirds of the oil consumed in the U.S. is used for motor vehicles. But gasoline demand for this sector is strongly inelastic and much more difficult to displace, unlike the fuel-switchable, price sensitive industrial and electric utility markets that use very little oil. Therefore, to drastically reduce oil use in the next 20 years, it is necessary for the Federal government to be a leader in accelerating both the development of an NGV infrastructure and the conversion of fleets.

The utilization program for FY 1994 focuses on advanced turbine systems (\$49.3 million) and fuel cells for power generation (\$58.2 million). Another major funding area is natural gas-fueled vehicles (\$24.1 million for CNG vehicles and vehicle fuel cells RD&D). Supply RD&D targets improved drilling, stimulation, and completion technologies, diagnostics, and reservoir characterization for all reservoirs. DOE believes that improved technologies ease the burden of complying with environmental regulations.

New Directions

To respond to the Administration's goal of redirecting national efforts toward technologies critical to today's businesses and a growing economy, DOE is requesting initial and increased funding for two new program areas -- End Use Delivery and Storage, and Environmental/Regulatory Impact.

Order 636 is increasing the strategic role of gas storage and deliverability. DOE will develop storage technologies and help create information highways that will increase gas system efficiency, reduce costs for industry and consumers, and provide accurate and timely deliverability information. The development of a national electronic communication network that provides real time information on gas production and deliverability is critical for economic expansion in the gas market.

DOE supports accelerated development of new, low cost environmental compliance technologies for both downstream and upstream sectors, encourages sound environmental practices through outreach and assistance to industry, and seeks to work with regulators to ensure a proper balance between environmental protection and economic and energy impacts. A strategy for an environmental RD&D program addressing downstream operations will be developed in 1994. DOE believes that environmental goals should be incorporated in RD&D consortia for natural gas technologies.

For the first time, DOE is summarizing gas RD&D programs and funding levels of other Federal agencies and organizations. This effort will promote interagency cooperation and coordination, and prepare the foundation for developing a government-wide natural gas strategy. Spending by other Federal agencies and organizations on natural gas-related activities totals \$80 million in FY 1993. (See Section 3, Budget Overview.) In addition, both new and existing gas technology

programs will be regularly evaluated against pre-established criteria to determine if they should remain part of a Federal or DOE program. DOE will develop a technology program performance appraisal methodology in 1994.

Federal agencies need to design procurement policies that will foster market opportunities for new gas technologies. The Federal Government, particularly Defense and the National Aeronautics and Space Administration, is a large customer for high technology products. Life-cycle costs, including environmental, health, and safety costs, should be considered rather than acquisition costs. This places a premium on natural gas in comparison to other fuels and electricity. It is a priority of this Administration to review and reform its procurement policy.

A new challenge for industry and government lies in the international arena. Global competition increasingly challenges traditional thinking and efficiency, productivity, and quality. DOE's support of the International Energy Agency for Gas Technology Information Center, commercialization assistance, and long-term investment plan will increase the competitiveness of U.S. companies in overseas markets. A goal of the DOE Natural Gas Program is to develop an international strategy to promote exports of U.S. gas technologies and information. This strategy will address opportunities in international markets, define the DOE's role in this area, and determine how DOE offices should coordinate with each other.

Many of these new initiatives mentioned above are included in DOE's Domestic Natural Gas and Oil Initiative, announced by the Secretary of Energy in December 1992. Major Secretarial initiatives for the future, relating to natural gas, are summarized in Appendix A.

2.4 SITUATION ANALYSIS: KEY CUSTOMER CONSIDERATIONS

Public: The public recognizes the value of natural gas as a relatively clean, affordable, and secure domestic fuel source.

Gas Industry: Although the participants in the gas industry are quite diverse, they generally seek an expanded and more competitive gas market.

Producers: Producers support RD&D programs in production technology and resource characteriza-

tion. However, they are concerned about other near-term issues: tax incentives; regulatory relief; control of environmental compliance costs; competition from imports; capital availability; and competitive gas prices that allow recovery of exploration and production costs. Independents are interested in better transfer of technology information from GRI, Institute of Gas Technology, Federal Government, and the universities.

Marketers: With evolving competition in the gas industry, independent and affiliated (owned by distributors or pipelines) marketers are selling an increasing share of gas to end use purchasers. They seek regulatory reform to increase economic efficiency, expand growth, improve performance and reliability, enhance customer service, and alleviate problems such as how to fund RD&D and market entry.

Pipeline Companies: Pipelines support regulatory reform that facilitates construction of pipelines and facilities (new and expansion), and creates more efficient and flexible rate structures. They seek regulatory and market stability, particularly because Order 636 eliminates their traditional role as marketers.

Local Distribution Companies (LDCs): LDCs seek consistent and flexible Federal and State regulation, and fair and timely cost recovery to improve their marketing of gas. These companies are concerned with maximizing the reliability and flexibility of services, and seek innovative product development for new uses of gas. Also, LDCs are concerned about by-pass.

Automobile Manufacturers: The alternative fuel market will depend in large part on the production and marketing of vehicles capable of using natural gas while meeting efficiency and emission goals.

Vehicle Fleet Users: The adoption of NGVs into private and government-owned vehicle fleet operations is required to establish a natural gas market for vehicles.

Gas Consumers: Industrial and Power Generation: Independent power producers, electric utilities, and industrial gas consumers believe that they benefit from reform of Federal and State statutes and regulations. They require adequate, reliable supplies and price stability to facilitate long-term planning and to preclude supply interruptions. These groups will likely increase their use of gas to

meet environmental requirements. Industrial users are opposed to any technology developments which may expand gas markets, and pressures which will add to the bottom line cost of their products.

Commercial and Residential: Residential and commercial consumers are concerned that the changing regulatory framework will result in higher, more volatile gas prices and less reliable service.

Environmental Organizations: These groups continue to press for reduced emissions and to demand that environmental externalities be considered in the selection of fossil fuels. They are generally proponents of energy conservation and zero emission technologies. They continue to view natural gas as the fossil energy resource of choice, but continue to support restrictive access to new resource development.

Federal Government: The Departments of State and Commerce support the objectives and goals of DOE's Natural Gas Program because it offers trade opportunities and environmentally and economically sound technology options for natural gas using countries. The Office of Management and Budget and EPA support DOE's aggressive RD&D program initiative because of its environmental benefits. The Department of the Interior has close programmatic cooperation with DOE's natural gas program in its collection and evaluation of resource and reserve data.

Federal, State, and Local Regulatory Agencies: Regulatory agencies, such as FERC, EPA, and Public Utility Commissions (PUCs), generally support the development of a market-based natural gas system conditioned upon avoiding abuse of market power, protecting "captive" customers, and requiring environmental compliance. They have been leaders in adopting externality policies.

State Governments: States govern gas utility rates, resource prorationing, and environmental issues within their jurisdiction. They are increasingly concerned with proper disposal of produced waters and drilling fluids, and operations in environmentally sensitive areas. Consuming States want active government involvement to ensure supply availability and deliverability. Producing States are concerned about resource conservation and management. State geological surveys provide geological data for DOE's Gas Research Program. State regulators are concerned that the

move toward a market driven gas system will result in increased costs and unreliable service. Many State governments now require IRP and demand-side management programs.

Foreign Governments: Interest in gas use is increasing internationally as energy demand grows and environmental concerns increase. Foreign governments seek to expand their countries' market share of gas and to increase liquefied natural gas (LNG) exports to the United States. These efforts are creating competition for U.S. producers. There is increasing demand for U.S. gas supplies from Mexico.

Research and Educational Community: Research organizations, numerous colleges and universities, and the National Laboratories are active in gas RD&D activities. Some are funded exclusively by DOE; some provide cost-sharing; and others are working collaboratively with private industry. These organizations seek expanded Federal funding for RD&D efforts.

Equipment Vendors: Equipment suppliers are developing equipment to improve efficiency and reduce costs in all areas of the gas system. End use manufacturers are seeking to develop and sell more efficient, less polluting utilization technologies to maintain their competitiveness in the U.S. and overseas markets. Some manufacturers of products, such as gas cooling, fuel cells, and CNG vehicles, have difficulty commercializing their technologies because of high "first costs," limited infrastructure, consumer acceptance, and regulatory impediments.

Investment Community: The investment community is concerned with reducing the risks of financing gas-related activities such as commercializing end use technologies and constructing required storage and distribution systems. The evolution of the New York Mercantile Exchange gas futures market has made it possible for buyers and sellers to hedge the price risk of future gas transactions.

Congress: DOE's new strategy, incorporating higher cost-shared, industry driven RD&D programs with GRI and other nonfederal sources, is supported by Congress. Historically, there has been a wide disparity between the Administration's natural gas budget requests to Congress and the budgets that emerge in the appropriations process.

2.5 SITUATION ANALYSIS: KEY PLANNING ASSUMPTIONS

- Key areas that will lead to growth in the natural gas industry are: (1) continuing regulatory reform and industry restructuring; (2) increased deliverability of the natural gas system; (3) continued development and commercialization of technology to reduce costs and expand market opportunities; and (4) perceived reliability to customers.
- Natural gas will maintain a competitive advantage in new markets due to its environmental advantages relative to other fossil fuels. However, environmental constraints associated with siting, permitting, and construction of facilities, storage, LNG and pipeline projects, and power plants are likely to be more stringent. The "greenhouse" effect (CO₂ and methane emissions) will continue as a major policy concern.
- The domestic natural gas resource base will remain sufficient to meet projected increased demand given continued development and commercialization of technology. Lower cost, conventional gas resources will continue to play a dominant role in the near-term. Resources now considered nonconventional will capture an increasing share of the market in the mid-term.
- Federal and State restrictions on onshore and offshore lands for gas production will continue in the near-term.
- Gas supply and consumption patterns will change, creating a need for construction of new transportation and storage facilities.
- Natural gas demand will increase, driven primarily by the electric generation and industrial sectors. Economic and environmental benefits will follow from the use of this clean domestic fuel, and advanced utilization technologies with higher efficiency and lower emissions will increase these benefits.
- The demand for NGVs and vehicle refueling infrastructure is likely to outstrip the capacity of industry to respond in the near-term. The increased demand will reflect increased interest in lowering vehicle emissions to meet air quality requirements.
- Although residential and commercial market customers are expected to increase by 2010, conservation may offset the increased con-

sumption due to growth in end use technology markets. Natural gas will continue to face stiff competition from the electric industry.

- Increasing interest in considering demand-side options along with supply-side resources, within the IRP process, may lead to greater penetration of new, highly efficient end use technologies. This will act as a moderating influence on the increased use of gas within all customer classes.
- Changes will continue at the State regulatory level as competitive forces push for changes in regulatory and environmental requirements, and place increased responsibility on the States. Environmental externalities will continue to be considered by the States.
- Natural gas imports to the U.S. will increase in the future (LNG and Canadian gas); natural gas exports to Japan, Mexico, and eastern Canada will also increase.

2.6 SITUATION ANALYSIS: KEY TRENDS

Market Trends

Current market conditions are characterized by modest wellhead prices (in real terms), responsive spot market transactions, unbundling of pipeline transportation and sales, emergence and growth of independent power producers, and increased imports and exports. The market expanded substantially between 1986 and 1992, with annual consumption increasing from 16.2 to 19.7 Tcf. It is estimated that total consumption will reach 24 Tcf in 2010, because of increased gas use in electric generation, commercial cooling and heating, and NGVs. Consumer sectors have benefitted from an eight year decline in wellhead prices, but both wellhead and consumer prices increased in 1992. Total annual dry gas production increased from 16.5 Tcf in 1985 to 17.8 Tcf in 1992. Total annual imports reached two Tcf in 1992 (10 percent of total gas consumption) and are estimated to reach 4.15 Tcf by the year 2010.

Technology Trends

GRI, EPRI, the National Laboratories, and others in the industry are cooperating with manufacturers to promote expanded gas use by developing advanced supply and utilization technologies. Advancements in power generation and transportation technologies are continuing with the development of high efficiency, low NO_x gas turbines; zero

emission fuel cells; and cost-effective CNG vehicles. Increasing competition has mandated quality control and cost reduction in the supply sector. According to the National Petroleum Council (NPC), between 1970 and 1989, there was an underlying, technology-based, cost savings trend of about three percent per year. In gas exploration and production, developments will continue in improved geologic evaluation, subsurface imaging techniques, slim hole drilling, deeper drilling capabilities, and horizontal well technology. Deliverability improvements have been made in the cost effectiveness, reliability, and efficiency of gas transportation, distribution, and storage facilities. Contributing factors include application of horizontal wells for storage reservoirs, and improvements in transport measurement technologies, interior distribution components, meters, and installation techniques. Industry's need for more cost-effective control technology to comply with environmental regulations is also expected to continue.

Resource Base Trends

Historically, the Lower 48 resource base estimates by industry and government have changed drastically, but always reflected an upward trend. Exhibit 2-1 highlights the disparity between one early estimate of ultimate production -- 870 Tcf with 91 percent of the resource base already depleted (Hubbert, 1970s) -- and the 1990 DOE resource study estimate of 2,017 Tcf (includes advanced technology and access) with only 39 percent depleted. The 1992 NPC natural gas study concludes that the U.S. has a vast resource base of 1,295 Tcf (assumes advanced technology and access) that can be produced and delivered at prices that allow expanded gas use. Growth in the resource base is attributed to continuing evolution in technology and its applications. Continuing technology developments, opening of nonaccess areas, and including the speculative resource base will increase the current estimates. Other key trends related to natural gas are also shown in Exhibit 2-1.

Environmental Trends

The public is less accepting of environmental risk, leading to increased emphasis on pollution prevention, source reductions, waste minimization, and toxics use reduction. Significant advances in environmental monitoring systems are likely to continue in the future. These systems have increased the information available on toxics and

more regulatory agencies are requiring regular monitoring of pollutants. Fuel- and life-cycle costs are beginning to be considered in procurement policies and purchasing decisions of both the public and private sectors. Use of pollution taxes, credits, fees, and other market-based pollution abatement incentives are being used. There is increasing globalization of environmental issues, programs, and policies.

Regulatory/Policy Trends

The regulatory and policy agenda has changed considerably from the 1970s and 1980s, when it was mistakenly believed that natural gas was in short supply. With the introduction of, among other things, open access transportation, wellhead price deregulation, and pipeline restructuring under Order 636, the focus of the regulatory and policy agenda shifts to transportation service issues and State regulatory issues. The Federal government's goal is to complete reform of regulations to allow a more market oriented system to operate, thereby fostering the increased use of gas.

2.7 STRATEGIC ISSUES

If not resolved, the following key obstacles may prevent DOE from realizing its vision:

- Continuing natural gas regulatory reforms, incorporating market oriented solutions, are needed or gas use will not be economically efficient or consistent with technology availability. Full market maturation will not occur until industry restructuring and regulatory reform is completed.
- Current natural gas utilization technologies cannot meet some projected emission regulations. If an acceleration of RD&D does not occur, U.S. industry will not meet timetables and provisions for air quality goals.
- The cumulative impact of compliance costs associated with Federal, State, and local regulations could constrain future production and utilization of gas.
- Competing targets of reduced emissions (e.g., NO_x) and increased efficiency could hinder the development of end use technologies. In addition, proposed emission levels for technologies being developed now might not meet requirements at the time of commercialization.

- Some current gas technologies (e.g., gas cooling, fuel cells) are not being used by end users because of the absence of aggressive demonstration programs, general lack of public knowledge about products, and high startup costs.
- Without continued aggressive development of gas supply technologies by private and government sectors, production and deliverability of gas will not be maintained at projected low market-clearing prices and development of new supply sources may not occur to meet growing demands.
- The combination of government and private sector resources is inadequate to support the RD&D and commercialization of advanced gas supply, storage, transmission, utilization, and environmental technologies.
- Without government support of utilization technology development, the competitive position of U.S. equipment manufacturers will be negatively affected.
- Improved evaluations of total fuel-cycle costs need to be developed and refined to form a reliable basis for policymaking. Scientific understanding of energy use impact on the environment is often inadequate to guide efficient environmental regulations.
- Federal and State governments and industry must cooperate to develop an approach for responding to emergencies that threaten gas deliverability. Many customers do not have confidence in natural gas as a reliable and economic long-term energy source.
- Because of the gas system unbundling, accurate and timely natural gas information is currently not available. Such information is necessary to make well-informed decisions concerning gas markets and future research and development projects.
- Current Federal and State regulations, variable prices, and end use deliverability concerns affect the ability of electric utilities to choose natural gas relative to coal or oil.
- If the environmental benefits of leasing/permitting restrictions and drilling moratoria are not balanced against the environmental and economic benefits of increased gas use, future production and utilization of gas will be constrained.

2.8 NATURAL GAS PROGRAM OBJECTIVES AND STRATEGIES

Resource and Extraction Area

Near-Term (By year 2000)

1. Assess the domestic resources/reserves, and complete development of a portfolio of methodologies for increasing recovery of resources in order to reduce exploration and production costs and to upgrade low quality gas. DOE plans to:
 - a. Prepare natural gas data sets and atlases for the primary producing regions of the U.S., and develop computer models providing capability for analysis of the gas industry "system";
 - b. Develop a unique, large bench-scale, physical laboratory to conduct fracture fluid rheology and treatment design tests on a custom and/or routine basis;
 - c. Perform hydraulic fracturing field research resulting in the development of improved fracturing diagnostics, treatment design, and real time fracturing control technology;
 - d. Develop laboratory and field-based geologic, geotechnical, and geophysical technology to detect, map, and predict natural fractures in low permeability reservoirs;
 - e. Develop new technologies and evaluate state-of-the-art technologies for gas contaminant separation and upgrading of low quality gas;
 - f. Develop and demonstrate drilling, completion, and stimulation products related to minimum formation damage drilling and stimulation technology. Conduct projects for improving the efficiency of gas recovery from mature gas fields;
 - g. Integrate geologic and resource studies, field demonstrations, wells-of-opportunity tests, and supporting RD&D into a strategy for economic and effective development of low permeability formations;
 - h. Develop and demonstrate strategies for extracting gas from deposits where coal-seams coexist with shallow, gas bearing sandstones and shales. Disseminate

state-of-the-art coalseam methane recovery information to the public; and

- i. Conduct workshops to transfer technology from RD&D programs to potential users.

Mid-Term (By year 2010)

1. Enable industry to supplement U.S. conventional production and gas imports with sufficient supply from nonconventional resources (minimum of four Tcf per year) in order to sustain an annual supply of 23 Tcf (price range of \$2.50 - \$3.50 per million Btu, 1990\$). DOE plans to:
 - a. Develop, demonstrate, and transfer to industry indirect methods for detection and analysis of natural fracture systems and advanced hydraulic fracturing techniques for use in low permeability formations;
 - b. Develop, demonstrate, and transfer to industry integrated strategies for increasing the recovery efficiency from low permeability formations located in basins providing highest supply levels;
 - c. Develop, demonstrate, and transfer to industry integrated drilling, completion, and stimulation systems that are environmentally benign, nondamaging to reservoirs, and cost-competitive; and
 - d. Encourage development of gas resources suited primarily for local use, including mine gas, landfill gas, and remote gas.

Utilization Area

Near-Term (By year 2000)

1. Complete program leading to commercial offering by industry of ultra-high efficiency, environmentally superior, cost-competitive gas turbine systems for utility and industrial applications. Utility systems will have efficiency of 60 percent or greater lower heating value, while industrial systems will improve simple cycle efficiency by 15 percent in heat rate. Both systems also will have low emissions (NO_x less than eight parts per million). DOE plans to:
 - a. Conduct a cost-shared RD&D program to achieve prototype demonstration of advanced gas turbine systems, both industrial and utility service;

- b. Develop ceramic technology for high temperature gas turbines; and
 - c. Conduct cost-shared government/industry RD&D programs to improve efficiency of industrial processes in energy intensive industries such as gas chillers, heat pumps, and cogeneration.
-
2. Complete program leading to commercial offering by industry of economically competitive and environmentally acceptable processes for direct conversion of light hydrocarbons to transportation fuels which will be competitive with crude oil prices. DOE plans to:
 - a. Conduct a cost-shared collaborative RD&D program to achieve prototype demonstration of one or more direct conversion processes for the production of hydrocarbon transportation fuels.
 3. Complete program leading to commercialization by industry of molten carbonate and solid oxide fuel cell power plants for dispersed applications in industrial and public utility markets (U.S. and overseas). Efficiency targets are 55 to 60 percent higher heating value (HHV) or better for molten carbonate fuel cell and solid oxide fuel cell, with both technologies cost competitive with other power technologies. DOE plans to:
 - a. Support development, integration, and scaleup of molten carbonate and solid oxide fuel cell power plants through the demonstration plant stage (with increasing levels of cost sharing).
 4. Complete a collaborative program with industry, GRI, and the gas utilities leading to market introduction in 1996 of a cost competitive, first generation advanced cycle absorption heat pump with ammonia/water as the working fluid for residential and light commercial applications. Performance targets are a coefficient of performance of 1.7 in heating and 0.8 in cooling. Cost will be competitive with standard heating, ventilation and air conditioning (HVAC) equipment and a large production volume is anticipated. DOE plans to:
 - a. Conduct an industry cost-shared collaborative RD&D program to develop laboratory prototype units that meet cost, performance, and manufacturability goals; and

- b. Conduct a multi-unit field demonstration of production prototype units in collaboration with a major manufacturer of HVAC equipment and the gas industry.
5. Complete program leading to commercialization in 1996, by industry, of a cost-competitive advanced cycle absorption chiller with lithium bromide/water as the working fluid for large commercial applications. The target coefficient of performance is 1.6 in cooling. DOE plans to:
 - a. Conduct an industry cost-shared collaborative RD&D program to develop laboratory prototype units for evaluation and demonstration of performance, reliability, and cost. Conduct a field test leading to commercial product availability.
6. Complete an industry cost-shared program that achieves a major cost reduction of the phosphoric acid fuel cell and modifications for use in building cogeneration systems by 1998. The overall efficiency target is 80 percent or better in a cogeneration mode with a cost of \$1,500/kilowatt. DOE plans to:
 - a. Increase support for an industry cost-shared RD&D program to bring the cost of the phosphoric acid fuel cell down to a market clearing price and adapt them to building applications for power and thermal loads.
7. Initiate NGV commercialization activity using the Federal fleet as the catalyst for other fleet users. By the year 2000, Federal fleet will be acquiring 75 percent alternative fuel vehicles in its annual vehicle purchases (approximately half will be NGVs).
- plants through the demonstration plant stage (with increasing levels of cost-sharing).
2. Complete commercialization of advanced gas turbine systems developed in the near-term that have efficiency improvements and greatly reduced emissions. DOE plans to:
 - a. Conduct long-range RD&D program to develop gas turbine systems integrated with fuel cells; and
 - b. Conduct basic RD&D program to improve performance of advanced gas turbine systems.
3. Improve energy efficiency in industrial processes and increase productivity in processes using natural gas. DOE plans to:
 - a. Conduct RD&D to establish the capability to meet CAAA environmental objectives through process technology improvements and feedstock alternatives development; and
 - b. Increase support of RD&D on equipment that will improve energy conversion efficiency, recover energy from industrial waste heat, and promote industrial cogeneration technology.
4. In conjunction with industry and GRI, develop highly efficient thermally activated heat pumps that use natural gas to heat and cool buildings. Significantly increase the use of gas to cost-effectively provide energy requirements for commercial and residential buildings. DOE plans to:
 - a. Increase support for RD&D to reduce costs and improve performance of building energy technologies;
 - b. Improve the energy efficiency of appliances by using existing authority to update efficiency standards to keep pace with new technology. The technological potential exists for energy use reductions of 50 percent in space heating and 30-40 percent in air conditioning and refrigeration. More efficient gas appliances will decrease energy costs for consumers and, thus, encourage more gas use;
 - c. Complete a collaborative program with industry, GRI, and the gas utilities that results in large-scale market introduction in 2002 of a cost-competitive, second generation (HiCool) advanced cycle ab-

Mid-Term (By year 2010)

1. Achieve commercialization by industry of molten carbonate and solid oxide fuel cell power plants for new and repowering central power plant applications in U.S. and overseas nonutility generator and utility markets, and in residential and commercial markets. Achieve efficiency targets of 60 percent (HHV) or better for molten carbonate fuel cell, and 55 percent (HHV) or better for solid oxide fuel cell, with both technologies cost competitive with other power technologies. DOE plans to:
 - a. Support development, integration, scale-up and demonstration of large molten carbonate and solid oxide fuel cell power

- sorption heat pump for residential and light commercial buildings in cooling dominated climates. Performance targets are a coefficient of performance of 2.0 in heating and 1.1 in cooling with a first cost consistent with large market share. Increase RD&D support to encompass critical technologies for HiCool heat pumps such as advanced cycles, new working fluids, advanced materials, simulation and control and heat/mass transfer; and
- d. Complete a collaborative program with industry, GRI, and EPRI that achieves commercialization of proton exchange membrane (PEM) fuel cell technology for small to medium size buildings. Increase RD&D support to address building-unique technology; and product requirements including high temperature operation, integrated fuel reforming, and building thermal and electrical integration.
5. Support the development of an infrastructure to promote natural gas as a significant transportation fuel, reducing vulnerability to oil supply disruptions. DOE plans to:
 - a. Support conversion of fleets (Federal passenger automobiles, light and heavy duty trucks) to natural gas, and promote private sector investment in gas under the authority of the Alternative Motor Fuels Act of 1988, EPACT, and the Executive Order 12844;
 - b. Promote natural gas vehicle penetration into the market by acquiring a significant number of light duty vehicles for the Federal fleet and supporting the bus program of Department of Transportation's Urban Mass Transportation Administration;
 - c. Support mid- and long-term development of fuel cell technology for transportation applications. Develop the PEM fuel cell as a mid-term option for cars, vans, buses, and locomotives;
 - d. Develop ceramic component technology as a means to resolve technical issues associated with increased engine efficiency;
 - e. Support development of appropriate safety regulations related to gas utilization in transportation applications; and
 - f. Support legislation that ensures both tank safety and manufacturer flexibility for CNG storage tanks.
6. Continue NGV commercialization activity using the Federal fleet purchases as a catalyst to develop partnerships that promote NGVs. Emphasize commercialization of dedicated NGVs compared to bi-fuel systems. The mid-term goal is to displace 30 percent of transportation petroleum consumption with alternative fuels, with natural gas as a major contributor.

Delivery and Storage Area

Near-Term (By year 2000)

1. Identify and evaluate the feasibility of alternative technologies suitable for gas storage and delivery applications.
2. Identify strategic market areas for new and growing natural gas use, project gas demand, and the storage capacity/delivery required for these areas. Assess potential geologic formations for their development as storage reservoirs in these market areas.
3. Investigate field development strategies for new and expanding gas storage fields.
4. Identify communication system technology leading to development of a national electronic gas deliverability system. DOE plans to:
 - a. Identify and address aspects that will lead to improved storage/delivery technology to establish confidence in gas deliverability;
 - b. Evaluate alternative gas storage methods that have the potential to meet the expected demand increase from major gas consumers;
 - c. Define and improve system aspects of gas storage/delivery technologies and participate in gas storage/end user demonstration tests to establish the reliability of peak-load deliverability; and
 - d. Identify market growth areas, projected demand, and potential storage sites.

Mid-Term (By year 2010)

1. Demonstrate new storage and delivery technologies to optimize the economics of gas storage and delivery.

2. Evaluate and demonstrate techniques to control gas migration from the storage area, address constraints associated with aquifer storage, and reduce investment costs.
3. Support the development of a national electronic gas deliverability system to support new and growing gas markets. DOE plans to:
 - a. Participate in gas storage/end user demonstration tests to establish the reliability of alternative storage methods;
 - b. Participate in verification tests to demonstrate reservoir management techniques to mitigate effects of gas migration, to reduce investment costs by replacing working gas with less expensive inert gas, and to improve inventory verification; and
 - c. Develop technologies that address the constraints associated with gas storage in aquifers thereby facilitating the construction of new aquifer storage capacity.
2. Provide industry with the tools to comply with environmental requirements in order to maintain and increase economic gas production. Reduce the cost of compliance with current and future requirements. Provide a sound scientific basis for regulation and mitigation measures. DOE plans to:
 - a. Develop lower cost environmental mitigation and waste management technologies and methods for gas exploration to meet current and future regulatory requirements;
 - b. Through various DOE programs, sponsor research and environmental science assessment on global warming, air quality standards (both mobile and stationary sources), geologic hazards, aquifer protection, wetlands operations, and other air, water, and solid waste environmental concerns related to natural gas, including the role of NO_x, CO₂, methane, naturally occurring radioactive materials, and basic research on combustion and catalysis; and
 - c. Transfer environmental technologies and technical information to appropriate parties (e.g., Federal and State agencies, gas industry).

Environmental/Regulatory Impact Area

Near-Term (By year 2000)

1. Identify, analyze, and recommend the removal of impediments to cost-effective gas utilization. DOE plans to:
 - a. Work with FERC to complete Federal regulatory reforms to permit increased gas use. Issues requiring the greatest attention are: implementation of Order 636; the development of a minimally regulated secondary market for pipeline capacity; and development of a streamlined certification and siting process for production, transportation, storage, and utilization facilities;
 - b. Work with FERC, PUCs, and National Association of Regulatory Utility Commissioners to develop policies providing for efficient operation of the energy system and to ensure market opportunities for natural gas, such as a robust secondary market for pipeline capacity and incentive rate reform; and
 - c. Work with States to promote cooperative approaches to enhancing gas usage focusing on regulatory and environmental issues that affect access, production, storage, transmission, and utilization.
3. Enhance the capability to analyze the costs and energy impacts of proposed environmental laws and regulations on the gas industry. Obtain improved Federal and State regulations affecting gas production, transportation, distribution, and utilization networks. DOE plans to:
 - a. Work with regulatory bodies to establish improved criteria for environmental regulations based on such factors as risk assessment, cost/benefit analysis, and cumulative regulatory impact;
 - b. Analyze the energy impact of environmental regulations and legislation, such as new regulations under the CAAA and reauthorization of the Resource Conservation and Recovery Act, and ensure that such information is made available to environmental regulators and legislators; and
 - c. Formulate air and water quality standards and waste management requirements.

4. Maintain relationships with foreign governments and international organizations to continue the exchange of information and to expand trade and investment opportunities.
5. Develop regulations involving fuel provider fleets and private fleets required by EPACT that accelerate the development of natural gas fuels for transportation.

Mid-Term (By year 2010)

1. Contribute to evaluations of environmental science and externalities for all fuel cycles to achieve the optimal total fuel-cycle cost mix for different energy uses affecting natural gas.

2.9 KEY PERFORMANCE INDICATORS

Measurable parameters used to evaluate the level of performance or success for programs.

Resource and Extraction Area

Near-Term (By year 2000)

- Development and transfer of three natural gas atlases and companion data management system to a minimum of 1,500 domestic users for each atlas series.
- Levels of impact on supply availability through dissemination of knowledge, mitigation of cost increases, and improved exploration and recovery processes that allow the industry to find and produce more gas at competitive prices.

Mid-Term (By year 2010)

- Increase in domestic gas supply by an additional four Tcf over 1991 levels.
- Demonstration and technology transfer of advanced recovery technologies such as infill drilling; drilling, completion, stimulation systems; and low quality gas upgrading.

Utilization Area

Near-Term (By year 2000)

- Number of new gas technologies that have been commercialized in the industrial, transportation, buildings (residential and commercial) and electric utility sectors.
- Industrial cost participation in DOE natural gas programs.

- Commercial offering of efficient advanced gas turbines with low NO_x emissions and natural gas-fueled vehicles.
- Cost of gas technologies for power production and residential/commercial heating and cooling compared to other energy sources.

Mid-Term (By year 2010)

- Increase in share of primary energy markets supplied by gas, achieved through increased commercialization of gas technologies.
- Energy efficiency improvements of up to 0.11 quad per year, made through the conduct of cost-shared government/industry RD&D programs in energy intensive industry processes such as gas chillers, heat pumps, and cogeneration.
- Better measurement of total fuel-cycle costs for NGVs.
- Implementation of gas IRP by States.

Delivery and Storage Area

Near-term (By year 2000)

- Completion of the National Deliverability Capacity model and dissemination of analytical capability.
- Demonstration and dissemination of the Energy and Natural Resource Information Mapping System (ENRIMS) underground storage application capability for evaluating changes in the development and use of storage, and the interconnections among storage areas and pipelines.
- Demonstration of natural gas as a reliable fuel source by using storage reservoirs to supply gas during peak-demand periods for the power generation market through actual tests and demonstrations.
- Completion of the design and demonstration of a national electronic natural gas deliverability information network system.

Mid-Term (By year 2010)

- Improved reservoir management techniques to mitigate the effects of gas migration from storage reservoirs, demonstrated in research and verification tests.
- Alternative storage methods identified in areas where conventional underground storage is

- not feasible, and feasibility/verification tests evaluated for these methods.
- Producing States connected through an online system to a national electronic natural gas deliverability information network.
- Improvement in gas reliability and monitoring of gas supplies from the wellhead to the burnertip through the national electronic gas deliverability information network system.
- Completion of analysis of Federal and State barriers to the increased use of gas in electric generation.
- Initiation of efforts to address regional environmental constraints to gas supply. Expansion of analytical capability to assess relationship between environmental compliance and access constraints to gas resource recovery.
- Issuance of estimates of contribution by natural gas to global methane concentrations by 1996.

Environmental/Regulatory Impact Area

Near-Term (By year 2000)

- Development of policies to ensure a minimally regulated secondary market for pipeline capacity, and a streamlined certification and siting process for production, transportation, storage, and utilization facilities.
- Completion of research and analysis projects that support States interested in reforming their gas regulatory programs. Number of conferences and workshops held with States and industry on regulatory issues.

Mid-Term (By year 2010)

- Reduction of pipeline methane losses by 25 percent, in cooperation with EPA.
- Increased market share by natural gas, due to coordination, streamlining, and reduction of Federal and State barriers to gas use.

Exhibit 2-1. Natural Gas Key Trends

Views of Resource Base U.S. Lower 48 States

	Middle and Late 1970s	Current			
Reference	Hubbert	DOE 1990	PGC ¹ 1990	Enron 1993	NPC ² 1992
Ultimate Production	870 ± 30 Tcf	2,017 Tcf ³	1,605 Tcf ⁴	1,303 Tcf ³	1,295 Tcf ⁵
Percent Depleted	91	39	49	40	38

¹ Potential Gas Committee

² National Petroleum Council

³ Advanced technology and access

⁴ Base case, existing technology

⁵ Advanced and existing technology

Exhibit 2-1. Natural Gas Key Trends (Continued)

3.0 FY 1992-1994 BUDGET OVERVIEW

3.0 FY 1992-1994 BUDGET OVERVIEW

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***Natural Gas RD&D Budget
FY 1994 Budget DOE-Wide
(\$ in millions)**

Program Area	FY 1992 (Enacted)	FY 1993 (Enacted)	FY 1994 (Approp.)	Cost-Sharing Target (%)
Resource and Extraction	18.1	19.9	23.8	25-50
Delivery and Storage	0.2	0.1	1.1	50
Utilization	95.9	125.3	172.0	45-50
Environmental / Regulatory Impact	0	4.3	6.9	25
Total	\$114.2	\$149.6	\$203.8	25-50

* Excludes gas produced from biomass and coal gasification program.

STRUCTURED TO ACHIEVE ADMINISTRATION GOALS & OBJECTIVES

- Emphasize utilization technology RD&D, de-emphasize supply RD&D targeted towards conventional or unconventional gas recovery. Supply RD&D focuses on all gas reservoirs.
 - Focus resource RD&D on reducing exploration and production costs and addressing near- and mid-term needs of industry.
 - Initiate an environmental/regulatory impact RD&D program in FY 1993.
 - Initiate new program in end use delivery and storage RD&D in FY 1994.
-
- Initiate RD&D in the gas program on ultra low NO_x advanced gas turbines with higher efficiencies.
 - Conclude RD&D on phosphoric acid fuel cells; scale up molten carbonate technology. Scale down solid oxide technology (long-term RD&D) in FY 1993.
 - More emphasis on natural gas vehicle technology which will displace oil use.
-
- Coordinate DOE gas programs (EE, FE, ER, and PO).
 - Cost-shared programs with GRI and industry.

**DOE Natural Gas RD&D Program
Summary of Changes in Spending**

Note: Includes all DOE Fuel Cell programs

**Natural Gas RD&D Budget
DOE Budgets FY 1992-1994
Program Balance Summary (% of Total RD&D Obligations)**

Program Area	FY 1992 (Enacted)	FY 1993 (Enacted)	FY 1994 (Approp.)
Resource and Extraction	15.9	13.3	11.7
Delivery and Storage	0.2	0.1	0.5
Utilization	83.9	83.7	84.4
Environmental / Regulatory Impact	0	2.9	3.4
Total	100%	100%	100%

Program Balance Summary

**DOE Natural Gas RD&D Crosscut Program
FY 1992-1994 Budgets (\$ in millions)
Summary of Changes in Spending**

Program Office	FY 1992 (Enacted)	FY 1993 (Enacted)	FY 1994 (Approp.)	% Change 1992-1994
Fossil Energy (FE) ¹	66.5	81.5	99.0	+49
Energy Efficiency and Renewable Energy (EE) ²	36.9	54.3	78.6	+113
Energy Research (ER) ³	10.7	13.7	26.1	+144
Intelligence and National Security (IS)	0.1	0.1	0.1	-
Total	114.2	149.6	203.8	+78

- NOTES: 1. Spending includes fuel cells program. Fuel Cells program was in the FE Coal budget for FY 1992 and 1993.
2. EE gas activities are not grouped together in the EE budget. Includes the EE Fuel Cells program.
3. ER gas activities are not grouped together in the ER budget, but rather are dispersed throughout budget programs.

Summary of Changes in Spending

Note: IS funding is too small to be shown.

Natural Gas Crosscut Budget FY 1993-1994 (\$ in millions)

NATURAL GAS PROGRAM AREAS	Department-Wide			GRI	Fossil Energy			Energy Efficiency			Energy Research		
	DOE FY 93	Approp. Incrmt.	DOE FY 94	Planned FY 94	FE FY 93	Approp. Incrmt.	FE FY 94	EE FY 93	Approp. Incrmt.	EE FY 94	ER FY 93	Approp. Incrmt.	ER FY 94
RESOURCE AND EXTRACTION	19.9	3.9	23.8	53.4 ¹	13.2	1.9	15.1	-	-	-	6.7 ¹	2.0	8.7
• Conventional				22.7									
• Nonconventional				12.4									
• Fundamental Geosciences				9.5							6.7	2.0	8.7
• Other				8.8									
DELIVERY AND STORAGE	0.1	1.0	1.1	29.1	0.0	1.0	1.0	-	-	-	-	-	-
UTILIZATION	125.3	46.7	172.0	80.9	66.5	14.0	80.5	54.3	24.3	78.6	4.5 ²	8.4	12.9
• Combustion Systems	12.6	8.1	20.7	34.4	1.0	-1.0	0.0	7.1 ¹	0.7	7.8	4.5	8.4	12.9
• Heat Pumps (Heating & Cooling)	5.0	3.2	8.2	16.8	-	-	-	5.0 ²	3.2	8.2			
• Heat Engines	26.6	22.7	49.3	1.4	9.8 ¹	14.4	24.2	16.8 ³	8.3	25.1			
• Natural Gas Vehicles	14.8	9.3	24.1	11.5	-	-	-	14.8 ⁴	9.3	24.1			
• Fuel Cells	54.9	3.3	58.2	4.8	51.2 ²	0.6	51.8	3.7 ⁵	2.7	6.4			
• Gas-to-Liquids	4.0	-0.4	3.6	-	4.0 ³	-0.4	3.6	-	-	-			
• Other	7.4	0.5	7.9	12.0	0.5 ⁴	0.4	0.9	6.9 ⁶	6.1	7.0			
ENVIRONMENTAL/REGULATORY IMPACT	4.3	2.6	6.9	- ²	1.8 ⁵	0.6	2.4	-	-	-	2.5 ³	2.0	4.5 ⁴
TOTAL	\$149.6	\$54.2	\$203.8	\$163.4 ³	\$81.5	\$17.5	\$99.0	\$54.3	\$24.3	\$78.6	\$13.7	\$12.4	\$26.1

GRI Footnotes

1. Includes environmental RD&D.
2. RD&D spending included in Resource and Extraction area total.
3. All area totals above exclude management spending and technology analysis. Therefore, GRI total spending (\$163.4 million) excludes RD&D management spending for all gas areas, the category of crosscutting research, general expenses, and capital asset purchases.

Fossil Energy Footnotes

1. Gas Turbines moved from FE Coal budget to Gas Program in FY 1993.
2. FE Fuel Cells Program included in Coal budget; moved to Gas budget in FY 1994.
3. Gas-to-Liquids Program moved from Advanced Extraction and Process Technology (AEPT) Program to Gas Program in FY 1993.
4. Other: Enhanced Technology Transfer funding will be moved from Environmental/Regulatory Impact Program to Utilization Program for FY 1994.
5. Includes Enhanced Technology Transfer efforts in cooperation with GRI.

Energy Efficiency and Renewable Energy Footnotes

1. Combustion Systems include: Improved Combustion Efficiency (Industrial Combustion Equipment), Improved Combustion Efficiency (General Combustion), Materials Processing, and Alternative Fuels Utilization (Engine Optimization and Atmospheric Reactions).
2. Heat Pumps (heating and cooling) include: Process Heating and Cooling, and Heat Pumps RD&D.
3. Includes: Advanced Turbine Systems, Continuous Fiber Ceramic Composites, Cogeneration, and Heat Engine Development.
4. NGVs: includes funds for demonstrating Federal fleet vehicles.
5. Fuel Cells for Transportation.
6. Other: includes Municipal Solid Waste to Gas, Materials Development (transportation), Electric and Hybrid Vehicles, Gas IRP, and Gas DSM Technologies.

Energy Research Footnotes

1. Fundamental Geosciences Research area. Includes projects in geochemistry (oil and gas generation), fluid migration, reservoir characterization, exploration geophysical techniques, and production technologies.
2. Includes projects in Fundamental Chemical Research and Fundamental Engineering Research Related to Natural Gas.
3. Projects: Sources of Atmospheric Methane (\$0.5 million), and Atmospheric Chemistry Associated with Natural Gas (\$2.0 million).
4. Projects: Sources of Atmospheric Methane (\$0.5 million), and Atmospheric Chemistry Associated with Natural Gas (\$4.0 million).

Natural Gas RD&D Budget Comparisons - FY 1991-1995 (\$ in millions)

NATURAL GAS PROGRAM AREAS	1991	1992		1993		1994				1995	
	DOE Actual	DOE Actual	GRI Approved	DOE Approp.	GRI Planned	DOE Approp.	GRI Planned	GIIG Recom. for DOE	SEB Recom. for DOE	GRI Planned	GIIG Recom. for DOE
RESOURCE AND EXTRACTION	16.5	18.1	57.4	19.9	52.1	23.8	53.4	46.0	-	54.6	53.0
• Conventional	4.1		10.5	Categories Not Used Anymore	24.0	Categories Not Used Anymore	22.7	9.0		23.3	12.0
• Nonconventional	10.1		28.2		10.2		12.4	17.0		12.1	19.0
• Fundamental Geosciences			9.6		9.8		9.5	15.0		9.8	16.0
• Other	2.3		9.1 ¹		8.1 ¹		8.8 ¹	5.0 ²		9.4 ¹	6.0 ²
DELIVERY AND STORAGE	0.0	0.2	31.7	0.1³	28.8	1.1	29.1	-		29.1	-
UTILIZATION	76.2	95.9	83.1	125.3	82.3	172.0	80.9	196.0	196.0	78.8	213.0
• Combustion Systems	11.4	9.8	32.3	12.6	34.3	20.7	34.4	53.2	66.0 ⁸	34.0	53.2
• Heat Pumps (Heating & Cooling)	5.4	4.8	20.0	5.0	17.2	8.2	16.8	20.0	20.0 ⁹	17.2	21.0
• Heat Engines	0.8	16.0	1.2	26.6 ⁴	1.5	49.3 ⁷	1.4	12.8	-	1.4	15.8
• Natural Gas Vehicles	4.4	5.7	11.6	14.8	12.4	24.1	11.5	41.0	41.0 ¹⁰	10.7	45.0
• Fuel Cells	50.8	53.8	4.0	54.9 ⁵	4.7	58.2	4.8	69.0	69.0 ¹¹	4.5	78.0
• Gas-to-Liquids	3.4	3.2	-	4.0 ⁶	-	3.6	-	-	-	-	-
• Other		2.6	14.0 ¹²	7.4	12.2 ¹²	7.9	12.0 ¹²	-	-	11.0 ¹²	-
ENVIRONMENTAL/REGULATORY IMPACT	0.0	0.0	- ¹³	4.3	- ¹³	6.9	- ¹³	- ¹³	-	- ¹³	- ¹³
TOTAL	\$92.7	\$114.2	\$172.2	\$149.6	\$163.2	\$203.8	\$163.4	\$242.0	\$196.0	\$162.5	\$266.0

GRI: Gas Research Institute

GIIG: Gas Industry R&D Initiative Group [Funding levels recommended by a group of 34 gas companies and 10 research and trade organizations including the Institute of Gas Technology (IGT), and the American Gas Association (AGA)].

SEB: A Sustainable Energy Budget (Funding levels recommended by a group of 90 environmental, energy policy, consumer, public health, government and community groups).

EPRI: Electric Power Research Institute.

NOTES:

- Columns for GIIG and SEB reflect recommended RD&D budget levels for DOE.
- GIIG-recommended funding levels for Coal Gasification are not included. DOE's Coal Gasification program budget appropriated for FY 1993 in the FE Coal budget is \$11 million.
- GRI budget reflects approved 1992 and planned 1993-1997 levels. Excludes GRI RD&D budget management, and cofunding levels; and crosscutting projects in Energy Economics, Technology Analysis, Benefits Analysis, Properties Research, and Exploratory Concept.

RECOMMENDED NATURAL GAS RESEARCH FUNDING LEVELS FOR DOE (\$ MILLIONS)

Source	Funding Level
National Petroleum Council	250/Year
Washington Policy and Analysis	250/Year

EPRI NATURAL GAS UTILIZATION PROJECTS (\$ MILLIONS)

Project	1993	1994	1995	1996	1997	Total
Natural Gas-Fired Central Station	8.1	8.7	9.3	9.4	9.6	45.1
Gas-Fired Dispersed Generation	5.1	4.7	4.8	5.5	5.0	25.1
Total	13.2	13.4	14.1	14.9	14.6	70.2

Source: Electric Power Research Institute (EPRI)

- Includes Advanced Gas Processing, Advanced Gas Separation, and Supply Technology Analysis projects.
- Includes Advanced Biofuels projects.
- New RD&D program area. Includes \$0.1 million on EMERGE project by Office of Intelligence and National Security.
- Gas Turbines moved from the FE Coal budget into the FE Natural Gas budget in FY 1993.
- Fuel Cells remain in the FY 1993 Coal budget; will move into the Natural Gas budget in FY 1994.
- Gas-to-Liquids moved from AEPT (Petroleum budget) into the Natural Gas budget in FY 1993.
- Includes \$28.5 million for Advanced Turbine Systems.
- Includes Industrial Systems (\$42 million), Commercial/Residential Equipment (\$7.2 million), and Heat Engines (\$16.8 million).
- Natural Gas Cooling. Includes Residential/Commercial Equipment (\$16.5 million), and Large Commercial and Institutional Equipment (\$3.5 million).
- Includes Advanced Propulsion Systems, Vehicle Systems and Demonstration, and Advanced Storage/Advanced Refueling.
- Includes Phosphoric Acid (\$7 million), Molten Carbonate (\$40 million), Solid Electrolyte (\$18 million), and Polymer Membrane (\$4 million).
- Includes projects in Environment (emission control, waste processing, air quality), Equipment Safety, and Basic Research.
- Included in other research elements.

**Natural Gas RD&D Program
FY 1994 Budget Appropriation
(\$ in millions)**

Program Area	DOE	% of Total	Gas Research Institute ¹	% of Total	Recommended for DOE by Industry (GIIG) ²	% of Total
Resource and Extraction	23.8	11.7	53.4 ³	32.7	46.0 ⁴	19.0
Delivery and Storage	1.1	0.5	29.1 ⁵	17.8	-	-
Utilization	172.0 ⁶	84.4	80.9 ⁷	49.5	196.0 ⁸	81.0
Environmental/ Regulatory Impact	6.9	3.4	- ⁹	-	- ⁹	-
Total	\$203.8 ¹⁰	100%	\$163.4 ¹¹	100%	\$242.0 ¹²	100%

1. GRI budget excludes RD&D budget management funding levels.
2. Gas Industry R&D Initiative Group. [Funding levels are recommended by a group of 34 gas companies and 10 research and trade organizations including the Institute of Gas Technology (IGT), and the American Gas Association (AGA)].
3. Includes Advanced Gas Processing (\$6 million), Advanced Gas Separation Science and Technology (\$2.4 million), and Supply Technology Analysis (\$0.5 million).
4. Includes conventional and unconventional resource, and advanced biofuels funding. It does not include Coal Gasification subprogram.
5. Storage RD&D funding is \$1.2 million only.
6. DOE utilization funding is for 7 main areas: Combustion Systems, Heat Pumps, Heat Engines, Natural Gas Vehicles, Fuel Cells, Gas-to-Liquids, and Other activities.
7. GRI number excludes technical analysis and RD&D management spending. Includes funding (\$12 million) for projects in Environment (emission control, waste processing, air quality), Equipment Safety, and Basic Research.
8. Includes major programs: Combustion Systems, Natural Gas Fueled Vehicles, Fuel Cells Technology, and Industrial Applications.
9. Included in other research elements.
10. Total spending for gas-related projects in the offices of EE, FE, ER, and IS. Excludes DOE Coal Gasification program.
11. \$163.4 million represents a total RD&D funding level that excludes technology analysis and RD&D management spending for all gas areas and the category of crosscutting research. If these categories are included, then RD&D obligations total \$192 million. If general expenses and asset purchases are added, then total obligations are \$202 million.
12. \$242 million represents a preliminary forecast number for total budget minus \$8.0 million for Coal Gasification. Total recommended budget for DOE is \$250 million.

**DOE Energy RD&D Programs
FY 1993 and FY 1994 (\$ in millions)**

RD&D Programs	FY 1993 Adj. Approps.	% of Total	FY 1994 Request	% of Total
Renewables ¹	211.8	17.1	273.3	20.6
Nuclear Energy ²	206.7	16.6	102.5	7.7
Electric Energy Systems and Storage	42.6	3.4	49.9	3.8
Petroleum ³	62.4	5.0	80.9	6.1
Natural Gas	149.6	12.1	208.9	15.7
Coal ⁴	188.7	15.2	141.3	10.6
Conservation RD&D ⁵	380.5	30.6	472.3	35.5
Total	\$1,242.3	100%	\$1,329.1	100%

1. Includes Solar, Geothermal and Hydro.
2. Includes only Nuclear RD&D. Excludes Advanced Radioisotope, Space Reactor, Space Exploration and Program Direction.
3. Excludes Strategic Petroleum Reserve (SPR), and Naval Petroleum Reserve (NPR).
4. Includes Coal RD&D only.
5. Excludes policy and management, and grants.

**DOE Fossil Fuel RD&D Program
Spending - FY 1993 and 1994
Program Balance**

**FY 1993 RD&D APPROPRIATIONS
TOTAL: \$400.7 MILLION**

* No Clean Coal funding.

**FY 1994 REQUEST
TOTAL: \$431.1 MILLION**

* Clean Coal: \$250 million not added in.

**1992 FOSSIL FUEL CONSUMPTION
(EIA, 10/1993)**

**DOE Natural Gas RD&D Program
Spending - FY 1993 and 1994
Program Balance**

**FY 1993 ENERGY RD&D APPROPRIATIONS
TOTAL: \$1,242.3 MILLION**

**FY 1994 REQUEST
TOTAL: \$1,329.1 MILLION**

1. Excludes policy and management, and grants.
2. Includes Coal RD&D (No Clean Coal Demonstrations).
3. RD&D activities conducted in Offices of Fossil Energy, Energy Efficiency and Renewable Energy, and Energy Research.
4. Includes Solar, Geothermal, and Hydro.
5. Excludes Advanced Radioisotope, Space Reactor, Space Exploration and Program Direction.
6. Excludes SPR and NPR.

**Natural Gas Related RD&D Funding by DOE and
Other Federal Departments and Agencies¹
(\$ in millions)**

Department/Agency	Actual FY 1991	Actual FY 1992	Enacted FY 1993	Request FY 1994
Department of Energy (DOE)	92.700	114.200	149.600	208.900 ²
Department of Defense (DOD)	n/a ³	n/a	46.400	88.050 ⁴
Department of Transportation Office of Pipeline Safety (DOT)	0.265	0.445	0.700	0.850
Department of the Interior U.S. Geological Survey (USGS)	n/a	n/a	0.728	4.000
Department of the Interior Minerals Management Service (MMS)	n/a	0.223	0.250	0.450
Environmental Protection Agency (EPA)	n/a	n/a	7.720	1.600
General Services Administration (GSA)	1.263 ⁵	27.730 ⁵	24.256 ⁵	1.693 ⁵
National Oceanic and Atmospheric Administration (NOAA)	0.060	0.060	0.060	0.060
Total	94.288	142.658 (+51%)	229.714 (+61%)	305.603 (+33%)

1. See Appendix C for details.

2. FY 1994 Appropriation is \$203.8 million.

3. Not available.

4. Conference Budget is \$65.9 million.

5. Alternative fuel vehicle acquisition funding excludes DOE funding.

U.S. Natural Gas RD&D Budget¹
Estimated for FY 1993

Sectors	\$ Millions	% of Total
Producers	\$180-230	23-25
Service Companies	\$90-120	11.4-13
LDCs/Pipelines	\$40-50	5
Manufacturers	\$80-120	10-13
GRI	\$163 ²	21-18
Other Associations	\$5-10	0.6-1
Federal Government	\$230 ³	29-25
Total	\$788-923	100%

1. Source of budget numbers: The National Petroleum Council, as part of its 1992 comprehensive gas study, surveyed producers, service companies, LDCs, pipelines, manufacturers, and trade associations to determine total private sector funding in the natural gas RD&D area. Source of the Federal Government and GRI numbers is the Office of Fossil Energy, Office of Oil and Gas Processing.
2. Gas Research Institute: Budget represents a total RD&D funding level that excludes technology analysis and RD&D management spending for all gas areas, and the category of crosscutting research. If these categories are included along with general expenses and capital asset purchases, then total budget obligations are \$202 million.
3. Includes DOE (\$149.6 million), DOD (\$46.4 million), and other Federal Agencies (\$33.7 million).

4.0 MULTI-YEAR PROGRAM CROSSCUT PLAN

4.0 MULTI-YEAR PROGRAM CROSSCUT PLAN

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ABBREVIATIONS

ADL	Arthur D. Little, Inc.
AFV	Alternative Fuel Vehicle
AGA	American Gas Association
AGM	Advanced Glass Melters
AMFA	Alternative Motor Fuels Act of 1988
ANL	Argonne National Laboratory
ARCS	Advanced Radiant Combustion Systems
AR&TD	Advanced Research and Technology Development
ATS	Advance Turbine Systems
Bartlesville	Bartlesville Project Office (DOE)
BAT	Best Available Technology
Bcf	Billion Cubic Feet
BEG	Texas Bureau of Economic Geology
BERL	Burner Engineering Research Laboratory
BNL	Brookhaven National Laboratory
Btu	British Thermal Unit
C-H	Carbon-Hydrogen
CAAA	Clean Air Act Amendments of 1990
CADDET	Center for Analysis Dissemination and Demonstration of Energy Technologies
CAFE	Corporate Average Fuel Economy
CFCs	Chlorofluorocarbons
CFCC	Continuous Fiber Ceramic Composites
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
COP	Coefficient of Performance
CRADA	Cooperative Research and Development Agreement
CWA	Clean Water Act of 1972
Defense	Department of Defense
DCS	Drilling, Completion, and Stimulation
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
DSM	Demand-Side Management
EE	Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
Energy Efficiency	Office of Energy Efficiency and Renewable Energy
Energy Research	Office of Energy Research
ENRIMS	Energy and Natural Gas Resource Information Management System
EOC	Emergency Operations Center (DOE)
EPA	Environmental Protection Agency

ABBREVIATIONS (CONTINUED)

EPACT	Energy Policy Act of 1992
EPRI	Electric Power Research Institute
ER	Office of Energy Research
EV	Electric Vehicle
FCVs	Fuel Cell Vehicles
FE	Office of Fossil Energy
FERC	Federal Energy Regulatory Commission
FFCF	Fracturing Fluid Characterization Facility
Fossil Energy	Office of Fossil Energy
FTA	Federal Transit Administration (DOT)
FY	Fiscal Year
GASIS	Gas Information System
GEC	Geoscience Electronics Corporation
GGRB	Greater Green River Basin
GIS	Geographic Information System
GM	General Motors Corporation
GNP	Gross National Product
GRI	Gas Research Institute
GSA	General Services Administration
GSAM	Gas Systems Analysis Model
HHV	Higher Heating Value
HV	Hybrid Vehicle
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
IGT	Institute of Gas Technology
INEL	Idaho National Engineering Laboratory
IRP	Integrated Resource Planning
IS	Office of Intelligence and National Security
kW	Kilowatt
LBL	Lawrence Berkeley Laboratory
LDC	Local Distribution Company
LHV	Lower Heating Value
LLNL	Lawrence Livermore National Laboratory
LNG	Liquefied Natural Gas
LQNG	Low Quality Natural Gas
M-Sites	Multi-Site Projects
Mcf	Thousand Cubic Feet
MCFC	Molten Carbonate Fuel Cell
MIT	Massachusetts Institute of Technology
MITI	Ministry of International Trade and Industry (Japan)
MMBtu	Million British Thermal Unit

ABBREVIATIONS (CONTINUED)

MMS	Minerals Management Service (DOI)
Morgantown	Morgantown Energy Technology Center (DOE)
MSW	Municipal Solid Waste
MW	Megawatt
MWD	Measurement-While-Drilling
MWX	Multi-Well Experiment Test Site
NARUC	National Association of Regulatory Utility Commissioners
NASA	National Aeronautics and Space Administration
NDE	Nondestructive Evaluation
NEPA	National Environmental Policy Act
NGV	Natural Gas Vehicle
NIPER	National Institute for Petroleum Energy Research
NIST	National Institute of Standards and Technology
NORM	Naturally Occurring Radioactive Material
NO _x	Nitrogen Oxides
NPC	National Petroleum Council
NRC	National Research Council
NREL	National Renewable Energy Laboratory
OBES	Office of Basic Sciences (ER)
OIT	Office of Industrial Technology (EE)
Order 636	FERC Order No. 636
ORNL	Oak Ridge National Laboratory
PAFC	Phosphoric Acid Fuel Cell
PC	Personal Computer
PEM	Proton Exchange Membrane
PEFC	Polymer Electrolyte Fuel Cell
PERF	Petroleum Environmental Research Forum
Pittsburgh	Pittsburgh Energy Technology Center (DOE)
ppm	Parts Per Million
PRDA	Program Research and Development Announcement
psig	Pounds Per Square Inch Gauge
PUC	Public Utility Commission
RCRA	Resource Conservation and Recovery Act of 1976
RD&D	Research, Development and Demonstration
RFP	Request for Proposal
RGR	Rapid Glass Refining
SBIR	Small Business Innovative Research
Scf	Standard Cubic Feet
SDWA	Safe Drinking Water Act of 1984
SFE	Stage Field Experiments
SGR	Secondary Gas Recovery

ABBREVIATIONS (CONTINUED)

SNL	Sandia National Laboratories
SO ₂	Sulfur Dioxide
SOFC	Solid Oxide Fuel Cell
SPE	Society of Petroleum Engineers
TAHP	Thermally Activated Heat Pump
TBD	To Be Determined
Tcf	Trillion Cubic Feet
3-D	Three-Dimensional
UO	University of Oklahoma
U.S.	United States
USGS	United States Geological Survey (DOI)
WVU	West Virginia University

4.1 RESOURCE AND EXTRACTION AREA

4.1 RESOURCE AND EXTRACTION AREA

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OFFICES: FE: FOSSIL ENERGY

ER: ENERGY RESEARCH

4.1 RESOURCE AND EXTRACTION AREA

AREA SUMMARY

Mission

The United States (U.S.) Department of Energy's (DOE) mission is to enhance energy security, environmental quality, and economic strength by ensuring an adequate natural gas supply. This mission will be accomplished through research, development and demonstration (RD&D) activities aimed at developing improved gas supply technologies and systems that have commercialization potential. Confidence in long-term gas supply will be restored and maintained by sponsoring and conducting, in conjunction with industry, integrated projects to support: (1) cost-effective development of resources found in low permeability formations; (2) transfer of nonproprietary data and modeling capability; and (3) continuous development of improved supply technologies for all natural gas resources.

Mandates

External mandates for the DOE Resource and Extraction RD&D Program include the Resource Conservation and Recovery Act of 1976 (RCRA), the Clean Water Act of 1972 (CWA), 1993 Appropriations Act for Interior and Related Agencies, the Energy Policy Act of 1992 (EPACT), and the Clean Air Act Amendments of 1990 (CAAA) (P.L. 102-154). Internal mandates include Administration policy guidance and the Secretary of Energy Notice, SEN-25A-91.

Program Relationships

A major source of RD&D funding for natural gas supply in the private sector is the Gas Research Institute (GRI). This organization achieves wide industry participation in its program through a series of technical advisory groups, comprised of industry experts who provide advice on industry needs and priorities, and cost-sharing for particular projects. Based upon this guidance, GRI produces an annual program plan and a five-year RD&D plan including budget requirements, both of which require review and approval by Federal Energy Regulatory Commission (FERC).

It is the intent of DOE that its Resource and Extraction Program be fully integrated with GRI's supply research program. Cooperation is maintained between DOE and GRI regarding their respective programs supporting gas technology development, demonstration, and commercialization. This exchange of information avoids redundancy, benefits program synergism, secures appropriate cofunding of projects, and leverages funding for DOE, GRI, and the individual gas industry companies. The principal responsibility for research in resource and extraction falls within the Office of Fossil Energy (FE or Fossil Energy), under the Office of Gas and Petroleum Technology. The program is implemented by Morgantown Energy Technology Center (Morgantown). Basic science RD&D is supported by the Office of Energy Research's (ER or Energy Research) Office of Basic Sciences (OBES). OBES' Division of Engineering and Geosciences funds research in many areas including sedimentary processes, organic geochemistry, and geophysical imaging. The Office of Energy Efficiency and Renewable Energy (EE or Energy Efficiency), Geothermal Energy Program, conducts RD&D in geopressured/geothermal resources (methane dissolved in hot brine). Energy Efficiency also supports landfill gas and biomass projects.

The National Laboratories and the U.S. Geological Survey (USGS) also carry out research projects in the natural gas area; the USGS conducts resource assessments and the Laboratories conduct research primarily in the rock fracture RD&D area. The Lawrence Livermore National Laboratory (LLNL) has been active in computer simulation of hydraulic fracture growth in complex geological settings. The Sandia National Laboratories (SNL) has played a significant role in RD&D related to low permeability sandstone formations. Current efforts focus on development of methods for detection and prediction of natural fractures, and geotechnology for directional well analysis and exploiting fractured reservoirs.

Situation Analysis

Current Situation and Key Trends

Historically, natural gas resource studies have been conducted by the Federal Government, energy companies, and gas industry organizations. Past studies concluded that the amount of recoverable gas in the Lower 48 States (with existing technology) is approximately 1,000 trillion cubic feet (Tcf) (Hubbert, 1970; Fisher et al., 1988; DOE 1990). Recently, the 1992 National Petroleum Council (NPC) study, *The Potential For Natural Gas in the United States*, estimated the technically recoverable resource base at 1,295 Tcf for the Lower 48 States. This estimate includes current proven reserves, plus assessed technically recoverable resources under technology projected to be applicable by the year 2010. The disparity between early estimates and the most recent estimates is attributed to technology evolution and reduction of uncertainty. Continuing technology developments and the speculative resource base will increase the current estimates.

Advancement in gas supply technologies has and will continue to be a key factor for growth in the recoverable resource base for the Lower 48 States, resulting in reliable, cost-competitive supplies. Increasing competition and continuing low gas prices have mandated quality control and cost reduction in the exploration and production industry. According to the NPC study, drilling technology gains historically have contributed to a three percent/year cost reduction trend in drilling costs (current dollars). The application of improved geologic evaluation, subsurface imaging, improved stimulation techniques, and horizontal wells have led to more efficient exploration and production. Key technology areas in future years will include improved exploration tools, additional advances in reservoir stimulation, improved methods for detecting and producing from uncontacted portions of developed fields, and enhanced environmental compliance technologies.

Domestic natural gas is plentiful and the resource base is no longer considered a limiting factor to the expanded use of natural gas. Given the NPC resource base estimate of 1,295 Tcf, continued technology advancement will ensure that recoverable resources will be available to meet increasing demands. Natural gas is relatively inexpensive; it is environmentally less damaging than any other fossil fuel; and because we do not rely on imported gas to any significant extent, gas is not subject to disruptive events abroad. Despite these advantages, demand in the U.S. fell from over 22 Tcf per year during the peak years of the early 1970s, to a low of approximately 16 Tcf in 1986. This decline is a legacy of the curtailment years of the 1970s and is partly due to a continuing lack of confidence in the stability of future supply and price. In response to the shortages and curtailments of the mid-1970s, the Power Plant and Industrial Fuel Use Act was enacted in 1978 as part of the National Energy Plan. This act limited the use of natural gas in the power and industrial sectors. Prices for new gas increased under the Natural Gas Policy Act of 1978. This price increase prompted increased drilling activity and reserve additions. These reserve additions resulted in a gas surplus demand reduction due to increased prices, legislated restrictions on gas use, and the 1982 recession.

More recently, the natural gas market has continued to grow, sustaining an upward trend since 1986. Wellhead gas prices have increased 12 percent from 1991, to \$1.84 per thousand cubic feet (Mcf) in 1992, ending an eight-year decline in prices. Total consumption in 1992 reached 19.8 Tcf, the highest level since 1980. Successful research, development, and commercialization of end use technologies will continue to promote growth in consumption. Utilization research in such areas as high efficiency gas turbines, natural gas fuel cells for electric power generation and transportation, and conversion of vehicles to natural gas will continue to promote increased demand. The CAAA will provide a major impetus in this direction because it requires compliance with emissions limits, offering significant opportunities for increased gas use. Demand increases of four Tcf (from 19 to 23 Tcf) are envisioned by the 2000-2010 time period.

As shown in Exhibit 4-1, gas production from conventional sources, reservoirs with high porosities and permeabilities that permit economic recovery in the \$2.00 to \$2.50 per million British Thermal Unit (MMBtu) price range (1990\$), can probably be maintained at current levels for the remainder of this decade. In the mid-term period (2000-2010), supply increases above the current level will require additional gas imports and a gradually increasing contribution from gas in low permeability formations -- sandstones, shales, and coals -- that will permit economic recovery in the \$2.50 to \$4.50 per MMBtu (1990\$) price range. The existence of resource base growth limitations, such as increasingly stringent environmental regulations and leasing moratoria, will further increase the demand for contributions from low permeability formation gas. The volume of gas in this nonconventional category is enormous, but the viability of future economic recovery of this gas will rest on market and technology issues. The importance to the Nation of the projected requirement for gas production from nonconventional resources has been emphasized in the 1992 NPC Study, *The Potential For Natural Gas In the United States*. Addressing these issues will require a sustained RD&D program.

The Resource and Extraction Program has moved from a program organization which categorized projects into conventional and nonconventional research. Many of the projects are crosscutting, supporting RD&D for both conventional and nonconventional resources, thereby eliminating the need for these categories. Research efforts which crosscut conventional and nonconventional gas supplies include development of advanced extraction technologies, gas atlases, and databases. Projects targeted for development of low permeability formations focus more on technology RD&D to recover gas from nonconventional reservoirs.

DOE Position

DOE supports enlarging and stabilizing the domestic gas supply reserve base to increase public confidence in the long-term availability of affordable gas. DOE's gas program in resource and extraction research will focus on this goal during the fiscal year (FY) 1994-1999 period covered by this Plan.

The products are an integration of resource and extraction projects to provide extraction technologies which are efficient and environmentally sound, and a long-term, secure supply of competitively priced natural gas. Resource and extraction projects have been integrated into three product areas: Resource and Reserves; Drilling, Completion, and Stimulation; and Low Permeability Formations. The Resource and Reserves product includes databases and computer models to provide accurate and timely resource and reserve estimates. The Drilling, Completion, and Stimulation product consists of new or improved existing technology components for extraction of natural gas from domestic resources. The Low Permeability Formations product focuses on the integration and application of existing technologies including laboratory experimentation, computer modeling, and field-scale technology demonstrations for development of low permeability formations.

Product RD&D will provide industry, government, and academia with efficient, cost-effective systems for recovery of future domestic gas supplies. Although research related to speculative resources has not been integrated into the product framework, increasing emphasis will be placed on the projects in the mid- and long-term periods.

While long-range RD&D will be sustained in the program, emphasis will be placed on resolving key issues related to the development of near- and mid-term gas resources and recovery technologies. Emphasis will be placed on industry cost-shared projects that support the acceleration of technology RD&D and market entry. Assessment of technologies will be based on total fuel-cycle costs -- by evaluating the gas system from the wellhead to the burnertip. Performance indicators will be used to measure progress and program direction will be adjusted to ensure that objectives and goals are reached.

Exhibit 4-1. Natural Gas Supply Outlook

Note: Recoverable Resource and Import Estimates are based on the 1992 National Petroleum Council Study, The Potential for Natural Gas in the United States.

Department-Wide Program

Strategic Objectives and Strategies

Fossil Energy will continue conducting fundamental and applied RD&D in the Resource and Extraction Program Area. The objectives and strategies designed to meet the program mission, as specified in the current Strategic Plan for Natural Gas, are as follows:

Near-Term (By the Year 2000)

1. Assess the domestic resources/reserves. Complete development of a portfolio of methodologies for increasing recovery of resources in order to reduce of exploration and production costs and to upgrade low quality gas. DOE plans to:
 - a. Prepare natural gas data sets and atlases for the primary producing regions of the U.S., and develop computer models providing capability for analysis of the gas industry "system";
 - b. Develop a unique, large bench-scale physical laboratory to conduct fracture fluid rheology and treatment design tests on a custom and/or routine basis;
 - c. Perform hydraulic fracturing field research, resulting in the development of improved fracturing diagnostics, treatment design, and real-time fracturing control technology;
 - d. Develop laboratory and field-based geologic, geotechnical, and geophysical technology to detect, map, and predict natural fractures in low permeability reservoirs;
 - e. Develop new technologies, and evaluate state-of-the-art technologies for gas contaminant separation and upgrading of low quality gas;
 - f. Develop and demonstrate drilling, completion, and stimulation products related to minimum formation damage drilling and stimulation technology. Conduct projects for improving the efficiency of gas recovery from mature gas fields;
 - g. Integrate geologic and resource studies, field demonstrations and wells-of-opportunity tests, and supporting RD&D into a strategy for economical and effective development of low permeability formations;
 - h. Develop and demonstrate strategies for extracting gas from deposits where coalseams coexist with shallow, gas bearing sandstones and shales. Disseminate state-of-the-art coalseam methane recovery information to the public; and
 - i. Conduct workshops to transfer technology from RD&D programs to potential users.

Mid-Term (By the Year 2010)

1. Enable industry to supplement the U.S. conventional production and gas imports with sufficient supply from nonconventional resources (minimum of four Tcf per year), to sustain an annual supply of 23 Tcf (price range of \$2.50 - \$3.50 per MMBtu, 1990\$). DOE plans to:
 - a. Develop, demonstrate, and transfer to industry indirect methods for detection and analysis of natural fracture systems; and advanced hydraulic fracturing techniques for use in low permeability formations;
 - b. Develop, demonstrate, and transfer to industry integrated strategies for increasing the recovery

efficiency from low permeability formations located in basins providing the potential for highest supply levels;

- c. Develop, demonstrate, and transfer to industry integrated drilling, completion, and stimulation systems that are environmentally benign, nondamaging to reservoirs, and cost-competitive; and
- d. Encourage development of gas resources suited primarily for local use, including mine gas, landfill gas, and remote gas.

Key Performance Indicators

Near-Term (By the Year 2000)

- Development and transfer of three natural gas atlases and companion data management system to a minimum of 1,500 domestic users for each atlas series; and
- Levels of impact on supply availability through dissemination of knowledge, mitigation of cost increases, and improved exploration and recovery processes that allow the industry to find and produce more gas at competitive prices.

Mid-Term (By the Year 2010)

- Increase in domestic gas supply by an additional four Tcf over 1991 levels.
- Demonstration and technology transfer of advanced recovery technologies such as infill drilling; drilling, completion, stimulation systems; and low quality gas upgrading.

Program Activity Summary

The Resource and Extraction RD&D program implements strategies for the FY 1994-1999 time period, which are described below:

The program includes nine main project areas: (1) Atlas Series and Database Analysis System; (2) Fracture Technology and Diagnostics; (3) Low Quality Gas Upgrading; (4) Drilling, Completion, and Stimulation; (5) Secondary Gas Recovery; (6) Follow-Up Research per NPC Gas Study; (7) Development of Low Permeability Formations; (8) Coalseam Methane; and (9) Fundamental Geosciences Research. This combination of projects represents a significant expansion of research activities related to conventional gas extraction, and continues the transition from the previous natural gas program into the first year of the current multi-year gas program (1994-1999).

Work supporting the *Atlas Series and Database* project includes continuation of efforts to develop a gas database and atlas for the Appalachian Basin. This work is being carried out by the State Geological Surveys of West Virginia, Ohio, Pennsylvania, and Kentucky. A three-year program is underway. An oil and gas atlas covering the Northern Gulf of Mexico was initiated in 1992 and is scheduled for completion in 1996. This work is being done in coordination with Bartlesville Project Office (Bartlesville), Minerals Management Service (MMS) of the Department of the Interior (DOI), and GRI.

In 1992 and 1993, the *Gas Systems Analysis Model* (GSAM) and the *Gas Information System* (GASIS) were initiated. GSAM is intended to be a comprehensive, nonproprietary/personal computer (PC) or work station based computer model capable of assessing the impact of changes in various components of the gas system on U.S. natural gas supply and demand. GASIS will provide coordination and file management functions for the database work.

A new research area category added in FY 1993 is called *Fracture Technology and Diagnostics*. This research area comprises two subprograms or projects: Hydraulic Fracture Measurements and Natural Fracture Detection and Mapping. The Hydraulic Fracture Measurement activities will initially consist of two projects aimed at achieving a better understanding of the hydrofracturing process. The first activity at the University of Oklahoma (UO) will result in establishment of a Fracturing Fluid Characterization Facility (FFCF). The second activity consists of a series of field experiments designed to determine the geometries of induced fractures and to verify stimulation models. A key objective of the Natural Fracture Diagnostics activities is the development of techniques for prediction and detection of natural fracture systems that are essential to economic recovery of gas from otherwise impermeable formations. While progress has been made in this area of research, increased involvement of modern geophysical techniques is needed. This change in emphasis was begun in 1992, with a comprehensive seismic survey over an area well characterized by prior drilling, and will continue throughout the current plan period.

The primary purpose of the *Low Quality Gas Upgrading* project is to develop methods for low quality gas cleanup at reduced cost. Low quality refers to methane contaminated by other gases and/or water to the extent that it cannot be used without processing to remove the undesired gas or water fraction to meet pipeline specifications. About one-half of all natural gas produced in the U.S. requires processing technology for gas separation. The FY 1994-1999 program in low quality gas will focus on three topics: (1) sulfur removal; (2) membrane separation techniques; and (3) use of physical separation techniques.

The *Drilling, Completion, and Stimulation* (DCS) project represents a transition project which has been an outgrowth of the past efforts to develop air horizontal drilling technology to a more broad program encompassing drilling, completion, and stimulation technology product development. Historically, the research emphasis on this topic has been directed toward evaluation of horizontal drilling and advanced stimulation techniques for increased gas recovery from low permeability formations. New DCS systems will be economically viable, reliable, efficient, and environmentally acceptable. A balance of market pull/technology push commercialization will be incorporated in the product to ensure that the needs of the market are met while the contributions of the latest scientific breakthroughs are exploited. As operators move from better quality reservoirs to lower permeability formations, emphasis on minimum formation damage drilling and stimulation products will become increasingly important, and this project will aggressively pursue technology and product development to address these issues.

The *Secondary Gas Recovery* project began in September 1988, and is cosponsored by GRI. The goal of this multi-year project is to develop strategies for extracting a greater percentage of gas-in-place from complex, mature reservoirs. Work to date on this project has dealt primarily with sandstone reservoirs in the Gulf Coast area of Texas. Project results have been presented to industry representatives in a series of one-day workshops that began in October 1991.

Follow-Up Research per NPC Study project consists of two activities: (1) Gas Databases and Models; and (2) Natural Gas Production Reporting System Study. The first activity assesses and incorporates the data and findings developed in the NPC natural gas study into the DOE natural gas databases and models. The second activity is designed to increase consumer confidence in the availability of natural gas by providing more accurate and timely data on natural gas production at the State level. The end product will be a conceptual model of individual State gas production data collection systems and an assessment of system implementation requirements.

The *Low Permeability Formations* project represents a new, synergistic, integrated project derived from parts of the old Western Gas subprogram, and is an outgrowth of geologic and resource assessments, university and industry supporting research, and field-based production RD&D, all focused on western geologic basins. Early field RD&D successes, fully supported by laboratory and modeling research, showed that such high visibility field tests both developed production technology and stimulated local industry development of the low permeability gas resource. The product will be improved integration and application of technologies that include: (1) laboratory experimentation and computer modeling to identify barriers to higher gas recovery; and (2) concept development, design, and management of field-scale technology

demonstrations. Field demonstrations are implemented by government and industry teams with the end goal of commercializing both undeveloped and underdeveloped gas resources locked within low permeability formations. Gas recovery data, production technology, and spatial distribution of recoverable gas from low permeability sources are continually transferred to the gas industry and academic communities. This catalyzes commercial development of the target resource.

The *Coalseam Methane* project is a new program area for FY 1994, and will evaluate the potential for producing methane from coalseams that are interbedded within other low permeability gas reservoirs. DOE conducted a successful coalbed methane development program during the late 1970s and early 1980s, but focused primarily on the coalseam itself. This new effort would evaluate the more difficult challenge of developing drilling and extraction technology for gassy coalseams that are interbedded with other gas-bearing reservoirs. This is a research program authorized by EPACT.

Fundamental Geosciences Research will continue to address the following issues: stability of natural gas in the deep subsurface; rate and nature of natural gas generation from organic rich sediments; origin and development of secondary porosity; evolution of fracture systems; and geophysical imaging for characterization of reservoir and related rocks. Recent contributions that have been transferred to industry include computational models for oil and gas generation, downhole seismic sources and receivers, and nondestructive evaluation of in-situ stress determination models.

Changes from the Previous Plan

In 1993, Resource and Extraction Area projects have been combined or relocated under the Gas Program and will no longer be grouped under the Conventional, Unconventional, and Environmental/Long-Range Research categories. The Hydraulic Fracture Measurements and Natural Fracture Prediction/Detection/Mapping projects have been combined into one project, Fracture Technology and Diagnostics. The Air Drilled Horizontal Well Technology project has been expanded and is called Drilling, Completion, and Stimulation. The Second Gas Resource Study was cancelled because of the larger resource base estimate assessment being conducted by NPC in 1992. The Greater Green River Basin (GGRB) Field Test project was expanded and included in the Low Permeability Formations project. Coalseam Methane was included as a new project in FY 1994. The project description title and organization changes are given in Exhibit 4-2. Other changes include the following:

- The Resource and Extraction Program, for 1993 and beyond, will emphasize cost reduction and will complement the GRI program in its development of advanced technologies. Reductions in drilling costs will be a prime target for the Drilling, Completion, and Stimulation project.
- Secondary Gas Recovery research will shift its focus from sandstone reservoirs in Texas to both deltaic sandstone and carbonate reservoir systems in new, yet to be selected, geologic basin areas in the Mid-Continent region.
- In the Fracture Technology and Diagnostics project, the first phase of the Natural Fracture Prediction/Detection/Mapping research will progress from initial data acquisition and processing tasks to data analysis and interpretation in 1994.
- Delayed from FY 1993 startup, the focus in the Low Permeability Formations project will shift in FY 1994 from the Piceance Basin to the GGRB, in coordination with GRI.
- Beginning in FY 1993, the resource and extraction environmental research projects are incorporated into the Environmental/Regulatory Impact Area. Energy Research projects in the area of Fundamental Geoscience have been expanded in scope and funding by a number of new project starts in tomography, remote sensing, sedimentary process, and geochemistry.

Exhibit 4-2. Changes in the Resource and Extraction Program

Projects	Fiscal Year							
	1992	1993	1994	1995	1996	1997	1998	1999
Atlas Series and Database Analysis System								
Hydraulic Fracture Measurements								
Fracture Technology and Diagnostics								
Natural Fracture Prediction/Detection/Mapping								
Low Quality Gas Upgrading								
Air Drilled Horizontal Well Technology								
Drilling, Completion, and Stimulation								
Secondary Gas Recovery								
Follow-up Research per NPC Study								
Greater Green River Basin Field Test Laboratory								
Low Permeability Formations								
Gas Related ES&H Studies and Research Activities ¹								
Coalseam Methane								
Fundamental Geosciences Research								
Gas Hydrates								
Deep Sedimentary Gas								

¹ These activities will continue under Environmental/Regulatory Impact Program area

FY 1992-1994 Crosscut Budget Summary**Budget by DOE Office (\$ in millions)**

DOE Office	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Fossil Energy (FE)	11.66	13.24	16.86	15.07
Energy Research (ER)	6.41	6.70	8.70	8.70
Total DOE	18.07	19.94	25.56	23.77

Budget by Program (\$ in millions)

DOE Program	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Atlas Series and Database Analysis System (FE)	1.653	2.575	2.858	2.358
Fracture Technology and Diagnostics (FE)	3.517	5.253	3.854	4.354
Low Quality Gas Upgrading (FE)	1.908	1.512	1.157	1.157
Drilling, Completion, and Stimulation (FE)	0.975	1.041	4.367	2.867
Secondary Gas Recovery (FE)	0.526	0.964	0.963	0.963
Follow-Up Research per NPC Study (FE)				
• Gas Databases and Models	0.000	0.225	-	-
• State Reporting System Study	0.000	0.250	-	-
Low Permeability Formations (FE)	3.082	1.421	3.372	3.372
Coalseam Methane (FE)	-	-	0.289	0.000
Fundamental Geosciences Research (ER)	6.409	6.700	8.700	8.700
Total Resource and Extraction Area	18.070	19.941	25.560	23.771

ATLAS SERIES AND DATABASE ANALYSIS SYSTEM

Tactical Objective

To continue development of a natural gas atlas series and database system, in conjunction with GRI, that compiles geologically age-defined regional trends of major oil and gas reservoirs into subregional reservoir play groups. To develop a natural gas data analysis system (simulation model) and file management or database system for data integration.

Issues

The continuing decline in domestic oil production and increasing dependence on crude oil imports, combined with the potential for disruptions in petroleum supplies, emphasize the need for comprehensive analysis and assessment of national hydrocarbon resources. Such information is needed in the private sector to address investment strategies for planning exploration and development activities. In the public sector, information on the hydrocarbon resource base is required for national economic and security policy considerations.

The need for oil and gas resource atlases has increased as exploration emphasis in the Lower 48 States has shifted from frontier areas to focus on extended development of mature hydrocarbon provinces. The offshore northern Gulf of Mexico atlas series is of special interest to the oil and gas industry because more than 90 percent of all offshore oil and gas in the U.S. has been produced from the northern Gulf of Mexico region. It is estimated that the Gulf of Mexico offshore region contains 17 percent of the Nation's undiscovered conventional oil and 26 percent of the gas resources.

A database system containing information on hydrocarbon resources in the Gulf of Mexico would provide producers with information needed to more efficiently develop reservoirs, extend field limits, and better assess opportunities for intrafield exploration and development. The database system would also establish the framework for identifying future research needs. Information from the atlas series and the database system would benefit the smaller operators that are rapidly assuming ownership of marginal hydrocarbon resources in the United States.

The database system would also contain a directory of existing databases containing information relevant to the gas industry and provide communication links for effective user access to these databases.

Major Goals

- Compile comprehensive reservoir play descriptions that include descriptive and quantitative summaries of play characteristics, cumulative production, reserves, original gas-in-place, and various other engineering and geologic data;
- Classify and group gas reservoirs into a series of geologically defined reservoir plays and develop detailed summaries of representative type reservoirs for each play;
- Distribute computerized tables of reservoir engineering data in a standard geographic data format;
- Assemble reservoir play information from various U.S. basins into a computerized natural gas file management or database system;
- Develop a computerized directory that identifies existing gas databases or information centers containing data relevant to production and utilization of natural gas; and
- Develop a gas reservoir data analysis manipulation and presentation model for DOE use. The model will be generally available to other users, and will account for all gas resources.

Strategy (Total DOE FY 1994: \$2.358 Million)**Cost-Sharing Target: 28%**

This project will integrate the resources of DOE, GRI, DOI's MMS, private industry, and various State geological surveys to develop a natural gas atlas series and database/analysis system for various producing regions of the United States.

Natural Gas Atlas Series

Classification and organization of reservoirs into plays based on geological and engineering attributes, such as reservoir properties, structural style, and hydrocarbon source, have been proven to be an effective approach, as documented by two Texas atlases prepared by the Texas Bureau of Economic Geology (BEG). The gas atlases proposed here will use the same reservoir play concept. From this information, researchers will be able to group gas-bearing reservoirs into categories with similar characteristics. This knowledge would improve the chances that new or better production techniques applied successfully to one reservoir will also prove successful in other reservoirs in the same category. The resulting data, including maps and tables, will be published and made available to industry. The following gas atlases are being developed:

- The *Appalachian Gas Atlas* project covers seven states: Kentucky, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. Several plays will be defined in the same interval of geologic time due to changes in lateral facies and depositional environments, or in degree of structural control on gas accumulation. The Appalachian play groups have been assembled into 31 plays. The Atlas will be developed by West Virginia University and State Geological Surveys.
- The *Rocky Mountain Gas Atlas* project covers four states: Colorado, New Mexico, Utah, and Wyoming; the *Central and Eastern Gulf Coast Gas Atlas* covers four states: Alabama, Arkansas, Louisiana, and Mississippi; and the *Mid-Continent Gas Atlas* will cover three states: Arkansas, Kansas, and Oklahoma.
- The *Illinois/Michigan Gas Atlas* project will cover the four states of Illinois, Michigan, Indiana, and Western Kentucky.

Separate reservoirs sharing geologic and reservoir engineering attributes are being assigned to significant gas producing plays. This will allow these atlas users to relate reservoir engineering and production data to the geological framework and determine factors controlling the gas production from reservoirs in a play. Extrapolation of factors controlling production in major reservoirs to smaller reservoirs in a play, or to potentially significant reservoirs that have yet to be fully delineated, will help build the knowledge required to efficiently recover all potential resources.

Atlases will include compilation of geologically age-defined regional trends of major gas reservoirs into subregional reservoir play groups. Play groups are being defined on the basis of geologic attributes such as deposition setting, structural style, trapping mechanism, reservoir facies, hydrocarbon composition, production characteristics, and other engineering parameters that allow categorization of reservoirs with similar attributes.

Morgantown in-house research will include resource and reserve studies applicable to atlas development activities and involve determining that the atlases contain the types of information needed to support the gas industry and the development of the Morgantown Natural Gas Information System and Systems Analysis Model.

Natural Gas Information System and Systems Analysis Model, and Resource and Reserves Product Market Analysis

The GASIS development effort will be continued. Input from potential users will be selected to determine the components of the computerized database system, i.e., the matrix of data to be included and the format that is compatible with the simulation models used in industry. Potential users, for example, will include: Federal, State, and local agencies; university researchers; drilling contractors; consultants; and operators.

The computerized database system or GASIS will contain regional, pedigreed data sets from which natural gas atlases will be produced. These data sets will be of a consistent format for storing and transmitting data to ensure compatibility with end users' databases, statistical analysis, or simulation software. These data sets will include both the geologic characterization and engineering parameters for selected reservoirs. Data sets could be enhanced by commercial end users with their own data, if desired.

A computerized directory, also a part of GASIS, is also being developed. The directory will identify and contain information on existing databases, include information relevant to the natural gas industry, and provide communication links necessary for effective user access to these databases or information centers.

GSAM will continue to be developed. This activity involves the development of the necessary analysis tools/models to exploit the data sets developed from the atlases, to determine potential increases in reserves through the application of advanced production technologies. GSAM is a comprehensive, nonproprietary, work station based computer model capable of assessing the impact of changes in various natural gas system components on gas supply and demand in the United States. GSAM will extend the existing modeling capabilities (currently limited to low permeability sandstone formations/hydraulic fracturing only) to include conventional, nonconventional, and additional advanced extraction technologies.

GSAM will be capable of examining the technical and economic impacts of current and advanced extraction technologies, such as drilling, completion, stimulation, and gas processing, on supply and demand in the United States. The model will also have the capability to link with available computer models capable of analyzing distribution, storage, and utilization system components. Within each system component, GSAM will be comprised of modules (i.e., subroutines) that are linked together to perform all necessary calculations. Some modules will be unique to a specific system component, while other modules may be required in more than one system component. Example modules could include the following: geology, technology, costing, and economics.

GSAM will be compatible with existing gas databases and will have the flexibility to accommodate future databases. It includes an internal database to provide default values for those parameters not available in a given database. In addition, GSAM will allow the analysis of changes in regulatory, environmental, and tax policies on natural gas supply and demand; include a risk analysis capability for all system component areas; and provide a graphics capability for the analysis of all results while providing output format flexibility for post-processing with commonly available graphics or spreadsheet software.

A Resource and Reserves Product Market Analysis will be conducted to guide in the development of the atlases, GASIS, GSAM and other products such as basin analyses. These products will identify a resource and reserve potential for a given area, and provide a methodology to develop specific basin analyses and to assess natural gas resources and reserves for any given type of natural gas reservoir.

Morgantown in-house support includes resource and reserve product market analyses, GASIS and GSAM development monitoring activities.

Impact (Near- and Mid-Term)

Research results could accelerate conversion of undiscovered conventional resources and portion of the low permeability gas resources to economic reserves. In addition, speculative resources could become

the undiscovered reserves to meet future markets for natural gas. Anticipated impacts of the Natural Gas Atlas Series, GASIS and GSAM, and the Resource and Reserves Product Market Analysis include:

- Improves resource estimates: serves as a standard reference, and accurately portrays the nature and distribution of gas resources in some of the most prolific basins in the United States.
- Increases exploration and production success for gas producers: provides a comprehensive index and data reference for producers for more efficient development of reservoirs, extension of field limits, and better assessment of opportunities for intrafield exploration and development in mature gas provinces.
- Benefits small independents: helps increase exploration efforts, especially in the Gulf of Mexico. Small independents lack a large research staff and the basin-wide perspective of major integrated companies. Atlases will help independent operators by providing an integrated regional reservoir play framework throughout the Gulf of Mexico.
- Guides frontier exploration in ultra-deep water areas in the Gulf of Mexico: based on analysis of older submarine fan and slope-apron plays encountered beneath the shallower adjacent continental shelf.
- Maximizes field development efficiency: improved recovery efficiency from existing fields using current and innovative technologies.
- Provides a critical resource information base for MMS, GRI, and DOE: data can be incorporated into existing and proposed natural gas databases.
- Assists MMS: helps MMS in evaluating lease blocks and assessing bids for future offshore lease sales.
- Provides a critical resource information base for GRI and DOE: GASIS and GSAM can be utilized to provide policy information (regulatory, environmental, and tax policies on natural gas supply and demand) and RD&D planning information (extraction, distribution, storage, and utilization), as well as estimates of natural gas resources and reserves.

FY 1993 Accomplishments

- Completed the Central and Eastern Gulf Coast, Mid-Continent, and Rocky Mountain Gas Atlases.
- Continued the second year activities on development of the Appalachian Gas Atlas, including review of the initial 10 plays.
- Developed a prototype of the Gas Systems Analysis Model.
- Initiated a cost-shared cooperative agreement to develop the Oil and Gas Resource Atlas Series, Offshore Northern Gulf of Mexico.
- Initiated development of the GASIS and the GASIS users input query.

Planned Products

- Development of the Central and Eastern Gulf Coast, Mid-Continent, Rocky Mountain, Appalachian, and Illinois/Michigan Gas Atlases.
- Development of a gas database system, GASIS, containing the regional pedigreed data sets from which natural gas atlases covering the various gas producing regions of the U.S. will be produced.

- Development of a directory (part of GASIS) for the existing natural gas databases and/or information centers. The directory will contain information relevant to the gas industry and provide communication links necessary for effective user access to these databases and/or information centers.
- Development of an analytical tool, GSAM, to exploit the pedigreed data sets to determine potential increases in resources and/or reserves through application of advanced production technologies.
- Conduct of a Resource and Reserves Product Market Analysis (update periodically) to guide in the development of the atlases, GASIS and GSAM, and the various basin analyses.

Program Funding

DOE Historical Spending (\$ in millions)

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Gas Hydrates Consortium (Colorado School of Mines)	0.000	0.030	0.000	0.000
National Geoscience/Data Repository (American Geological Institute)	0.000	0.065	0.000	0.000
Appalachian Gas Atlas (WVU ¹ and State Geological Surveys)	0.928 ² (1.428)	0.734 ² (1.396)	0.511	0.511
Gulf of Mexico Gas Atlas (MMS ³ , GRI ⁴ , BEG ⁵)	0.100 ² (0.350)	0.304 ² (0.554)	0.401 ² (0.651)	0.401 ² (0.651)
Illinois/Michigan Gas Atlas (TBD ⁶)	-	-	0.500	0.000
Atlas Development Assistance (USGS ⁷)	-	0.0	0.125	0.125
Gas Systems Analysis Model (GSAM) (ICF Resources)	0.500	0.500	0.433	0.433
Gas Information System (GASIS) (Energy and Environmental Analysis, Inc.)	-	0.617	0.563	0.563
Offshore Energy Assessments (NRC ⁸ and Marine Board)	0.025	0.025	0.025	0.025
Gas Research Support (In-House)	0.100	0.300	0.300	0.300
Total DOE	1.653	2.575	2.858	2.358

¹ WVU: West Virginia University

² Bartlesville Project Office (Bartlesville) funding on the Appalachian/Gulf of Mexico Gas Atlases for FY 1992-1994: \$0.500 million/\$0.250 million, \$0.662 million/\$0.250 million, \$0/\$0.250 million, respectively. The funding amount shown in () is the total funding, Morgantown plus Bartlesville.

³ MMS: Minerals Management Service

⁴ GRI: Gas Research Institute

⁵ BEG: Texas Bureau of Economic Geology

⁶ TBD: To be determined

⁷ USGS: U.S. Geological Survey

⁸ NRC: National Research Council

Cost-Sharing (\$ in millions)

The program efforts are coordinated, and in several cases, cost-shared with USGS, MMS, GRI, State agencies, universities, and industry.

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
WVU ¹ and State Geological Surveys	Appalachian Gas Atlas	0.344	0.375	0.057
MMS ² , GRI ³ , BEG ⁴	Gulf of Mexico Gas Atlas	0.350	0.550	0.650
Total		0.694	0.925	0.707

¹ WVU: West Virginia University

² MMS: Minerals Management Service

³ GRI: Gas Research Institute

⁴ BEG: Texas Bureau of Economic Geology

Natural Gas Atlas Series

- Gulf of Mexico Region: DOE, GRI, and MMS will provide funding. The lead technical contractor is BEG.
- Appalachian Basin: WVU and State Geological Surveys are cost-sharing. Coordinated with the USGS to maximize use of available geologic data. Project coordinator is DOE/Morgantown.
- Texas, Rocky Mountains, Central and Eastern Gulf Coast, Mid-Continent Regions: GRI and State agencies are cost-sharing. Project coordinator is GRI.
- Offshore Energy Assessment Activities: DOE and other Federal Agencies will provide the funding. Project coordinator is MMS.

Natural Gas Database and Analysis Systems, and Resource and Reserve Product Market Analysis

- GASIS: Energy and Environmental Analysis, Inc., is developing GASIS. Project coordinator is DOE/Morgantown.
- GSAM: ICF Resources is developing GSAM. Project coordinator is DOE/Morgantown.
- Resource and Reserve Product Market Analysis: The contract is expected to be issued during the latter part of FY 1994. Project coordinator is DOE/Morgantown.

Flow Diagram

Projects	1994	1995	1996	1997	1998	1999
Rocky Mountain Gas Atlas (New Mexico Bureau of Mines and Mineral Resources)	T					
Appalachian Gas Atlas (WVU and State Geological Surveys)		T				
Gulf of Mexico Gas Atlas (MMS, GRI, BEG, etc.)			T			
Gas Information System (GASIS) (TBD)		P	D	D	D	T
Gas Analysis System (GSAM) (ICF Resources)	S	D	D	D	D	T
Resource/Reserve Prod. Market Analysis (TBD)		T	T	T	T	
Offshore Energy Assessment Act (Marine Board)	T	T	T	T	T	T

Coding:

T = Transfer technology or information for application

P = Achieve proof-of-concept

D = Initiate field demonstration

S = Select most promising concept for further development

FRACTURE TECHNOLOGY AND DIAGNOSTICS

Tactical Objective

To provide a semifield-scale laboratory facility, in collaboration with GRI, to measure geometries and mechanical behavior of fractures induced during hydrofracturing experiments. To measure the rheological properties of fracturing fluids in a laboratory setting, with specialized equipment.

To provide multiple field test sites, in collaboration with GRI, to conduct fracturing diagnostics research and to verify the performance of hydraulic fracturing models in a field setting.

To develop technology for detection, mapping, and prediction of naturally fractured gas reservoirs to economically recover natural gas from low permeability reservoirs.

Issues

Hydraulic fracturing to stimulate hydrocarbon flow from low permeability formations is a major oil and gas service business. It is estimated that approximately one billion dollars is spent annually, worldwide, on the application of hydraulic fracturing treatments.

Despite industry's large expenditures on hydraulic fracturing and the enormous potential resource target, much uncertainty exists concerning the actual sizes and geometries of fractures that are induced. In addition, rheologies of fluids used to apply fracturing pressure to the target reservoirs, at the temperature and pressures actually encountered, are not adequately understood. In the absence of basic measurements needed to quantify both the fracture characteristics and the physical and chemical properties of the fracturing fluids, economic failures of hydraulic fracturing treatments are rarely understood.

The domestic gas resource target of low permeability formations is very large. The 1992 NPC study has estimated a technically recoverable resource base of 141 Tcf in western basins containing such formations. Economically viable production of natural gas from low permeability reservoirs can be achieved only in zones that have been adequately fractured by geologic processes as fractures provide flow channels necessary to extract the trapped gas. The following factors are critical in exploiting such gas:

- Locations of fractured reservoirs within otherwise low permeability formations must either be predictable from geological investigations or directly detected in exploration data;
- Wellbore orientation (horizontal and high angle wells) must be designed to penetrate as many fractures as possible; and
- Methods must be applied for increasing natural fracture apertures and interconnecting linkages to the borehole by various stimulation techniques, such as hydraulic fracturing.

The desired information is not only whether fractures are present within the target reservoir formation, but also whether the fractures are of the preferred orientation and intensity. Various seismic techniques have shown promise in providing this information.

Detectable effects on a seismic wave field introduced by the presence of fractures include: (1) changes in seismic velocity; (2) shear-wave splitting (birefringence); and (3) particle motion distortion. The phenomenon of birefringence in seismic wave propagation has been known from laboratory measurements for many years, but has just begun to find its way into full-scale exploration applications. Techniques for measurement of this phenomenon, using multiple source and receiver orientations, offer a good possibility of estimating both the intensity and orientation of subsurface fracture systems.

Major Goals

- Improve understanding of the relationship between formation characteristics in low permeability gas sandstone wells, and the well specific engineering design and production performance impact of hydraulic stimulation methods;
- Develop a fracture diagnostic technique that will measure the length of induced hydraulic fractures within 25 percent accuracy at 1,000 feet;
- Develop an understanding of fracturing fluid performance under conditions representative of the downhole fracturing process. Improve current practices and the specification of new or improved fluids for cost-effective stimulation of low permeability gas sandstones; and
- Increase the efficiency of natural gas recovery from low permeability formation reservoirs by developing better techniques to detect and characterize natural fracture systems.

Strategy (Total DOE FY 1994: \$4.354 Million)**Cost-Sharing Target: 35%**

The major technical focal points for this project area will be: (1) improved technologies to identify and measure those low permeability sandstone formation characteristics that have the most influence on gas production; (2) fracturing fluid rheology RD&D; (3) improved hydraulic fracture stimulation through experimental validation of computer models, and real-time analysis and control of stimulation treatments; and (4) natural fracture detection and diagnostics methodology development to improve well productivity in low permeability gas reservoirs.

The gas-in-place resource target is comprised of the blanket type and lenticular low permeability sandstones. Secondary technical emphasis is on geologic modeling, resource characterization, detection, and description of natural fracture systems. Technical studies are designed to provide information, in order to more cost-effectively site wells and select the most productive well completion intervals.

Building on the experience gained from the Stage Field Experiments (SFE) and Multi-Well Experiment Test Site (MWX) field tests, critical field and laboratory sites will be established and tests will be conducted during 1993-1995 to achieve a greater level of scientific and operational control. In 1993, continued strong emphasis was placed on laboratory and field-based efforts to fully understand the role of fluid rheology in fracture stimulation, to achieve field verification of fracture stimulation performance, and to develop techniques for detecting and mapping natural fracture systems.

Experiments and tests will be conducted in specially designed research facilities: hydraulic fracturing test sites and a fracturing fluid characterization facility. Complementary cooperative well experiments will be conducted at varying levels of complexity and control, as required to support the development and testing of individual production strategies and technologies. Laboratory and field-based geologic, geotechnical, and geophysical research will be conducted to develop technology to detect, map, and predict naturally fractured gas reservoirs to economically recover natural gas from low permeability reservoirs.

The seismic approach to detecting natural fractures will be tested in FY 1993 and FY 1994 as part of this project. A comprehensive seismic survey will be conducted over an area that is well characterized by prior drilling. In particular, the gain in fracture detection sensitivity from added shear wave information will be tested through this experiment. A contractor has been selected to perform this work and data acquisition is scheduled for completion by the end of Summer 1994.

The work will be augmented by basic rock properties measurements (Stanford University), seismic field work and data processing and analysis [Stanford University and Lawrence Berkeley Laboratory (LBL)], and a large-scale, fracture prediction approach based on geological and geophysical principles for economical optimization of fracture detection and analysis techniques.

Impact (Near-Term)

- Improves industry fracture treatments through field tests, resulting in increased efficiency and well productivity.
- Transfers test results continuously to industry through direct industry involvement in RD&D and conventional DOE and GRI technology transfer channels. (When applied in the field, the technology will result in more efficient fracturing jobs and increased productivity of industry wells.)
- Allows placement of wells, both vertical and horizontal, in the most suitable areas for economic gas production thus increasing gas recovery efficiency. Contributes significantly to the target of an additional four Tcf per year of gas supply that is stated in both the NPC Study, *The Potential for Natural Gas in the United States*, and the DOE Strategic Plan for Natural Gas.

Impact (Mid-Term)

- Research investment by DOE, GRI, and industry to develop and construct the Fracturing Fluid Characterization Facility directly benefits industry clients, independent operators, and majors in designing and conducting hydraulic fracture treatments in gas reservoirs. (At the conclusion of the DOE project, the FFCF laboratory will be operated by a vendor as a fracturing service laboratory for industry clients.)
- Multi-Site Projects (M-Sites) research verifies hydraulic fracturing models and diagnostics for improved stimulation performance. Continually transfers developed technology to industry to improve low permeability gas sandstone production and economics.

FY 1993 Accomplishments

- Conducted shakedown testing of the FFCF high pressure cell at the University of Oklahoma. The cell is now fully operational.
- Completed test pad preparation, including installation of utility infrastructure at the Multi-Site projects.
- Received the final release of the "Fee Flap" interactive hydraulic fracturing code from LLNL.
- Completed (LBL/industry) analysis of well-to-well and vertical velocity profiles using shear waves at the Conoco field site.
- Completed (Stanford University) seismic field surveys in a fractured gas reservoir in the Powder River Basin.
- Completed (SNL) the final report on in-depth study of natural fractures for the Piceance Basin in Colorado.

Planned Products

- Hydraulic fracturing research products: available concurrently with field experiments.
- Technology transfer benefits: while the FFCF is in the shakedown and testing stages.
- A service laboratory commercially available to the industry at large: providing clients a unique, large bench-scale, physical model to conduct fracture fluid rheology and treatment design tests on a custom and/or routine basis.

- Completion of cooperative hydraulic fracturing measurement research: conducted at the FFCF of the University of Oklahoma, and at low permeability sandstone Hydraulic Fracturing M-Sites near Rifle (MWX) and Colbran (Red Mountain), both in western Colorado and operated by CER Corp.
- Improved fracturing diagnostics, treatment design, and real time fracturing control technology.

Program Funding

DOE Historical Spending (\$ in millions)

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Hydraulic Fracturing Measurements	1.823	3.353	2.313	2.813
M-Sites Field Test (CER/GRI ¹)	-	1.445	1.313	1.313
University of Oklahoma FFCF (UO ² /GRI)	1.823	1.908	1.000	1.500
Natural Fracture Detection and Mapping	1.694	1.900	1.541	1.541
Morgantown In-House	-	0.506	0.300	0.300
Heterogeneous Reservoir Definition Study (LBL ³ /Industry)	0.300	0.320	0.350	0.350
Detection, Mapping, and Analysis of Fractured Reservoirs (Industry, Coleman Research Corporation)	0.660	-	-	-
Geotechnology for Low Permeability Gas Reservoirs (SNL ⁴)	0.250	0.250	0.250	0.250
Hydrofracturing in Fractured Reservoirs (TBD ⁵)	0.220	-	-	-
Integrated Seismic Study of Naturally Fractured Low Permeability Gas Reservoirs (Stanford University)	0.264	-	-	-
Optimization of Techniques for Detection of Natural Fractures in Gas Reservoirs (TBD)	-	0.824	0.641	0.641
Total DOE	3.517	5.253	3.854	4.354

- ¹ GRI: Gas Research Institute
² UO: University of Oklahoma
³ LBL: Lawrence Berkeley Laboratory
⁴ SNL: Sandia National Laboratories
⁵ TBD: To be determined

Cost-Sharing (\$ in millions)

Performers	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
Hydraulic Fracturing Measurements				
CER/GRI	Field M-Sites Test	-	1.500	1.500
University of Oklahoma/GRI	University of Oklahoma FFCF	1.753	3.369	2.217
Total		1.753	4.869	3.717

Flow Diagram

Projects	1994	1995	1996	1997	1998	1999
Hydraulic Fracturing Measurements						
Hydraulic Fracturing	T	S	T			
Multi-Sites (HFMS)						
Fracturing Fluid Characterization Facility (FFCF)	T	T	T			
Natural Fracture Detection and Mapping						
Heterogeneous Reservoir Definition Study (LBL ¹ /Industry)			P			
Detection, Mapping, and Analysis of Fractured Reservoirs (Industry)		T				
Geotechnology for Low Permeability Gas Reservoirs (SNL ²)		T				
Hydrofracturing in Fractured Reservoirs (LLNL ³)	T					
Integrated Seismic Study of Naturally Fractured Low Permeability Gas Reservoirs (Stanford University)	P					
Validation of Fracture Diagnostics in Seismic Data (TBD ⁴)					T	
Optimization of Techniques for Detection of Natural Fractures in Gas Reservoirs - Supporting Research (TBD)						T

¹ LBL: Lawrence Berkeley Laboratory² SNL: Sandia National Laboratories³ LLNL: Lawrence Livermore National Laboratory⁴ TBD: To be determined

Coding:

S = Select most promising concept for further development

T = Transfer technology or information for application

P = Achieve proof-of-concept

LOW QUALITY GAS UPGRADING

Tactical Objective

To complete the resource estimate of low quality natural gas (LQNG) that might be recovered through advanced gas upgrading technologies when available. To conduct advanced natural gas upgrading research at both laboratory and field demonstration scales to verify promising gas upgrading technologies.

Issues

LQNG contains sufficient nonhydrocarbon gases to lower the fuel value or other qualities of the produced gas below commercial pipeline standards. There are considerable quantities of LQNG available in the U.S., but much of this natural gas cannot be produced economically. The most common nonhydrocarbon gases are nitrogen, carbon dioxide (CO₂), and hydrogen sulfide. Less frequently occurring contaminants are helium, argon, hydrogen, and oxygen.

Methods in use today for gas separation are liquefaction and distillation, absorption, adsorption, and membrane technologies. Membrane separation technologies are rapidly emerging as the economic contender, particularly for portable skid-mounted and packaged field processing units. However, the available methods are generally too costly for practical use in natural gas cleanup.

In general, utilization of LQNG will depend on the separation of hydrocarbon and nonhydrocarbon components and the overall market opportunities. For instance, nonhydrocarbon component(s) also may be marketable, e.g., nitrogen and/or carbon dioxide for enhanced oil recovery operations and hydrogen sulfide for conversion to elemental sulfur.

Consequently, LQNG is viewed as an extensive but largely under-developed energy resource. If this latent energy resource is to be exploited, markets for nonhydrocarbon components must be promoted and expanded, and more cost-effective methods of LQNG upgrading technologies must be developed.

Major Goals

Advanced gas upgrading technologies will assist in increasing the available U.S. natural gas reserves. Development of cost-effective separation processes for gas mixtures will continue to be an important issue in the gas supply RD&D picture for the foreseeable future. Processes include treating conventional and difficult to produce natural gas, separating natural gas from inert cushion gas in gas storage operations, upgrading gas to meet specific quality requirements for end-use applications, and producing synthetic natural gas. Specifically, the goals are as follows:

- **Membranes:** Conduct parallel research on novel passive and facilitated transport polymeric membrane concepts to seek increased selectivity, permeability, and long-term stability in practical operating conditions;
- **Adsorbents/Absorbents:** Conduct research to develop novel adsorbents and absorbents and evaluate them in a pressure or vacuum swing mode;
- **Hybrid Separation and other Technologies:** Identify advanced and potentially economic LQNG separation technologies (e.g., membrane adsorption), assess their feasibility, and if an economic technology is identified, develop and test a prototype system; and
- **Process and Economic Evaluations:** Conduct process and economic evaluations of these technologies to upgrade LQNG to pipeline specifications.

Strategy (Total DOE FY 1994: \$1.157 Million)**Cost-Sharing Target: 14%**

This project will integrate the resources of DOE, National Institute of Standards and Technology (NIST), GRI, and private industry to determine potentially economic LQNG upgrading technologies for single-well scale of operation. Important issues for separation technologies are: (1) cost of fuel needed to drive the separations, and the need to increase the energy efficiency of the process; and (2) high unit cost of gas conditioning if processed in scaled down quantities. There is a need to develop new separation concepts that could yield significant efficiency improvements and cost reductions, such as through research on novel membrane applications and adsorption fundamentals, as well as basic research on the thermodynamics and chemistry of natural gas mixtures.

LQNG research to advance the development of polymeric membrane materials, identifying existing novel or advanced gas separation technologies, should continue to determine technical and economic feasibility of LQNG upgrading technologies. Where feasible, demonstrate promising gas separation concepts should be further developed through applied programs in the field.

Membranes

Membranes are effective in separating CO₂ and hydrogen sulfide from mixtures containing hydrogen, carbon monoxide (CO), methane, and higher hydrocarbons. Thin, composite transport ion exchange membrane films need to be developed and characterized. Research also needs to include: (1) advanced polyimide membranes for removal of acid gases, water vapor, and nitrogen; and (2) inorganic membranes that combine small pore diameters, narrow pore size distributions, and tailored pore surface chemistries, useful for separating gases by such mechanisms as molecular sieving or pervaporation. Such studies would provide information required for design optimization of other large scale processes to remove nonhydrocarbons from natural gas, and for economic evaluation of these other processes.

Adsorbents/Absorbents

Adsorbents/absorbents research is targeted toward developing novel adsorbents and absorbents and evaluating them in a pressure, temperature, or vacuum swing mode. Such research efforts are needed for producing pipeline-specification natural gas from nitrogen contaminated natural gas at the wellhead. In one process, nitrogen would be separated from natural gas via a novel liquid absorbent. Another adsorbent/absorbent gas separation process makes use of a rotor, containing packing arranged in an annulus and a casing. Lastly, an absorbent process utilizes microbes to accelerate the redox solution reoxidation.

Hybrid Separation and Other Technologies

Hybrid separation and other technology research efforts will identify novel advanced and potentially economic LQNG separation and other technologies; determine the feasibility of innovative concepts (e.g., feasibility of upgrading and utilizing LQNG while meeting the latest environmental regulations); and, if the technology appears economical, develop the technology for field application. If the economics are robust, a prototype system should be constructed and tested at a well site. Primary consideration should be given to system applications that can be efficiently applied to a single well scale of operation.

Process and Economic Evaluations

New separation concepts that could yield significant efficiency improvements and cost reductions need to be developed, as well as basic research conducted on the thermodynamics and chemistry of natural gas mixtures. Such an effort would perform process and economic evaluations of membranes, adsorbents, absorbents, and other hybrid technologies as they apply to upgrading LQNG to pipeline specifications.

Impact (Near- and Mid-Term)

- Increases natural gas reserves: economical upgrading of currently shut-in gas adds to domestic natural gas reserves.
- Benefits small operators: LQNG upgrading technologies can help small operators in sustaining production from gas wells that may otherwise be abandoned.
- Expands opportunities for gob gas utilization: LQNG upgrading of gob gas from coal mining subsidence areas will conserve a currently wasted resource, and also serve to reduce the greenhouse effect.
- Potential to maximize field development efficiency: improved recovery efficiency from existing fields that contain pockets of contaminated gas and/or contamination from enhanced recovery technologies.

FY 1993 Accomplishments

- In the NIST project, research was initiated with the objective of combining a low temperature redox catalyst with a hydrogen sulfide selective membrane to create a composite catalytic membrane reactor to achieve pipeline quality natural gas levels of less than four parts per million (ppm). Small laboratory-scale tests were conducted and promising results were obtained and feasibility has essentially been demonstrated.
- In the Syracuse University research, experiments were completed with a ternary mixture of the acid gases and methane using a novel fluorine-containing polyimide membrane. Process design calculations indicated that cost savings of up to 35 percent may be realized by the use of the newly developed polyimide membrane in place of the currently used cellulose acetate membranes in large industrial systems.
- In the Sandia National Laboratories research, a novel two-step deposition strategy has been developed to reproducibly prepare very thin membranes which exhibit molecular sieving. For all the membranes coated with a second layer containing oligomers, the separation factor increased above the Knudsen values.
- The study on utilization of waste coal mine methane was completed. Gas enrichment proved to be the process of choice. The gas enrichment system design that is expected to be the most favorable from both technical and economic viewpoints is an integrated facility consisting of: (1) a pressure-swing adsorption or solvent absorption nitrogen rejection unit; (2) a catalytic combustion deoxygenation process; (3) an amine or membrane CO₂ removal system; and (4) a conventional dehydration unit. The economics were very good with a projected after-tax internal rate-of-return exceeding 20 percent.
- Continued two efforts in determining the economic feasibility and development of technologies for removing and/or recovering sulfur from sulfur contaminated natural gas. The first effort, by Membrane Technology and Research, Inc., utilizes a polyamide-polyether copolymer membrane system for upgrading the natural gas stream. The second effort by CNG Research Company, utilizes a three process stream, called the CFZ/CNG-Claus Process, for upgrading the natural gas stream. This process includes the Exxon Controlled Freeze Zone (CFZ) Process, the CNG Triple-Point Crystallization (TPC) Process, and the CNG-Claus High Pressure Sulfur Recovery Process. These two have demonstrated feasibility and are now in Phase II bench-scale testing.
- Continued a cooperative agreement with the Institute of Gas Technology (IGT) to evaluate high-efficiency gas-liquid contactors for natural gas processing. This effort is evaluating rotating gas-liquid contactors (Centrifugal type) for natural gas processing with primary emphasis on improving dehydration economics and an extension to acid-gas removal by expanding the current knowledge base and establishing operation reliability.

- Demonstrated in a Small Business Innovation Research Program (SBIR) that nitrogen can be separated from contaminated natural gas via a novel liquid absorbent. Bend Research demonstrated reversible nitrogen complexation by the absorbent under "pressure swing" conditions.
- Demonstrated in a SBIR study that hollow-fiber membrane modules can be used to dehydrate natural gas with minimal gas loss at pressures to 500 psig. Bend Research is currently field testing prototype modules (modules containing 10 sq. ft. of membrane) on an actual natural gas stream.

Planned Products

- Development and characterization of thin, composite enhanced transport ion exchange membrane films for removal of CO₂ and hydrogen sulfide; and conduct of field tests.
- Conduct of laboratory-scale testing of advanced polyimide membranes for separating CO₂, hydrogen sulfide, water vapor, and nitrogen from contaminated natural gas by selective permeation.
- Development of inorganic soil-gel thin film membranes that combine small pore diameters, narrow pore size distributions, and tailoring of pore surface chemistries, useful for separating gases by such mechanisms as molecular sieving or pervaporation.
- Development and demonstration of an advanced membrane gas separation technology for economic removal, recovery, and/or disposal of sulfur from sulfur contaminated natural gas, e.g., economical upgrading of the sulfur contaminated gas to pipeline specifications, and recovery and/or proper disposal of the sulfur or sulfur compounds in an environmentally acceptable manner.
- Development and demonstration of an advanced absorption gas separation technology for economical removal, recovery, and/or disposal of sulfur from sulfur contaminated natural gas; e.g., economical upgrading of the sulfur contaminated gas to pipeline specifications, and recovery and/or proper disposal of the sulfur or sulfur compounds in an environmentally acceptable manner.
- Development of a centrifugal type adsorption/absorption gas separation process for separating hydrogen sulfide and water vapor from contaminated natural gas.
- Development of an economical, efficient, novel liquid absorbent process for producing pipeline-specification natural gas from nitrogen contaminated gas at the wellhead. This absorbent will be designed to have a high affinity for nitrogen and little or no affinity for methane or any other hydrocarbon present.
- Development of an economical, efficient, and robust hollow-fiber membrane natural gas dehydration process for reproducing pipeline-specification natural gas from wellhead natural gas. This membrane will be designed to reduce methane losses.
- Conduct of process and economic evaluations of the above and other advanced competing gas separation processes for upgrading LQNG to pipeline specifications.

Program Funding**DOE Historical Spending (\$ in millions)**

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Low Temperature Membranes for Acid Gas Removal (NIST ¹)	0.397	-	-	-
Upgrading Natural Gas via Organic Membranes (Syracuse University)	0.151	0.150	0.150	0.150
Upgrading Natural Gas via Soil-Gel Membranes (SNL ²)	0.125	0.125	0.125	0.125
LQNG Sulfur Removal/Recovery No. 1 (MTR ³ , Inc.)	0.384	0.510	0.039	0.039
LQNG Sulfur Removal/Recovery No. 2 (CNG Research Company)	0.159	0.000	0.504	0.504
Upgrading Natural Gas via Rotating Contactors (IGT ⁴ , GRI ⁵)	0.603	0.577	0.139	0.139
Gob Gas and Coal Mine Methane Utilization (Resource Enterprises, Inc.)	0.089	-	-	-
Microbial Redox Reoxidation (Texas A&M)	0.000	0.000	0.050	0.050
Gas Research Support (In-House)	-	0.150	0.150	0.150
Total DOE	1.908	1.512	1.157	1.157

¹ NIST: National Institute of Standards and Technology² SNL: Sandia National Laboratories³ MTR: Membrane Technology and Research Inc.⁴ IGT: Institute of Gas Technology⁵ GRI: Gas Research Institute**Cost-Sharing (\$ in millions)**

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
Syracuse University	Upgrading Natural Gas via Membranes	0.020	0.020	0.020
CNG Research Company	Sulfur Removal/Recovery No. 2	0.019	0.045	0.019
IGT & GRI	Rotating Contactor Upgrading	0.534	0.511	0.123
Resource Enterprises, Inc.	Utilizing Gob Gas and Coal Mine Gas	0.011	-	-
Total		0.584	0.576	0.162

The following efforts are coordinated, and in several cases cost-shared, with GRI, universities, and industry.

- Thin composite films of enhanced transport ion exchange membranes for removal of acid gases, and low temperature hydrogen sulfide separation process using membrane reactor with redox catalyst (FY 1990-1994): NIST will cost-share. Project coordinator is DOE/Morgantown.
- Upgrade natural gas via membrane separation processes (FY 1991-1996): Syracuse University will cost-share. Project coordinator is DOE/Morgantown.
- Inorganic polymer derived gas separation semi-rigid membranes (FY 1991-1996): Joint DOE and GRI funding. Project coordination is through DOE/Morgantown and GRI.
- LQNG sulfur removal/recovery No. 1 (FY 1992-1995): DOE funding is \$0.933 million. Project coordinator is DOE/Morgantown.
- LQNG sulfur removal/recovery No. 2 (FY 1992-1995): CNG Research Company will cost-share. Project coordinator is DOE/Morgantown.
- Evaluate high efficiency gas-liquid contactors for natural gas processing (FY 1992-1994): Joint DOE and GRI funding. Project coordination is through DOE/Morgantown and GRI.
- Develop hollow-fiber membrane modules for the dehydration/purification of natural gas (FY 1992-1994): DOE funding is \$0.550 million for Phases I and II.
- Demonstrate an advanced gas separation technology for economic removal, recovery, and/or disposal of sulfur from sulfur contaminated natural gas, Phase III (FY 1996-1999): Joint DOE and industry funding. Project coordination is through DOE/Morgantown.
- Evaluate the utilization of microbes to accelerate the reoxidation of redox solutions such as LO-CAT and Sulferox (FY 1994-1998): Joint DOE and GRI funding. Project coordination is through DOE/Morgantown and GRI.
- Develop a nitrogen removal technology from nitrogen contaminated natural gas with economics improved by 50 to 100 percent over conventional cryogenic technology (FY 1995-1999): Project coordinator is DOE/Morgantown.
- Demonstrate an advanced hybrid gas separation technology for economic removal and recovery of sour or acid gas to pipeline specifications in a single or near-single pass (FY 1996-1999): Project coordinator is DOE/Morgantown.

Flow Diagram

Projects	1994	1995	1996	1997	1998	1999
Low Temperature Membranes for Acid Gas Removal	<u>P/G T P/T</u>					
Upgrading Gas via Membranes	<u> T T P/T</u>					
Upgrading Gas via Soil-Gel Membranes	<u> T T P</u>					
LQNG Sulfur Removal/Recovery No. 1	<u> T S/P</u>					
LQNG Sulfur Removal/Recovery No. 2	<u> T S/P</u>					
Upgrading Gas via Rotating Contactors	<u> G P/T</u>					
Microbial Redox Reoxidation	<u> T P/T D P/T</u>					
Nitrogen Rejection, Gas Separation	<u> T S/D T T</u>					
Hollow-Fiber Membrane Gas Dehydration	<u> P</u>					
LQNG Sulfur Removal/Recovery Phase III	<u> D T P P/T</u>					
Other Advanced Hybrid Gas Separation Technologies	<u> T/G T/P/D P/T</u>					

Coding:

D = Initiate field demonstration

S = Select most promising concept for further development

G = Go/no go decision

T = Transfer technology or information for application

P = Achieve proof-of-concept

DRILLING, COMPLETION, AND STIMULATION

Tactical Objective

To develop the technology sufficient to accelerate widespread use and acceptance of drilling, completion, and stimulation products that reduce costs and minimize formation damage in selected geographic areas of low permeability gas formations in the United States. To develop products that will improve efficiency of vertically, directionally, and horizontally drilled wells in low permeability formations throughout the United States.

Issues

The majority of the traditional producer/service industry is focused on advances in drilling technology. Little is being done to develop underbalanced drilling technology such as aerated mud, foam, air mist, air, and inert/natural gas drilling technology. In addition, an increase in awareness and concern over developing methods or techniques for minimizing formation damage associated with drilling, completion, and stimulation of low permeability gas formations are expected as operators turn to developing subeconomic gas resources. Underbalanced/minimum formation damage technology for vertical, directional, and horizontal wells must be developed in order to maintain the gas reserves required for an expanding gas utilization market.

Gas deposits in subeconomic/low permeability sandstone reservoirs typically are found in onshore domestic basins containing medium and hard formations. Development of underbalanced drilling technology has, as a primary benefit, resulted in a multiple-fold increase in penetration rates, thus reducing drilling costs. As a secondary benefit, reduced formation damage may permit wells to flow without stimulation. Basins where underbalanced drilling and minimum formation damage drilling and stimulation can be used include: Appalachian, Arkoma, Anadarko, Permian, Piceance, San Juan, and Greater Green River. These basins are located in the Northeast, Mid-Continent, Greater Southwest, and Rocky Mountain areas.

As the domestic petroleum industry expands its interest in developing low permeability gas formations, the need for increased use of underbalanced drilling systems with minimal formation damage will be increasingly emphasized. Drilling contractors and engineers will become more aware of the benefits and advantages of using a minimum formation damage/underbalanced drilling systems in the successful development of low permeability gas reservoirs throughout the United States.

Major Goals

- Develop an electromagnetic MWD system to complete the commercial development of a steerable air motor horizontal drilling system;
- Accelerate the development of improvements in MWD technology in the area of near-bit sensors;
- Assist industry in the development of an integrated air motor MWD system for air drilling;
- Assist industry in the development of an integrated air percussion MWD system for air drilling in difficult drilling environments;
- Design, test, and fabricate a steerable air percussion drilling system for hard rock drilling;
- Perform system studies of air drilling technology to understand the full impact of technology development on low permeability gas formations;
- Evaluate target reservoirs for development of minimum formation damage drilling products;

- Develop slim hole drilling products to reduce risk associated with the execution of completion technology;
- Develop novel advanced drilling technology for high speed/high efficiency drilling for development of gas resources in deep, hot, or difficult formations; and
- Develop cost-effective retrofit rig components to improve overall drilling efficiency.

Strategy (Total DOE FY 1994: \$2.867 Million)

Cost-Sharing Target: 30%

Research will focus on a number of issues: (1) screen and identify target basins for DCS products development; (2) develop and field test two prototype steerable air percussion drilling systems; (3) develop near-bit sensors for underbalanced/minimum formation damage directional and horizontal drilling; (4) initiate development of new underbalanced/minimum formation damage drilling technology products; (5) initiate an advanced drilling technology feasibility/prototype development project; (6) develop and test new slim hole drilling products; (7) demonstrate integrated air motor/MWD systems in target basins; and (8) start a new drilling initiative to solve technological problems that face today's drilling industry. The program strategies include:

- Provide geological and engineering systems support for DCS related product development.
- Continue to develop new DCS products with service companies and producers.
- Initiate field tests of integrated air motor/MWD test in target basins where underbalanced/minimum formation damage drilling is applicable.
- Initiate new drilling initiative with service companies to test advanced drilling methods.
- Initiate testing of advanced stimulation methods in target low permeability basins where operator interest is high.

Impact (Near-Term)

- Removes technical barriers to the widespread use of slim hole drilling, and reduces finding costs for natural gas to levels less than \$0.50 per Mcf in selected priority basins.
- Develops an air MWD system to match an industry air motor drilling system and provides the first complete based steerable air motor horizontal drilling system.
- Develops an effective steerable air percussion drilling system enabling faster drilling in geologic areas where steerable air motor systems are less efficient. This will permit economic, development of low permeability formation gas in selected areas.
- Develops new drilling products that will reduce costs and improve efficiency of marginally economic, low permeability formation gas accumulations.

Impact (Mid-Term)

- Develops near-bit sensors for oil field drilling applications permitting the economic development of thin gas formations using long horizontal wells.
- Develops new drilling products that reduce overall drilling costs, improving competitive development of U.S. gas resources.

- Retrofits existing domestic drilling rigs with economic pulldown and pipe handling equipment, extending their competitiveness and improving drilling efficiency in the marketplace and reducing cost per foot drilling cost.

FY 1993 Accomplishments

- Completed a technology assessment of air drilling potential in the United States. Final report will be used for future strategic planning.
- Completed two additional field test using the newly designed electromagnetic MWD tools operated by Geoscience Electronics Corporation (GEC). One of the field tests demonstrated for the first time a 99-hour mean time between failure while being rotated in a vertical well.
- Fabricated a hammer testing facility at Smith International as part of the development and testing of two complete prototype steerable air percussion drilling systems to be tested in two vertical, two directional, and three horizontal wells in the U.S. over the next two years.
- NRC has completed a draft report on the Advanced Drilling Study which identifies promising advanced drilling methods for the 21st century.
- Finalized drilling plans for a 2,000-foot horizontal well demonstration with Belden & Blake in Mahoning County, Ohio.
- Stimulated two additional wells for a total of 10 wells treated with the carbon dioxide/sand fracturing technology.

Planned Products

- Near-bit sensor systems for real time drilling and reservoir information in difficult drilling environments.
- Slim hole/coil tubing products for drilling and completing cheap vertical, directional, and horizontal wells in subeconomic reservoirs.
- Newly developed advanced drilling systems having significant improvement in drilling efficiency and cost savings.
- Integrated air percussion MWD drilling system demonstrated and commercially available in all target basins.
- Integrated air motor MWD drilling system demonstrated and commercially available in all target basins.
- Cost-effective drilling rig retrofit systems for improved rotary drive and pipe handling.

Program Funding**DOE Historical Spending (\$ in millions)**

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
MWD Development for Minimum Formation Damage Drilling (GEC ¹)	0.144	-	-	-
Steerable Air Percussion Drilling System (Smith International)	0.626	0.101	0.020	0.020
Near-Bit Sensor Development (TBD ²)	-	0.129	0.300	0.296
Technology Assessment of Air Drilling Potential (GSM)	0.066	-	-	-
Horizontal Drilling Research (MEI)	-	0.011	-	-
Advanced Drilling Study (NRC)	0.030	0.000	0.200	0.200
Geologic Engineering for Air Drilling (Morgantown In-House)	0.109	-	0.400	0.400
System Study Air Drilling Potential (Morgantown In-House)	-	0.300	-	-
New Drilling and Completion Product Development (TBD)	-	0.300	0.947	1.451
New Drilling Initiative (TBD)	-	-	2.000	0.000
Integrated Air Motor/MWD Demonstration Project (TBD)	-	-	0.250	0.250
Advanced Stimulation Product Testing (TBD)	-	-	0.250	0.250
Export Initiative (K&M Engineering and Consulting Corp.)	0.000	0.200	0.000	0.000
Total DOE	0.975	1.041	4.367	2.867

¹ GEC: Geoscience Electronics Corporation² TBD: To be determined

Cost-Sharing (\$ in millions)

Performers	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
GEC	Air MWD Development	0.031	-	-
Smith Int'l	Steerable Air Percussion Drilling	0.594	0.047	-
TBD ¹	Near-Bit Sensor Development	-	0.020	0.050
TBD	Slim Hole/Coil Tubing Research	-	0.200	-
NRC/NAS	Advanced Drilling Study	-	-	-
TBD	New Drilling and Completion Product Development	-	0.100	0.233
TBD	New Drilling Initiative	-	-	1.000
TBD	Integrated Motor/MWD Demonstration	-	-	0.500
TBD	Advanced Stimulation Product Testing	-	-	0.500
Total		0.625	0.367	2.283

¹ TBD: To be determined

Flow Diagram

Projects	1994	1995	1996	1997	1998	1999
Near-Bit Sensor Development/ Demonstration Project	S	D		T		
Advanced Drilling Concept Feasibility/ Demonstration Project	S	P				D
Drilling and Completion Product Development and Demonstration Project	S	P				D
Integrated Air Percussion MWD Drilling System Demonstrations (New basins)	P	D				T
Integrated Air Motor MWD Drilling System Demonstrations (New basins)		D				T
Slim Hole/Coil Tubing Product Development Project	S	D	T			
New Drilling Initiative with Producers/Industry	S			D		T
Advanced Stimulation Product Testing		S	P		D	T
Minimum Formation Damage Drilling System Demonstrations (Target basins)		T		S		D

Coding:

D = Initiate field demonstration

S = Select most promising concept for further development

T = Transfer technology or information for application

P = Achieve proof-of-concept

SECONDARY GAS RECOVERY

Tactical Objective

To develop a portfolio of technologies and methodologies, in coordination with GRI, with near-term potential for increasing the recovery of natural gas from known fields. Research is focused on two principal targets: (1) untapped reservoir compartments of gas within established fields; and (2) bypassed gas and partially drained zones in existing wells. The applications and assessments in this project will continue to focus on both sandstone and carbonate gas reservoirs.

Issues

There is a growing recognition within the gas industry that a smaller percentage of the gas contained in geologically complex reservoirs is being recovered than previously had been thought. According to some estimates, as much as 25 percent of the recoverable gas present in some reservoirs may not be recovered by conventional methods. It is estimated that a gas resource of over 100 Tcf may have been bypassed in the development of mature gas fields of the Lower 48 States.

Natural gas prices have been favorable to U.S. consumers in recent years, falling by more than 20 percent in the last six years. Despite falling wellhead prices and real pressures on profits, production and reserve additions have remained strong. In fact, reserve additions have closely paced production for the past decade. Much of this success can be attributed to the declining cost of oil field services, and more importantly, to improvements in infield drilling practices.

Infield reserve growth can continue to be an important source of low cost gas for the 1990s. However, further improvement of methods for reservoir definition, precision reservoir engineering, and reservoir management practices will be needed. Application of state-of-the-art techniques and development of advanced technologies, such as crosswell seismic tomography and through casing resistivity logging, will be needed to properly address these issues.

Inadequate technology transfer is a major issue in connection with the conventional gas resource. It is likely that significant increases in gas recovery can be obtained simply through a more rigorous analysis of the reservoir, followed by application of known reservoir engineering principles. Reports and workshops simply do not reach enough of the smaller operators who are in greatest need of assistance. More effective technology transfer techniques are needed.

Major Goals

- Develop improved sandstone reservoir definition, stimulation, and reservoir management techniques;
- Complement the GRI program in the development of lower cost technologies to promote gas use and its benefits to gas consumers; and
- Validate Gulf Coast Basin analysis by extrapolating the secondary gas recovery (SGR) approach to a similar basin (Mid-Continent) that contains significant sandstone and carbonate gas resources.

Strategy (Total DOE FY 1994: \$0.963 Million)

Cost-Sharing Target: 50%

The overall strategy is to conduct additional SGR studies in a basin outside the Gulf Coast of Texas by transferring results learned in the recently completed Gulf Coast basin studies. Results from a gas industry survey show that a large majority of producers targeted the Mid-Continent region as the next area to evaluate for incremental gas recovery.

This project is a continuation of field studies conducted by GRI, DOE, and BEG in Oligocene Frio reservoirs

in South Texas. Work efforts during the first four years of the project, which began in September 1988, concentrated on sandstone reservoirs in three large gas fields located in South Texas (Seeligson, McAllen Ranch, and Stratton fields) and on one gas field on the Texas upper coast (Lake Creek field). A wide variety of techniques were employed, including analysis of pressure and production data, stratigraphic analysis, formation evaluations using open-hole and cased-hole well logs, cross-well tomography, vertical seismic profiling, and three-dimensional (3-D) seismic reflection surveys.

The following are key findings to date:

- Analysis of reservoir pressure information within sandstone units indicates that reservoir compartments exist in some mature gas fields even when well spacing is less than 640 and 320 acres. For example, at McAllen Ranch, infill wells completed in 80-acres (filling gaps between existing completions) can recover up to two billion cubic feet (Bcf) per well;
- Incompletely drained compartments can contain significant gas reserves. A single well drilled in the Stratton Field in 1980 had an initial pressure of 995 psi which is less than one-half of the virgin pressure of the field. Despite the sharply reduced pressure, however, this well produced two Bcf of gas over the following ten-year period; and
- Depositional and diagenetic heterogeneities are key elements responsible for compartmentalization where incremental recovery has occurred. Variation in basin subsidence and sediment input patterns in the Mid-Continent region have contributed to significant differences in reservoir architecture relative to the Gulf Coast reservoirs. Confirmation of reservoir discontinuity by geophysical techniques will help operators identify those Mid-Continent gas fields with the greatest potential for resource appreciation. The estimated resource in the region is approximately 41 Tcf, at less than 15,000 feet in depth.

FY 1994 project activities are described below.

The Mid-Continent region includes multiple cratonic basins. Significant nonassociated gas resources are in sandstone reservoirs, mostly of Pennsylvanian age. Many of the Mid-Continent basins contain multiple plays that offer opportunities for infill reserve growth analysis of deltaic reservoir systems, with variation in depositional, tectonic, and diagenetic controls. Initial screening of potential basins and sandstone plays identified four areas in the Mid-Continent containing six different gas plays of potential interest to the SGR project.

Evaluation of depositional systems, operator activity levels, and potential cooperative partners has focused on the Fort Worth Basin and Texas-Oklahoma Panhandle areas as the best opportunities to define reserve growth potential within the Mid-Continent region. The Fort Worth Basin and Texas-Oklahoma Panhandle areas, and key deltaic gas plays within these two high priority areas, will initially be evaluated for incremental gas recovery.

FY 1992 Accomplishments

- Transferred technical results during the course of the SGR project to industry through contract technical reports, articles in technical literature, presentations with abstracts, and technology transfer workshops. Finalized five technical contract reports with a final report (in progress). Prepared a total of 44 articles and 16 abstracts.
- The most significant accomplishment in direct technology transfer has been the presentation of seven short courses in Houston, Corpus Christi, Midland, San Antonio, and New Orleans. Presented two core workshops dealing with project results in Oklahoma City and Austin. In addition, the Texas Independent Producers and Royalty Owners Association incorporated the SGR project results into an October 1992 seminar held in Austin, specifically designed to transfer reserve growth technologies to its membership. The seminar has been repeated in eight other Texas cities.

Other accomplishments during the past year include the following:

- Completed integrated studies of the Stratton field in South Texas, and compiled information collected through various field studies conducted under the project;
- Completed a series of technical reports related to analysis of the project sites studied in the Gulf Coast region; and
- Initiated extrapolation of the Gulf Coast Basin analysis to the Mid-Continent Basin which contains significant gas resources in sandstone reservoirs.

FY 1993 Accomplishments

- Completed assessment of the Gulf Coast for secondary gas recovery.

Impact (Near-Term)

- Increases recovery of natural gas from complex, mature sandstone reservoirs.

Impact (Mid-Term)

- Expands portfolio of recovery methodologies, which increases ultimate gas recovery from complex reservoirs.

Planned Products

- Topical reports.
- Technology transfer workshops.

Program Funding

DOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Secondary Gas Recovery	0.526	0.964	0.963	0.963
Total DOE	0.526	0.964	0.963	0.963

Cost-Sharing (\$ in millions)

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
GRI	Secondary Gas Recovery	2.460	1.000	1.000
State of Texas	Secondary Gas Recovery	0.340	0.190	0.190
Total		2.800	1.190	1.190

Flow Diagram

Projects	1994	1995	1996	1997	1998	1999
Field Work in First Selected Mid-Continent Reservoir	D _____ P					
Field Work in a New Reservoir		D _____ P				
Field Work in a Second New Reservoir		D _____ P				
Topical Reports			T _____ T			
Technology Transfer Workshops	T	T	T	T	T	T

Coding:

D = Initiate field demonstration

T = Transfer technology or information for application

P = Achieve proof-of-concept

FOLLOW-UP RESEARCH PER NPC GAS STUDY

I. GAS DATABASES AND MODELS

Tactical Objective

To assess and incorporate the data and findings developed in the NPC natural gas study into DOE natural gas databases and models.

Issues

As an advisory body to the Secretary of Energy, NPC conducted a comprehensive analysis of the potential for natural gas to make a larger contribution to the Nation's energy supply, and the potential barriers that could impede greater use of natural gas. NPC transmitted its report, *The Potential for Natural Gas in the United States*, to the Secretary in December 1992.

Four key findings of the study are:

- The natural gas resource base is abundant and can be produced and delivered at prices that allow both expansion of the market and continued development of the resource;
- The natural gas market is increasingly diverse with new challenges and opportunities;
- Increased reliance on competitive market forces has improved the gas industry's ability to serve customer needs in a diverse and expanding marketplace; and
- The gas industry faces significant challenges requiring proactive steps by industry and government.

In addition to the policy recommendations and directions given to DOE, the study also contained valuable data on the natural gas resource base, production technologies, transmission and storage issues, end use issues and technologies, and many other areas.

Major Goals

- Review the NPC study to determine if information and statistics developed in that work can be used to supplement DOE natural gas data systems for production, delivery, and use of natural gas.

Strategy (Total DOE FY 1994: \$0.00 Million)

Cost-Sharing Target: 30%

- Incorporate gas resource data developed during the study and related data into the development of a model of natural gas supply, transmission, and end use.
- Identify and evaluate information developed in the NPC study to determine the relevance and usefulness to DOE databases and models.
- Incorporate selected data into DOE databases/models.

Impact (Near-Term)

- Supports, in the near-term, the ongoing development of DOE databases and models concerning natural gas production, transmission, and end use.

- Takes advantage of the high quality data available from NPC to support the development of the DOE databases/models.

Impact (Mid-Term)

- Data acquired from NPC provides statistics and information that will become an integral part of DOE's gas databases and models.

FY 1993 Accomplishments

- Assessed the relevance and usefulness of the natural gas data created by the NPC study.
- Incorporated relevant data into the ongoing development of DOE's gas databases and models.

Planned Products

- The data selected from the NPC study in this effort will be part of the DOE gas databases and models currently being developed.

Program Funding

This is a one-year expenditure of funds. Cost-sharing target is 30 percent.

Flow Diagram

Not applicable.

II. NATURAL GAS PRODUCTION REPORTING SYSTEM STUDY**Tactical Objective**

To increase consumer confidence in the availability of natural gas supplies and the delivery of those supplies into the gas delivery system by providing more accurate and timely data on gas production at the State level. Most information on gas production and delivery into the interstate delivery system is gathered at the State level.

Issues

Natural gas production information is critical as more gas purchasers, who are generally unfamiliar with the gas industry, are becoming the direct buyers of natural gas. The FERC/DOE Task Force Report on natural gas deliverability stated that the present system of information gathering by States is not capable of providing timely and accurate data on gas production. Public utility regulators and the local distribution companies (LDCs) need information on the characteristics and use of gas, as well as gas producer production data. The report identified a number of concerns and issues that the Federal and State agencies and LDCs need to resolve to increase natural gas reliability. Initially, an assessment of the data collection and reporting systems needed by the States (hardware, software, and programs) is necessary.

Major Goals

Develop a conceptual model of an individual State gas production data collection system, and conduct an assessment of the requirements necessary for implementing the system in individual gas producing States.

Strategy (Total DOE FY 1994: \$0.00 Million)**Cost-Sharing: 65%**

At present, methods for collecting data vary and reporting systems are not compatible either within States or across States. Also, the systems used are often outdated. This project would build upon a conceptual design being developed for a common gas production data collection and reporting system that will be usable by all State agencies and all States. This initiative would assist States in implementing the system through acquisition of similar equipment and software. The objective is to have a single information collection point in each State and to achieve compatibility between States and the Federal Government. More accurate gas production information would then reach the marketplace in a timely fashion and would also assist the Federal Government in collecting the gas data to allow analysis of national trends. Program strategy is as follows:

- Two or more States would join in cooperatively upgrading their gas production systems to conform with the University of Oklahoma model; DOE would cofund hardware and software acquisition.
- Evaluation of the successful implementation of these initial systems would result in a plan for implementation of systems in all gas producing States. Although individual State needs are not identical, systems will be similar enough to assure complete compatibility among States.

Impact (Near-Term)

- Develops a conceptual design for a State-level gas production data gathering system.
- Develops an assessment of requirements for States to upgrade individual gas production data gathering systems.
- Promotes increased market analysis, increased natural gas use, and reduction of payments by displacing foreign oil.

Impact (Mid-Term)

- Allows major gas producing States to gather and disseminate data that is accurate and timely, providing the government and gas industry customers with the information required to plan and act with confidence.
- Creates jobs: An increase in jobs in the gas market would occur as timely and accurate information on gas production become available to allow near-term market analysis.
- Increases net domestic production: Timely, accurate data on production will facilitate increased deliverability by allowing for improved physical management of reserves, and will boost the low confidence in natural gas production capability that has limited new market opportunities.
- Reduces imported oil: Increased market penetration will directly displace oil especially in the Northeast where limited gas supply has hampered gas pipeline expansion, prevented new gas use, and resulted in the highest percentage of oil use in the Nation, most of which is imported.

FY 1993 Accomplishments

- Developed a conceptual design of a data gathering system.

Planned Products

- Development of a conceptual design of a data gathering and dissemination system for use at the individual State level.

- Assessment of individual State requirements for implementation of the conceptual model.

Program Funding

DOE Historical Spending (\$ in millions)

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Gas Databases and Models	-	0.225	-	-
University of Oklahoma State Reporting Upgrade	-	0.250	-	-
Total DOE	-	0.475	-	-

Note: FY 1994 and outyear gas deliverability projects are described in the Delivery and Storage Area section in this Plan. FY 1993 is the only year that this type of project will be included in the Resource and Extraction Area budget.

Cost-Sharing (\$ in millions)

An important activity in this effort will be the continued evaluation of opportunities for cost-sharing with industry for those extended reach drilling projects where the high cost of speculative drilling can be justified by the potential impact of the overall results.

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
USGS ¹ /GRI ²	Gas Databases and Models	0.300	0.300	
University of Oklahoma	Natural Gas Production Systems Study	-	-	
Total		0.300	0.300	1.100

¹ USGS: U.S. Geological Survey

² GRI: Gas Research Institute

Flow Diagram

Not available.

LOW PERMEABILITY FORMATIONS

Tactical Objective

To reduce the uncertainty of estimating gas in-place resources and the recoverable reserve potential in the western U.S., in partnership with industry. To develop and demonstrate efficient development strategies for low permeability gas formations, in cooperation with GRI. To demonstrate low permeability gas extraction technology in the Greater Green River Basin. To verify site selection criteria for efficient, multi-strata development of low permeability gas formations.

Issues

Total western low permeability gas-in-place resources were estimated by NPC in 1980 as 698 Tcf, with 454 Tcf identified as "maximum recoverable gas." The NPC, using 1979 data and techniques, estimated 49 Tcf in-place and 33 Tcf recoverable gas for the Piceance Basin, and 139 Tcf in place and 86 Tcf recoverable gas for the GGRB. Recent assessments given in the 1992 NPC study estimated 141 Tcf of total Rocky Mountain Foreland region technically recoverable resources in new plays. The Potential Gas Committee, using 1992 data and techniques, estimated 27 Tcf of recoverable gas in the GGRB.

In-depth resource characterization work is designed to update the earlier NPC study by defining the size and reservoir character of the natural gas resource contained in low permeability sandstones, shales, and coalseams in selected basins representative of the central Rocky Mountain low permeability gas province. Characterization of the geology and assessment of the resource base will provide information on gas reservoir rocks, trapping mechanisms, state of thermal maturation, and total low permeability gas in-place.

The production research element of the program will investigate directional drilling as a gas development alternative to conventional vertical wells. Testing will be done on emerging technology in the form of medium and short radius horizontal drilling, and its application to the mixed geology of lenticular and blanket sandstones as well as coalseams of the central Rocky Mountain basins.

Major Goals

- Estimate the reserve base of low permeability gas in the central Rocky Mountain basins, including sandstones and coals;
- Build the geologic foundation for industry use in development of low permeability formations when economic extraction technology is available;
- Encourage utilization of the available domestic energy resources by giving industry a starting point to prove commercial production;
- Boost industry confidence in the availability of technically recoverable resources with a verification of the slant well test at the Colorado multi-well site;
- Test new applications of horizontal well technology to enhance production;
- Extrapolate the results from successful field experiments in the Piceance Basin and verify the technology by conducting demonstration tests at a representative site in the GGRB;
- Integrate geologic and resource studies, field demonstrations, wells-of-opportunity tests, and supporting RD&D into a comprehensive strategy for efficient development of low permeability gas formations; transfer technology products to catalyze industry development of the low permeability gas resource; and

- Extrapolate multi-strata site selection criteria developed at the West Virginia College campus near Beckley, West Virginia, to another area to verify the low permeability gas development approach.

Strategy (Total DOE FY 1994: \$3.372 Million)

Cost-Sharing Target: 30%

Resource Characterization

Geologic characterization and multi-strata gas resource assessments of the Uinta, the GGRB, and Wind River Basins are planned. The GGRB field laboratory will be cofunded by GRI. DOE efforts in the Uinta and Wind River Basins will be coordinated with GRI low permeability gas studies in order to leverage research funds and avoid duplication of effort. The results will provide the basis for defining the recoverable gas-in-place in low permeability sandstone and coals of the western basins.

Information will be developed through contracts with State Geological Surveys or natural resource agencies in Colorado, Wyoming, and Utah, in close coordination with GRI. Building from the foundation of the USGS geologic and resource assessments for their respective States, agencies will develop methodologies to identify production "sweet spots." Reserve estimates will start with basinwide reservoir descriptions and gas-in-place assessments already provided by USGS.

Production Technology

DOE's MWX and the follow-on slant hole had a significant impact on low permeability gas development in the Piceance Basin. GRI has conducted a comprehensive SFE series in Texas and Wyoming to develop stimulation technology and to transfer that technology to industry. The project has developed a technical information base on low permeability gas production prospects, which was followed by a demonstration of an optimum development approach.

The production technology demonstration phase of the low permeability formations program in Wyoming's GGRB will include a vertical research well to characterize the reservoir section, followed by a slant or horizontal production test.

The GGRB field research activities in low permeability gas formations will include the following steps:

- Selecting a representative test site and finding an industry partner(s) for a field research program;
- Drilling and evaluating a vertical well to characterize the low permeability gas reservoir in the selected test site; and
- Drilling and evaluating reservoir production of a slant hole demonstration well, either a high angle or horizontal profile, as appropriate to the selected test site geology.

Results from the field tests will be verified and extrapolated to new areas by conducting cost-shared verification tests in cooperation with industry in wells-of-opportunity. Industry involvement in the tests will facilitate transfer of technology to operators. Research will focus first on the GGRB and will then be extrapolated to other Rocky Mountain basins.

Geotechnical Support Research

The GGRB field test will require technical support by a laboratory, and additional research on an as needed basis. Research will be topical and focused on low permeability gas reservoir engineering and well test analysis, natural fracture systems as related to test site selection and production prospects, and multi-strata completion and stimulation design and mechanics.

Impact (Near-Term)

- Builds industry producer and end user confidence in the gas production potential of western geologic basins, and in the gas-in-place resource base within low permeability sandstone and coal reservoirs. Results from previous efforts have stimulated industry interest, for example: (1) application of directional drilling technology to naturally fractured sandstone and gassy coals of the Piceance Basin; (2) technology transfer of USGS geologic characterization and gas resource assessments of the Piceance Basin and the GGRB; and (3) support of geotechnical RD&D. Some of the near-term impacts are:
 - The MWX, DOE's long-term comprehensive production technology field laboratory in the Piceance Basin, conducted extensive technology transfer to producers drilling in low permeability sandstones. The effectiveness of MWX technology transfer was shown by a correlated increase in Mesaverde low permeability gas drilling activity while the field test was in progress.
 - The Colorado slant hole completion test has been closely followed by industry, as demonstrated by many site visits by managers and technical staff from the major and independent companies, requests for information, attendance at slant hole exhibits, and requests for technical presentations. Technology transfer is also demonstrated by drilling of horizontal gas wells in the Piceance Basin by Barrett Resources, Chandler Associates, and Oryx, based on DOE's slant hole results.
 - There has been a recent upturn in exploratory and development activity in the Uinta Basin low permeability gas reservoirs, in part as the result of technology transfer of ongoing USGS geologic and reservoir characterization. This has been demonstrated by many industry visits and information requests to USGS Oil and Gas Branch in Denver.

Impact (Mid-Term)

A portion of the production and reservoir related knowledge base, along with directional drilling methods developed at the Piceance Basin's multi-well experiment and the slant hole test, will be extrapolated to the GGRB during the mid-term. DOE's site specific, in-depth production research, supported by topical geology and geotechnical research, has proven to be an effective technology transfer mechanism in the Piceance Basin. The same RD&D approach also should be successful in the GGRB. Each basin has unique geologic characteristics that require special technology and methods for efficient recovery. Technology results will be integrated into a comprehensive strategy for efficient development of low permeability gas formations. Some of the mid-term impacts are:

- Adds to the low permeability gas reserve base in the GGRB.
- Stimulates industry drilling and development in the GGRB by reducing the technical risk and cost of development.
- Benefits regional independent producers as well as major operators in encouraging and supporting development of the low permeability gas resources.

FY 1992 Accomplishments

- Completed the "Technology Extrapolation in the Piceance Basin" contract. The basin was partitioned into areas of similar low permeability gas production behavior, which then were verified by field tests in selected wells of opportunity. A final technical report was prepared.
- Compiled a "resource to reserve" reservoir/production database on the low permeability gas resources of the GGRB in Wyoming and Colorado. The computerized database is now being used to establish reservoir parameters, define recovery factors, and predict gas production. The database ultimately will be used to convert those factors into a recoverable low permeability gas reserve estimate.

- Completed production testing of the Cozzette sandstone in the horizontal leg of the slant hole test. The well produced over 150 million cubic feet of gas during the tests and showed that the horizontal completion can produce at rates five to 10 times those of conventional vertical wells. The slant hole has received wide industry attention.
- Completed a geologic reconnaissance of the GGRB in order to identify possible field sites for a projected low permeability gas field laboratory for DOE/GRI production RD&D. Four potential sites have been characterized and prioritized, and a topical report was prepared.
- Produced 13 technical papers and reports in FY 1992, by Western Gas Research, including seven papers by the Society of Petroleum Engineers (SPE) and the American Association of Petroleum Geologists, five formal published technical reports, and a comprehensive geologic guide book on the mineral and hydrocarbon resources of the Uinta Basin in Utah.

FY 1993 Accomplishments

- CER Corporation completed analysis and final reporting of the Colorado slant hole. The highly productive #1-SHCT well was given the prestigious, industry-sponsored "Best New Well" award at the 1993 "Best of the Rockies" competition.
- Coleman Research Corporation completed site selection for field test in the Uinta Basin of Utah.

Planned Products

- Characterization of the Wind River Basin geology.
- Gas-in-place resource assessment of multi-strata low permeability gas sandstones of the Uinta and Wind River Basins.
- Characterization of coal reserves and estimation of gas resource in the Greater Green River, Uinta, and Wind River Basins.
- Estimation of reserve base for low permeability gas in the Central Rocky Mountain basins, including sandstones and coals.
- Completion of geologic atlases for the Uinta and Wind River Basins that integrate all information available on low permeability gas reservoirs.
- Estimation of recoverable low permeability gas reserves in the Piceance, Uinta, Greater Green River, and Wind River Basins.
- Development of methodologies to locate and define favorable production areas within low permeability gas basins.
- Demonstration of efficient production technology for slant/horizontal drilling as a low permeability gas development strategy in the GGRB.
- Improvement of overall gas recovery from low permeability reservoirs.

Program Funding**DOE Historical Spending (\$ in millions)**

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
International Gas Conference	0.000	0.050	0.000	0.000
GGRB Field Test Demonstration (TBD ¹ /GRI ²)	-	-	1.305	1.305
GGRB Workshops/Technology Transfer (CER/GRI/TBD)	-	0.049	-	-
Efficient Development of Low Permeability Gas Formations (TBD/Industry)	-	-	-	-
Slant Hole Completion Test (CER)	1.940	0.391	0.289	0.289
Western Basins Geology/Resource Assessments (USGS ³)	0.249	0.343	0.350	0.350
Reserve Estimates in Western Basins (Scotia)	0.393	0.343	0.350	0.350
Geotechnical Project Support (Morgantown In-House)	0.500	0.098	0.500	0.500
Multi-Strata Site Selection (TBD)	-	0.147	0.578	0.578
Total DOE	3.082	1.421	3.372	3.372

¹ TBD: To be determined² GRI: Gas Research Institute³ USGS: U.S. Geological Survey**Cost-Sharing (\$ in millions)**

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
GRI/TBD	GGRB Field Test Demonstration	-	1.500	1.500
GRI	GGRB Workshops/Technology Transfer	-	0.050	-
Total		-	1.550	1.500

Coding:

D = Initiate field demonstration

G = Go/no go decision

T = Transfer technology or information for application

P = Achieve proof-of-concept

COALSEAM METHANE

Tactical Objective

To develop more effective technologies and methodologies to drain gas from coalseams and associated gas-bearing strata in both mineable and unmineable coalseams.

Issues

The Section 29 tax credit was instrumental in the development of coalbed methane by industry in the Black Warrior Basin (Alabama) and San Juan Basin (New Mexico) during the 1980s. Over 4,500 total permits were issued in Alabama since 1984, with peak years in 1989 (1,079) and 1990 (2,240). But in the first nine months of 1992, only 58 well drilling permits were issued for the Black Warrior Basin. The decline in coalbed methane drilling began in the Black Warrior Basin in 1991, with only 183 permits issued. During the last two years, many companies in Alabama and in the San Juan Basin have sold their leases and left the coalbed methane development arena. This is due largely to less-than-expected economic gas production from coalbeds. The methane gas is in place within the various coals, but the strategy and technology to recover gas from coalbeds is not readily available to industry.

Future development of coalbed methane is based on the economic viability of producing the gas. The rapid development in the late 1980s of coalbed gas suggested that the economics for success were in place. Coalbed gas has only been economic in geologically favorable areas. However, those areas are limited and are largely developed. As drilling extends beyond these areas, the economics become unfavorable, and a continued tax credit, higher wellhead prices, or improved technology/development strategies will be required to maintain development of this large gas resource in various coal basins of the United States.

Major Goals

- Develop more definitive technical and economic strategies for effective recovery, storage, and utilization of coalseam gas;
- Initiate a feasibility study emphasizing coalseam gas resources for demonstration of mineable coalseam gas utilization;
- Initiate resource and reserve studies of shallow multi-strata coalseams; and
- Initiate a feasibility study for coalseam gas use as a transportation fuel.

Strategy (Total DOE FY 1994: \$0.0 Million)

Cost-Sharing Target: 30%

DOE's role will emphasize a "systems approach" for developing the appropriate strategies and technologies required for economic gas development and utilization from mineable and unmineable coalseams. The research will focus on the complex interplay of all the geologic components comprising the coalseam gas reservoir.

DOE and industry place high priority on locating promising target coals, assessing the gas potential, and developing technology to produce the methane in high potential basins. DOE's role will be to assess geological factors, such as reservoir permeability and structure in various basins, to help design the optimal development plan for the gas resource. The application of favorable strategies could then be applied to a specific basin, which will allow for optimum coalseam gas production. DOE will complement the GRI program in the development of cost cutting technologies to mitigate low gas prices and to benefit the gas consumer.

Proposed activities for 1994 include formulating development strategies focused on locating optimum well sites, based upon geological parameters such as favorable gas-in-place resources, structure, and reservoir characteristics. Closely associated with site location will be the optimum design of production wells for coalseam gas. The evaluation of successful and marginally economic coalseam wells in several fields will be part of the research activities.

In addition, an assessment will be conducted on coalseam gas production from multiple coalseams or coalseam gas coproduced with gas from shallow gas strata. High potential areas containing large volumes of gas from shallow sandstones, shales, and coals will be located for multi-strata gas production. Due to the expiration of the Section 29 tax credit, a new emphasis needs to be focused on understanding why there is a large number of uneconomic coalbed wells. Utilization of the coalseam gas resource will also be evaluated for commercial and self-help potential. A study of the economics of gas and water production from coals will also be part of the FY 1994 activities. Key findings are as follows.

- Technology required for recovering the methane resource needs to be improved and verified in coal basins in both the west and the east. Each U.S. coal basin has a different geologic setting for consideration. Western coals, in general, are deeper, thicker, less permeable, and have unpredictable water problems;
- Eastern coals, on the other hand, are generally thinner, shallower, gassier, higher in ash and sulfur, and are permeable. These coals also have a more mature cleat system and unpredictable water production characteristics. Again, crosscutting technologies from various resources/reserves could enhance the economic viability of coalbed gas in the eastern United States; and
- Eastern coals have basin specific problems because mining technologies affect upper gas-bearing strata. Optimum well siting strategies for multiple gas strata need to be considered to improve the economics and to eliminate drilling of unnecessary wells.

FY 1992 Accomplishments

DOE's role in coalseam gas research and development during the 1980s has been low key but highly successful in sustaining efforts in which industry has expressed an interest. In-house work, and the SBIR projects involving coalbed gas, have helped to keep high visibility for many areas. Development strategies always have been a high priority for DOE.

Impact (Near-Term)

- Increases recovery of natural gas from mineable and unmineable coalseams in the United States.

Impact (Mid-Term)

- Expands validation of recovery methodologies, which will increase ultimate recovery of natural gas from coalseam gas reservoirs.

Planned Products

- Topical reports.
- Technology transfer workshops.

Program Funding**DOE Historical Spending** (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Coalseam Gas	0.0	0.0	0.289	0.0
Total DOE	0.0	0.0	0.289	0.0

Cost-Sharing (\$ in millions)

Performer	Project	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
TBD ¹	Coalseam Gas	0.0	0.0	0.100
Total		0.0	0.0	0.100

¹ TBD: To be determined**Flow Diagram**

Projects	1994	1995	1996	1997	1998	1999
Selected Economic Studies		(T)	S	(T)	T	
Multiple Gas Strata Development Strategy		D		T		
Coalseam Gas Utilization		D		D	T	
Water/Gas Production Study		D		T		
Topical Reports		T			T	T
Technology Transfer	T	T	T	T	T	T

Coding:

D = Initiate field demonstration

T = Transfer technology or information for application

S = Select most promising concept for further development

(T) = Interim technology transfer

FUNDAMENTAL GEOSCIENCES RESEARCH

Tactical Objective

To conduct fundamental studies on the origin, migration, and entrapment of natural gas for improved understanding of geologic factors controlling and limiting the availability of this resource.

Issues

This research is one facet of a broad-based geoscience research program emphasizing fluid flow (e.g., geothermal, hydrocarbon, groundwater) in porous and fractured geologic media. The issues requiring investigation include: (1) the rate and nature of natural gas and oil generation from organic rich sediments; (2) stability of natural gas in deep subsurface; (3) origin and development of secondary porosity; (4) evolution of fracture systems with particular emphasis on potential reservoir and seal rocks; and (5) geophysical imaging for characterization of reservoirs and related rocks.

Major Goals

- **Origin:** Obtain and interpret geochemical and isotopic data on the limits to oil and gas generation in deeply buried sediments during and subsequent to diagenesis;
- **Migration:** Develop basic understanding of fluid flow in porous and fractured rocks through laboratory, field, and modeling studies;
- **Entrapment:** Provide the foundation for understanding of scale-dependent reservoir heterogeneity and anisotropy;
- **Exploration:** Develop new and improved high resolution geophysical techniques and approaches for imaging subsurface fluid-bearing reservoirs; and
- **Production:** Provide new concepts and information on rock fracture and failure under in-situ conditions to improve drilling methods; develop sensor systems for geophysical imaging capability ahead of the bit as a basis for adaptive drilling.

The integrating theme is to reduce exploration and drilling costs and improve the environment through better understanding of the geologic host for the gas resource.

Strategy (Total DOE FY 1994: \$ 8.7 Million)

Cost-Sharing Target: None

The program strategy is to support fundamental research activities at the Nation's academic institutions and DOE laboratories. Much of this research is broad and generic, dealing with natural gas as one of the fluids of interest in the geologic environment. Specific research project areas related to natural gas include: origin, migration, entrapment, exploration, production, and unspecified new projects.

There are significant changes from the information provided in the previous edition of the Multi-Year Program Crosscut Plan. The greater number of topics and the increase in funding level reflect explicit addition of topics under exploration and production, listing of individual projects in a topical area rather than aggregation as done previously, and new projects started in 1992. In the previous edition, an estimate of fraction attributable specifically to natural gas was used to estimate the funding level. This year, full funding costs for each project are included. A comparable value for 1991 would be \$4.0 million, relative to the \$6.4 million in 1992.

Impact (Near-Term)

Limited impact is anticipated in the near-term due to the basic and fundamental nature of the research. However, important new insights are rapidly applied by scientists and engineers in the industry as a consequence of communication via publication in the open literature and presentations at regional, national, and international professional meetings.

Impact (Mid-Term)

Mid-term impact is well illustrated by contributions in previous years, which have been transferred to industrial organization, such as:

- Computational model for petroleum generation routinely used in industry;
- Downhole seismic sources and receivers undergoing commercialization; and
- Technique for nondestructive determination of in-situ stress commercially available.

FY 1992 Accomplishments

- Determined experimentally the pressure-volume-temperature relationships in C-O-H-N mixtures at conditions comparable to those in reservoirs.
- Concluded that rare gas isotopic composition in some reservoirs strongly suggests importance of long distance fluid transport.
- Determined experimentally the stability of aqueous acetate complexes.
- Investigated new use of synchrotron radiation to obtain pore and fracture distribution in rock samples at the microscopic scale.
- Conducted research in nonlinear seismology to provide basis for field testing and development.

Planned Products

Scientific and technical publications in professional literature, patents, and continued transfer of new technology to the private sector.

Program FundingDOE Historical Spending (\$ in millions)

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Fundamental Geosciences Research	6.409	6.700	8.700	8.700
Total DOE	6.409	6.700	8.700	8.700

Cost-Sharing

No formal cost-sharing, although many of the principal investigators participate in research funded by industry, Fossil Energy, or other Federal agencies.

Flow Diagram

Not applicable.

4.2 UTILIZATION AREA

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OFFICES: FE: FOSSIL ENERGY

ER: ENERGY RESEARCH

EE: ENERGY EFFICIENCY AND RENEWABLE ENERGY

4.2 UTILIZATION AREA

AREA SUMMARY

Mission

The mission of the Utilization Program is to encourage the Nation's economic growth and job creation, promote energy efficiency, protect human health and the environment, and enhance energy security. This will be done in conjunction with industry, private research organizations, universities, and Federal and State agencies. Progress will be achieved through projects, many of which are cost-shared and cosponsored by external customers, resulting in technology development, commercialization support, and infrastructure development for gas utilization. In particular, DOE will target opportunities to develop technology choices to generate electric power, fuel vehicles, industrial processes, cool and heat buildings, and reduce emissions of pollutants from gas use. The goal of the projects is to provide competitive, energy efficient, cost-effective means of using gas in both new and existing markets.

Mandates

The program will comply with all applicable Federal, State, and local laws and regulations, and Administration and DOE regulations and policies. It will be conducted within the guidance of Federal requirements, e.g., National Environmental Policy Act (NEPA), EPACT, CAAA, and the Alternative Motor Fuels Act of 1988 (AMFA), and Federal and DOE energy acquisition regulations.

Program Relationships

DOE's work on gas utilization must be coordinated with the efforts of our external customers, both private and public. Work is planned to complement other efforts and in many cases will be cooperatively supported by non-DOE funding organizations. These include GRI and the Electric Power Research Institute (EPRI) for utility projects. The work generally will be cost-shared by industrial participants that expect to benefit from the program results. GRI conducts a comprehensive program addressing gas utilization issues in all sectors, including electric power, industrial, transportation, residential, and commercial. The Utilization Program will be coordinated with GRI's program to incorporate GRI/industry participation and expertise, and to ensure that activities are cooperative and complementary. EPRI conducts a diverse program addressing issues of interest to member electric utilities. Like GRI, it enjoys effective industry participation in its program development and planning. EPRI's expertise covers a wide range of utility issues and technologies. In addition, government organizations other than DOE conduct programs that contribute significantly to the development of gas utilization technologies. These include the following:

Other Federal Agencies

The National Aeronautics and Space Administration (NASA), Department of Defense (Defense), and Department of Transportation (DOT) conduct natural gas RD&D activities. For example, gas turbine technology, initially developed for aircraft engines, can significantly advance the performance of gas systems in electric power applications. The Joint Services' integrated high performance turbine engine program and the Department of the Navy's intercooled recuperated turbine program will develop technology with such an application. See Appendix C for other Federal Agency programs.

State and Local Governments

Many State and local governments implement policies, programs, and regulations that directly affect gas utilization. These programs range from support for technology development (such as advanced systems for power generation) to regulations on air emissions. Several State public utility commissions (PUCs) require or encourage natural gas utilities to develop demand-side management (DSM) programs.

DSM, which includes conservation and load shaping programs, is receiving more acceptance by PUCs and utilities. DSM is part of the integrated resource planning (IRP) or least-cost planning concept, which was initially devised for the electric utility industry. The IRP process is used by PUCs and utilities in an effort to balance supply and demand options in a utility's investment plans to meet future energy needs with maximum efficiency at the lowest cost. Several States, including Nevada and Illinois, mandate integrated resource plans for natural gas utilities. Twenty-three States are at various stages of IRP development. Initial implementation has begun in California, Illinois, Maryland, Nevada, Oregon, Vermont, Washington, Wisconsin, and the District of Columbia. When compared to the electric utility industry, gas utility IRP/DSM practices are at early stages of development.

Situation Analysis

Current Situation

The natural gas market continued to expand in 1992, sustaining the upward trend evident since 1986. A much closer supply/demand balance currently exists than at any time in the last ten years. Natural gas plays a large and growing role in the total energy picture in the U.S., particularly because of its relatively low cost and clean burning characteristics. Gas provides more than one-fifth of the primary energy used in the U.S., and it is of particular importance in the residential sector where it supplies nearly half of the energy consumed in U.S. homes. Regulatory, legislative and administrative actions during 1992 and 1993 highlight the importance placed on the future role of natural gas in meeting the Nation's energy goals.

Recent technology improvements have helped to increase gas utilization; many significant advances occurred in the development of advanced gas turbines, fuel cells, and combustion technologies. In addition, industrial users with the capability to switch fuel and gas-fired cogeneration plants have increased their use of gas.

EPACT contains numerous gas-related provisions that will have significant impacts on gas use. It provides the opportunity for increased use of gas primarily in transportation and in electricity generation by nonutility power purchasers. EPACT also exempts wholesale power generators from the Public Utility Holding Company Act, which will encourage growth in gas powered electric generation plants. In addition, EPACT requires DOE to conduct RD&D programs relating to gas production and use. The Secretary is required to develop energy RD&D and commercial application plans and reports, which will be applicable to gas RD&D programs. It also contains several provisions requiring or encouraging the use of alternative fuel vehicles.

Provisions of the CAAA, requiring compliance with emissions limits, offer significant opportunities for increased natural gas use. Emission rates from gas use are the lowest of any fossil fuel, whether the emission is sulfur dioxide (SO₂), nitrogen oxides (NO_x), CO, or particulates. However, challenges will remain for increased gas use if emission standards become more stringent for NO_x (mobile and stationary sources), ammonia, and the greenhouse gas emissions, namely CO₂, methane, and chlorofluorocarbons (CFC).

Key Trends

- Energy consumption, though partially offset by conservation measures, continues to increase.
- Increasingly stringent environmental regulations encourage natural gas utilization.
- Natural gas use is affected not only by supply, availability, and reliability, but also by deliverability and availability of long-term supply contracts.
- The emergence of distributed power generation as an electricity supply strategy will encourage power production at a scale well suited to natural gas utilization.

- Various regulatory issues continue to restrict gas production, transportation, and use.
- Natural gas technologies that support expectations for increased gas utilization include high efficiency simple- and combined-cycle power plants with low NO_x combustion technology, vehicles and other engines, and fuel cells.
- Natural gas prices have been relatively low and more variable than oil prices; consequently, RD&D investment has not been stimulated.
- An increasing number of States will implement gas IRP programs.

DOE Position

DOE policy is to encourage efficient production of natural gas in an environmentally sound manner, and to remove regulatory and technical barriers to increased gas utilization and expanded markets. In particular, DOE supports the implementation of programs to address EPACT requirements. EPACT has numerous provisions to encourage the commercialization of such natural gas utilization technologies as high efficiency gas turbines for electric generation, natural gas vehicles, natural gas cooling, and natural gas fuel cells.

Key Planning Assumptions

- Continued development and commercialization of technology will reduce utilization costs and expand market opportunities, which will lead to growth in the gas industry.
- The domestic gas resource base will remain sufficient to meet projected increased demand given continued development and commercialization of end use technologies.
- Natural gas demand will increase, driven primarily by the electric generation and industrial sectors. Utilization technologies with higher efficiency and lower emissions will increase the economic and environmental benefits of gas use.
- Natural gas will maintain a competitive advantage in new markets due to its environmental advantages relative to other fossil fuels. However, environmental constraints associated with siting, permitting, and construction of facilities (storage, liquefied natural gas, pipeline projects, and power plants) likely will be more stringent. The "greenhouse" effect (CO₂ and methane emissions) will continue to be a major policy concern.
- Implementation of the CAAA and EPACT is expected to encourage gas use in the industrial, electric utility, and transportation sectors.
- Highly efficient end use gas technologies will lead to greater market penetration. Although residential and commercial market customers will increase, efficiency gains and conservation will cause consumption to decline. Natural gas will continue to face stiff competition from the electric industry.
- The demand for natural gas vehicles (NGVs) and vehicle refueling infrastructure is likely to outstrip the capacity of the industry to respond in the near-term. The increased demand will reflect increased interest in lowering vehicle emissions to meet air quality requirements.

Key Customer Considerations

A number of groups with significant interest in the success of the gas utilization program include the following:

- *Gas Producers, Pipeline Companies, LDCs:* These companies will benefit from an increased market provided by efficient, cost-effective end use technologies with low emissions.
- *Independent Power Producers, Electric Utilities, Industrial Gas Consumers:* These companies will also benefit from the development of viable, cost-competitive, advanced natural gas technologies.
- *Environmental Organizations:* These groups will continue to press for reduced environmental impacts. Development of advanced gas utilization technologies and systems will increase their view of natural gas as the fossil fuel of choice.
- *Federal, State, and Local Regulatory Agencies and Governments:* Success of the Utilization Program will provide these organizations with an increased collection of attractive options for environmental improvement. For example, the development of advanced high efficiency, environmentally benign gas turbine systems will provide reduced power plant emissions. Likewise, natural gas-fueled vehicles offer opportunities for reduced emissions.
- *Research and Educational Community:* These organizations will seek to expand Federal funding for their RD&D efforts and to participate with DOE in transferring advanced gas utilization technology to the private sector. They also will seek to train designers, users, and regulators of gas systems.
- *Equipment Vendors:* End use manufacturers are seeking to develop and sell more efficient, lower emission gas utilization technology to maintain their competitiveness in the U.S. and overseas markets.
- *Automobile Manufacturers:* The alternative fuel market will depend in a large part on the production and marketing of vehicles capable of using natural gas while meeting efficiency and emissions goals.
- *Vehicle Fleet Users:* The adoption of NGVs into private and government owned vehicle fleet operations is required to establish a natural gas market for vehicles.
- *Congress:* A credible, relevant gas utilization program will remain a major component of a viable overall gas program. Cost-shared, industry driven RD&D programs with GRI and other non-Federal sources will receive more Congressional support.

Department-Wide Program

Strategic Objectives and Strategies

Program planning and implementation for the utilization area will be in cooperation with and complementary to work efforts supported by GRI, EPRI, and other private and public organizations. DOE's program will address the following targets through the approaches shown below.

Near-Term (By the Year 2000)

1. Complete program leading to commercial offering by industry of ultra-high efficiency, environmentally superior, cost-competitive gas turbine systems for utility and industrial applications. Utility systems will have efficiency of 60 percent or greater [lower heating value (LHV)], while industrial systems will improve simple cycle efficiency by 15 percent in heat rate. Both systems will have low emissions (NO_x less than eight ppm). DOE plans to:

- a. Conduct a cost-shared RD&D program to achieve prototype demonstration of advanced gas turbine systems, for both industry and utility service;
 - b. Develop ceramic technology for high temperature gas turbines; and
 - c. Conduct cost-shared government/industry RD&D programs to improve efficiency of industrial processes in energy intensive industries such as gas chillers, heat pumps, and cogeneration.
2. Complete program leading to commercial offering by industry of economically competitive and environmentally acceptable processes for direct conversion of light hydrocarbons to transportation fuels which will be competitive with crude oil prices. DOE plans to:
 - a. Conduct a cost-shared collaborative RD&D program to achieve prototype demonstration of one or more direct conversion processes for the production of hydrocarbon transportation fuels.
 3. Complete program leading to commercialization by industry of molten carbonate and solid oxide fuel cell power plants for dispersed applications in industrial and public utility markets (U.S. and overseas). Efficiency targets are 55 to 60 percent [higher heating value (HHV)] or better for molten carbonate fuel cell (MCFC) and solid oxide fuel cell (SOFC), with both technologies cost competitive with other power technologies. DOE plans to:
 - a. Support development, integration, and scaleup of molten carbonate and solid oxide fuel cell power plants through the demonstration plant stage (with increasing levels of cost sharing).
 4. Complete a collaborative program with industry, GRI, and the gas utilities leading to market introduction in 1996 of a cost competitive, first generation advanced cycle absorption heat pump with ammonia/water as the working fluid for residential and light commercial applications. Performance targets are a coefficient of performance of 1.7 in heating and 0.8 in cooling. Cost will be competitive with standard heating, ventilation and air conditioning (HVAC) equipment and a large production volume is anticipated. DOE plans to:
 - a. Conduct an industrial cost-shared collaborative RD&D program to develop laboratory prototype units which meet cost, performance and manufacturability goals; and
 - b. Conduct a multi-unit field demonstration of production prototype units in collaboration with a major manufacturer of HVAC equipment and the gas industry.
 5. Complete program leading to commercialization in 1996, by industry, of a cost-competitive advanced cycle absorption chiller with lithium bromide/water as the working fluid for large commercial application. The target coefficient of performance is 1.6 in cooling. DOE plans to:
 - a. Conduct an industry cost-shared collaborative RD&D program to develop laboratory prototype units for evaluation and demonstration of performance, reliability and cost. Conduct a field test leading to commercial product availability.
 6. Complete an industry cost-shared program which achieves a major cost reduction of the phosphoric acid fuel cell (PAFC) and modifications for use in building cogeneration systems by 1998. The overall efficiency target is 80 percent or better in a cogeneration mode with a cost of \$1,500 per kilowatt (kW). DOE plans to:
 - a. Increase support for an industry cost-shared RD&D program to bring the cost of the PAFCs down to a market clearing price and adapt them to building applications for power and thermal loads.

7. Initiate NGV commercialization activity using the Federal fleet as the catalyst for other fleet users. By the year 2000, the Federal fleet will be acquiring 75 percent alternative fuel vehicles in its annual vehicle purchase (approximately half will be NGVs).

Mid-Term (By the Year 2010)

1. Achieve commercialization by industry of molten carbonate and solid oxide fuel cell power plants for new and repowering central power plant applications in U.S. and overseas nonutility generator and utility markets. Achieve efficiency targets of 60 percent (HHV) or better for molten carbonate fuel cell, and 55 percent (HHV) or better for solid oxide fuel cell, with both technologies cost competitive with other power technologies. DOE plans to:
 - a. Support development, integration, scaleup, and demonstration of large molten carbonate and solid oxide fuel cell power plants through the demonstration plant stage (with increasing levels of cost-sharing).
2. Complete commercialization of advanced gas turbine systems developed in the near-term that have efficiency improvements and greatly reduced emissions. DOE plans to:
 - a. Conduct a long-range RD&D program to develop gas turbine systems integrated with fuel cells; and
 - b. Conduct a basic RD&D program to improve performance of advanced gas turbine systems.
3. Improve energy efficiency in industrial processes and increase productivity in processes using gas. DOE plans to:
 - a. Conduct RD&D to establish the capability to meet CAAA environmental objectives through process technology improvements and feedstock alternatives development; and
 - b. Increase support of RD&D on equipment that will improve energy conversion efficiency, recover energy from industrial waste heat, and promote industrial cogeneration technology.
4. In conjunction with industry and GRI, develop highly efficient, thermally activated heat pumps that use natural gas to heat and cool buildings thereby, significantly increasing the use of gas to cost-effectively provide energy requirements for commercial and residential buildings. DOE plans to:
 - a. Increase support for RD&D to reduce costs and improve performance of building energy technologies;
 - b. Improve the energy efficiency of appliances by using existing authority to update efficiency standards to keep pace with new technology. The technological potential exists for energy use reductions of 50 percent in space heating and 30-40 percent in air conditioning and refrigeration. More efficient gas appliances will decrease energy costs for consumers and, thus encourage more gas use;
 - c. Complete a collaborative program with industry, GRI, and the gas utilities that results in large-scale market introduction in 2002 of a cost-competitive, second generation (HiCool) advanced cycle absorption heat pump for residential light commercial buildings in cooling dominated climates. Performance targets are a coefficient of performance of 2.0 in heating and 1.1 in cooling with a first cost consistent with large market share. Increase RD&D support to encompass critical technologies for HiCool heat pumps such as advanced cycles, new working fluids, advanced materials, simulation and control, and heat/mass transfer; and

- d. Complete a collaborative program with industry, GRI, and EPRI which achieves commercialization of proton exchange membrane (PEM) fuel cell technology for small to medium size buildings. Increase RD&D support to address building-unique technology and product requirements, including high temperature operation, integrated fuel reforming, and building thermal and electrical integration.
5. Support the development of an infrastructure to promote natural gas as a significant transportation fuel, reducing vulnerability to oil supply disruptions. DOE plans to:
 - a. Support conversion of fleets (Federal passenger automobiles, light and heavy duty trucks) to natural gas, and promote private sector investment in gas under the authority of AMFA, EPACT, and Executive Order 12844;
 - b. Promote gas vehicle penetration into the market by acquiring a significant number of light duty vehicles for Federal fleet, and supporting the bus program of the Department of Transportation's Urban Mass Transportation Administration;
 - c. Support mid- and long-term development of fuel cell technology for transportation applications. Develop the PEM fuel cell as a mid-term option for cars, vans, buses, and locomotives;
 - d. Develop ceramic component technology as a means to resolve technical issues associated with increased engine efficiency;
 - e. Support development of appropriate safety regulations related to gas utilization in transportation applications; and
 - f. Support legislation that ensures both tank safety and manufacturer flexibility for compressed natural gas (CNG) storage tanks.
6. Continue NGV commercialization activity using the Federal fleet purchases as a catalyst to develop partnerships that promote NGVs. Emphasize commercialization of dedicated NGVs compared to bi-fuel systems. The mid-term goal is to displace 30 percent of transportation petroleum consumption with alternative fuels, with natural gas as a major contributor.

Key Performance Indicators

Near-Term (By the Year 2000)

- Number of new gas technologies that have been commercialized in the industrial, transportation, buildings (residential and commercial) and electric utility sectors.
- Industrial cost participation in DOE natural gas programs.
- Commercial offering of efficient advanced gas turbines with low NO_x emissions and natural gas-fueled vehicles.
- Cost of gas technologies for power production and residential/commercial heating and cooling compared to other energy sources.

Mid-Term (By the Year 2010)

- Increase in share of primary energy markets supplied by gas achieved through increased commercialization of gas technologies.

- Energy efficiency improvements of up to 0.11 quad per year have been made through the conduct of cost-shared government/industry RD&D programs in energy intensive industry processes such as gas chillers, heat pumps, and cogeneration.
- Total fuel-cycle costs for NGVs are better measured.
- Gas IRP implemented by States.

Strategic Issues and Obstacles

- Continuing natural gas regulatory reforms, incorporating market oriented solutions, are needed or gas use will not be economically efficient or consistent with end use technology availability.
- The combination of government and private sector resources is inadequate to properly support the RD&D and commercialization of advanced gas utilization technologies.
- The cumulative impact of compliance costs associated with Federal, State, and local regulations could constrain future utilization of natural gas. Furthermore, extreme limits could eliminate gas utilization as a pollution mitigation approach.
- Market pricing of competing fossil fuels and other energy sources may not reflect the total fuel-cycle cost of their production, use, and disposal. Environmental and other social benefits of gas utilization may not be explicitly recognized in decisionmaking about competing energy supplies.
- Many customers do not have confidence in gas as a reliable, long-term energy source, and in many cases customers can find it difficult, complicated, and sometimes impossible to buy natural gas.
- If U.S. industry continues to focus primarily on short-term return-on-investment, necessary new investment in exploration, production, transmission, storage, and end use technologies will be inhibited.
- Gas technologies (e.g., chillers, fuel cells) are not being commercialized by the private sector because of higher initial costs and the absence of aggressive demonstration programs.
- New gas technologies being deployed in the market place often must meet more stringent requirements than familiar technologies; there is still a perception that new gas technology may be unsafe.

Program Activities Summary

The natural gas program consists of elements supported by Energy Efficiency, Fossil Energy, and Energy Research. The primary focus of the work is to develop advanced high efficiency, low pollution technologies for natural gas use and to overcome obstacles to their adoption. Although more detailed project summaries are presented later in this document, the following summarizes program activities:

- Advanced Turbine Systems (ATS) (Fossil Energy and Energy Efficiency) - A program has been initiated to develop advanced gas turbine systems for electric power production by utilities and nonutility generators. The systems will have ultra-high efficiency -- 60 percent or greater (LHV) for large central power applications and equivalent increases for industrial systems. They will be competitive with other technologies and have low emissions. The cost-shared program to develop these systems consists of four elements. Element I, "Innovative Cycle Development," targets the identification of high efficiency gas turbine systems that can meet ATS program goals. Element II consists of component development and prototype demonstration for utility systems, while Element III is made up of the same activity for industrial systems. RD&D on generic technology supporting the

ATS program constitutes Element IV. Work on the ATS program will be guided by a steering committee composed of representatives of Fossil Energy, Energy Efficiency, GRI, EPRI, and the Environmental Protection Agency (EPA). As the development of these systems moves toward the completion of full scale demonstration in the year 2000, it is expected that more advanced systems will be identified for even further performance improvements.

- Gas Turbines (Energy Efficiency) - These programs are modifying existing engines and developing ceramic components for stationary gas turbines. These will achieve considerable fuel savings and reduced emissions in industrial and utility applications.
- Fuel Cells (Fossil Energy and Energy Efficiency) - Fossil Energy and Energy Efficiency manage programs to develop, scaleup, and demonstrate fuel cell technologies. The Fossil Energy program is primarily concerned with development of fuel cell technology application to stationary power plants. Energy Efficiency's program primarily focuses on fuel cells use in transportation. Fuel cells also have significant potential for direct cogeneration in residential and commercial buildings. Different fuel cell types are being considered for different applications. PAFCs are being commercialized by industry for dispersed power applications. Advanced natural gas-based fuel cells (molten carbonate and solid oxide) are being developed by Fossil Energy for industrial and dispersed utility applications by the year 2000. Development of larger systems to serve central power plant applications will be completed by 2010. In the Energy Efficiency programs, polymer electrolyte and PAFC are being developed. A bus powered by a PAFC will be operated in 1994. Light duty vehicles powered with polymer electrolyte fuel cells will be tested in the late 1990s.
- Natural Gas Vehicles (Energy Efficiency) - This program is developing technologies to improve performance and decrease costs of natural gas as a transportation fuel. It also is encouraging the production of natural gas powered vehicles by supporting demonstration activities. DOE is managing three demonstration and testing projects, mandated by AMFA. In addition, the Presidential Executive Order 12844 and the Federal Fleet Conversion Task Force identify major NGV marketing initiatives of the President. DOE is implementing this initiative with the Clean Cities program. The Clean Cities program is focused on developing partnerships among Federal agency fleets, city and State fleets, and the private sector to promote concentration of alternative fuel vehicle activities.
- Gas-to-Liquids (Fossil Energy) - The Gas-to-Liquids research consists of two elements. The first element addresses direct conversion of natural gas to liquids. The second element focuses on process derived light hydrocarbons. Both elements are conducting fundamental applied research seeking to identify new process concepts, from which the most promising will be selected for subsequent development. This development will include laboratory verification, scaleup, and proof-of-concept testing at a scale sufficient to enable industry to commercialize the processes.
- Gas-Fired Heat Pumps (Energy Efficiency) - This program is developing efficient, thermally activated heat pumps that use natural gas to heat and cool buildings and to supply industrial process heating and cooling. Residential high efficiency gas furnaces, meeting requirements of the 1992 National Appliance Energy Conservation Act and advanced absorption gas-fired chillers, will be introduced to the market. Industrial sorption heat pumps will supply heat alternatively to boilers and fired heaters, and thus save energy. These heat pumps will reduce electric utility peak loads and eliminate CFC refrigerant use.
- Improved Combustion Efficiency (Energy Efficiency) - These programs will reduce natural gas combustion emissions to levels now attainable only using post combustion controls. Also, natural gas consumption in industrial processes will be reduced resulting in reduced need for electric reheat and decreased emissions of pollutants. Advanced burner systems will transfer energy to industrial processes more efficiently than conventional burners. These projects include: Rapid Glass Refining, Oxygen-Enriched Combustion, and Advanced Radiant Combustion Systems.

- Fundamental Chemical Engineering Research (Energy Research) - This program will study the biochemistry, genetics, molecular biology, and physiology of bacteria that consume or produce methane. Program work will also investigate the chemistry that underlies the catalysis of methane and the factors affecting its combustion in flames, industrial combustors, and in internal combustion engines. These analyses will lead to more efficient use of natural gas as a fuel.
- Other - Other programs included as part of the Utilization Program are described below:
 - *IRP Planning Handbook and Demand-Side Management Technology Status Report* (Energy Efficiency): These projects are directed to aid utilities in planning activities for efficient gas use. The handbook, to be prepared for State PUCs and gas utility staff, will contain specific information on the characteristics of the gas industry. The status report will contain information on the potential efficiency and costs of residential gas efficiency technologies that are being installed for utility DSM programs.
 - *Municipal Solid Waste* (Energy Efficiency): This program will demonstrate beneficial use of both municipal solid waste (MSW) and other organic wastes by converting these wastes into methane.
 - *Materials Development* (Energy Efficiency): This program will develop an industrial technology base in advanced materials for engines and will optimize the use of alternative fuels in vehicles.
 - *Electric and Hybrid Vehicles* (Energy Efficiency): This program will assist U.S. industry in developing and demonstrating the viability of a hybrid vehicle (HV) technology base, which is needed to enable the design, production, and future use of HVs as a competitive transportation alternative.
 - *International Energy Agency Center for Gas Technology Information* (Fossil Energy): This program is designed to promote the widespread commercialization of gas-related technologies by providing a continuing international forum to increase information dissemination, international cooperation, and collaboration concerning gas technologies.
- Other work performed by Fossil Energy, Energy Efficiency, and Energy Research, although not a formal part of the natural gas utilization program, may contribute to this effort. Some of the programs with a high likelihood of contribution are described below:
 - *Heat Engines Program* (Fossil Energy/Coal): Direct coal-fired gas turbines and direct coal-fired diesel engines are being developed for electric power, industrial, and transportation applications. Work under this program also addresses the combustion of low Btu gas in gas turbines that are fueled with coal gas, coupled with some work applicable to natural gas. Some technologies developed in this program have already been commercialized for natural gas applications and other contributions are expected.
 - *Advanced Combustion Program* (Fossil Energy): One of the key elements of this program is the development of indirectly fired coal systems. Much of the technology being developed would be applicable to indirectly fired (or direct fired/recuperated) natural gas systems with water or steam injection. These program elements could find direct application in the natural gas program ATS work.
 - *Gas Stream Cleanup Program* (Fossil Energy/Coal): This program is primarily targeted at cleaning hot gas streams in coal-fired gasification and combustion systems. Some results of the program could be applied directly to natural gas systems, while others could be adapted.
 - *Flue Gas Cleanup Program* (Fossil Energy/Coal): This program is concerned with cleanup of flue

gas streams from coal-fired systems. Technologies related to control of NO_x could be applied to natural gas systems.

- *Clean Coal Technology Program (Fossil Energy/Coal)*: In this program, advanced coal technologies are demonstrated at full scale in projects which are more than 50 percent cost-shared by industrial participants. Advanced systems, and components with application to natural gas as well as coal, will complete development in this program.
- *Gas-to-Liquids (Fossil Energy/Coal)*: DOE supports gas-to-liquids research and development beyond that included in the natural gas program. This work is cost-shared (including support by GRI), and addresses discovery of new chemistry and catalysts to promote chemical reactions required for conversion. There are hydrocarbon chemistry and catalysis activities in Fossil Energy's Coal Liquefaction, Surface Coal Gasification, and Advanced Extraction and Process Technology programs, all of which are seeking to discover new process concepts for other feedstocks (coal, coal-derived syngas, and petroleum). There are also biocatalysis and catalysis basic research activities conducted in the Energy Efficiency programs and in the Basic Energy Sciences program of Energy Research.
- *Biomass Thermochemical Conversion Program (Energy Efficiency)*: This program may produce results benefitting natural gas conversion systems. Also, solar thermal work such as the hybrid receiver and Stirling engine development, may enhance gas collection and conversion processes. Fuel cells can be effectively operated on this type of fuel.
- *Biomass Gasification Program (Energy Efficiency)*: In this program, technology is being developed to convert biomass to gas and liquid fuels for the production of electricity that could displace imported oil. This gas could be used in regions remote from pipeline facilities.
- *Implementation and Deployment (Energy Efficiency)*: Activities under this program will evaluate the impacts, benefits, and costs of transportation technologies; enhance scientific and engineering education related to transportation; and transfer data and technology information to industry, the scientific community, other government agencies, the educational system, and the general public.
- *Efficiency Improvement Programs (Energy Efficiency)*: Efficiency improvements for systems utilizing natural gas will have a significant impact on gas consumption. Improved efficiency will make end use systems more attractive to consumers, resulting in a net increase in gas consumption (even though individual systems use less gas).
- *Materials Programs (Energy Efficiency)*: These programs will supply basic materials technology, that will allow broad-based improvement in various types of gas utilization systems.
- Energy Research addresses fundamental chemistry, biochemistry, geoscience, and engineering research involving natural gas formation and its use. It also addresses environmental science, especially atmospheric gases. Advances from this program will provide guidance for improved technology in the utilization area, particularly in the areas of combustion and catalysis. Environmental studies will support increased gas utilization as the cleanest fossil fuel with respect to CO₂ and SO₂ emissions.

Changes from Previous Plan

Much of the natural gas utilization work in Energy Efficiency, Energy Research, and the coal portion of Fossil Energy programs has been planned and/or carried out in the past. Changes in these programs are more a matter of magnitude and emphasis rather than direction. However, new directions are being taken in the natural gas portion of the Fossil Energy program, which in the past did not include work on utilization.

The ATS initiative will provide high efficiency, cost-effective, low emission technology for central power and industrial electricity production. Low NO_x combustion will receive special attention, while gas-to-liquids advances may help displace some imported oil in the transportation sector. Expansion of the fuel cells program recognizes the potential of using this high efficiency technology for both dispersed and central power applications. This should expand a significant market for natural gas and allow consumers of electricity to take advantage of current low natural gas prices.

In FY 1994, Fossil Energy resource requirements for the ATS and Fuel Cells for Power Systems programs will be derived from natural gas program funding. The ATS program already is funded under natural gas in FY 1993, although the Fuel Cells program is funded separately in the Fossil Energy budget. This shift in Fuel Cells funding recognizes the fuel that this technology will use in near-term applications. In FY 1994, the natural gas budget increases substantially -- about 37 percent or \$46.7 million over the FY 1993 budget. Sixty-four (64) percent of the total FY 1994 natural gas budget is concentrated in the areas of fuel cells, advanced turbines, and NGVs.

FY 1992-1994 Crosscut Budget Summary

Budget by DOE Office (\$ in millions)

DOE Office	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Fossil Energy (FE)	54.7	66.5	76.7	80.5
Energy Efficiency and Renewable Energy (EE)	36.9	54.3	82.8	78.6
Energy Research (ER)	4.3	4.5	12.9	12.9
Total DOE	95.9	125.3	172.4	172.0

Budget by Program (\$ in millions)

DOE Program	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Combustion Systems	9.835	12.644	20.660	20.660
Combustion Systems/Emissions Control (FE)	-	1.000	0.000	0.000
Improved Combustion Efficiency - Industrial Combustion Equipment (EE)	0.190	0.970	0.600	0.600
Improved Combustion Efficiency - General Combustion (EE)	1.100	1.600	2.110	2.110
Materials Processing (EE)	0.745	0.464	1.450	1.450
Fundamental Chemical Research Related to Natural Gas (ER)	4.100	4.300	12.700	12.700
Fundamental Engineering Research Related to Natural Gas (ER)	0.200	0.210	0.200	0.200
Alternative Fuels Utilization (EE)	3.500	4.100	3.600	3.600

Budget by Program (\$ in millions) - Continued

DOE Program	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Heat Pumps	4.784	5.027	8.200	8.200
Process Heating and Cooling (EE)	0.554	0.497	0.400	0.400
Space Conditioning Equipment (EE)	4.230	4.530	7.800	7.800
Heat Engines	15.960	26.640	47.550	49.360
Advanced Turbine Systems (FE/EE)	2.900	12.800	31.460	28.460
Continuous Fiber Ceramic Composites (EE)	6.700	6.900	7.500	9.000
Cogeneration (EE)	2.200	3.200	4.500	7.700
Heat Engine Development (EE)	4.160	3.740	4.090	4.200
Natural Gas Vehicles	5.690	14.800	24.120	24.120
Alternative Fuels Utilization (EE)	5.690	14.800	24.120	24.120
Fuel Cells	53.770	54.900	57.700	58.200
Fuel Cells for Power Systems (FE)	50.800	51.200	49.200	51.800
Fuel Cells for Transportation (EE)	2.970	3.700	6.000	6.400
Micro-Cogeneration Fuel Cells for Buildings (EE)	-	0.000	2.500	0.000
Gas-to-Liquids	3.199	3.957	3.330	3.628
Gas-to-Liquids Conversion (FE)	3.199	3.957	3.330	3.628
Other	2.625	7.350	10.875	7.875
Gas Integrated Resource Planning (EE)	0.200	0.300	0.500	0.500
Gas DSM Technologies (EE)	0.025	0.025	0.000	0.000
Municipal Solid Waste (EE)	1.400	1.525	1.700	1.700
Materials Development (EE)	1.000	0.800	3.000	0.000
Electric and Hybrid Vehicles (EE)	0.000	4.200	4.800	4.800
International Energy Agency Center for Gas Technology Information (FE)	-	0.500	0.875	0.875
Total Utilization Area	95.863	125.318	172.435	172.043

COMBUSTION SYSTEMS/EMISSIONS CONTROL

Tactical Objective

To develop technology that can be used to reduce NO_x emissions from advanced, high efficiency gas turbines.

Issues

The environmental constraints imposed upon power generation systems are more severe today than in the past and are likely to become even more restrictive in the future. Gas turbines, in both simple-cycle and coupled with natural gas-fueled steam turbines in combined-cycle, are expected to capture a significant portion of the domestic and international power generation markets over the next decade.

Combined-cycle systems fueled with natural gas are available at efficiencies of over 50 percent, and the trend toward higher firing temperatures in pursuit of greater efficiency is expected to continue. As firing temperatures are increased, NO_x emissions also will increase without adequate controls.

Major Goals

- Environmental: develop dry, low NO_x technology that can be integrated into gas turbine systems to reduce NO_x emissions to less than 10 ppm without downstream cleanup;
- Reliability, Availability, Maintainability: develop techniques and/or technology that, when incorporated, will have virtually no detrimental effects on gas turbine power systems; and
- Cost: add less than five percent to the total capital cost for a gas-fired combined-cycle system.

Strategy (Total DOE FY 1994: \$ 0.0 Million)

Cost-Sharing Target: 20-35%

The research program will be completed in three general phases: Phase I - concept development and RD&D plan formulation (complete September 1993); Phase II - technical evaluation, component development and testing (complete March 1996); and Phase III - subsystem testing and performance evaluation (complete September 1999). The program will be coordinated with GRI, EPRI, and gas turbine manufacturers.

As part of the program definition and planning studies, system studies will be initiated to evaluate alternative concepts for NO_x reduction such as: staged addition of air and/or fuel; turbine combustor heat removal devices to achieve the "quick quench" concept; and lean premix combustion. From the systems studies, areas will be identified for further study and/or information and RD&D needs essential to conducting a credible evaluation of the concepts will be identified. RD&D will be initiated to evaluate technical feasibility of proposed concepts, and to develop baseline commercial system designs that include proposed concepts. As part of the cooperative RD&D phase, and based on RD&D results, commercial system designs will be updated and economics of proposed systems will be evaluated. Options that merit integration into gas turbine power systems and cooperative RD&D programs will be initiated with gas turbine manufacturers to develop integrated subsystems and to test the concepts.

Impact (Near-Term)

- Enhances environmental performance and acceptability of gas turbine power systems.

Impact (Mid-Term)

- Develops a technology base that can be utilized by gas turbine manufacturers to commercialize gas-fired turbine systems with improved environmental performance.

Planned Products

- Completion of study to define and evaluate options for low NO_x combustion techniques for gas turbine power systems.
- Verification of technical feasibility of low NO_x concepts using RD&D results.
- Development of preliminary commercial plant designs and economic analyses of gas turbine systems that integrate low NO_x concepts.
- Completion of gas turbine subsystem tests for evaluation of technical, economic, and environmental performance.

Program Funding**DOE Historical Spending (\$ in millions)**

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
System Studies (TBD ¹)	-	1.0	0.0	0.0
Total DOE	-	1.0	0.0	0.0

¹ TBD: To be determined

Cost-Sharing

Cost-sharing of about 20 percent will be sought when the program reaches component development phase. When the program reaches the subsystem/proof-of-concept phase, the cost-sharing target will be 35 percent.

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
TBD ¹	System Studies	-	0.0	0.0
Total		-	0.0	0.0

¹ TBD: To be determined

Flow Diagram

Initial RD&D phases will be conducted by universities and private sector research organizations, with the last phase involving gas turbine manufacturers.

Projects	1993	1994	1995	1996	1997	1998	1999
Phase I - Concept Development and RD&D Planning
Phase II - Technical Evaluation/Component Development and Testing							
Phase III - Subsystem Testing/Performance							

IMPROVED COMBUSTION EFFICIENCY - INDUSTRIAL COMBUSTION EQUIPMENT

Tactical Objective

To develop advanced burner systems that will transfer energy to industrial processes more efficiently than a conventional burner and with greatly decreased emissions.

Issues

The project is designed to obtain answers to the following uncertainties:

- Can an Advanced Radiant Combustion System (ARCS) that utilizes natural gas last sufficiently long enough to be commercially viable at the high temperatures of interest (1,800°F)?
- Will industry overcome its reluctance to adopt new burner technology?
- Can a full scale ARCS high temperature system achieve the reduction in NO_x, CO, and hydrocarbon emissions realized in the laboratory without the need for "add on" control technology?

Major Goals

The multi-phase project now underway has the following goals:

- Demonstrate technical feasibility of ARCS through pilot testing and identify a host site for demonstration;
- Complete design of ARCS and associated controls, and fabricate and test major combustion components; and
- Install and demonstrate the ARCS in an industrial facility (a steam reformer supplying hydrogen to a steel mill).

Strategy (Total DOE FY 1994: \$ 0.600 Million)

Cost-Sharing Target: 5-40%

The strategy includes the following: (1) utilize recently identified high heat burner materials that can survive the high temperature industrial process environment, and increase overall process efficiency while significantly reducing emissions; and (2) retrofit this new burner type to current generation industrial heaters and conduct a demonstration to show industry the value of this concept. Consequently, not only will the thermal efficiency be improved, but combustion related emissions, especially those of NO_x, will be sharply reduced relative to existing combustion equipment. The "greenhouse gases" also will be reduced. For example, up to eight percent less CO₂ will be produced due to increased efficiency, and because there is no need for a NO_x control system, there will be no N₂O emissions.

Impact (Near-Term)

- Reduces emission levels, especially NO_x (50 percent reduction), which makes this technology exceptionally attractive for adoption by industries in environmentally sensitive regions.
- Increases overall efficiency by up to eight percent in an already very efficient process (steam reforming) when conventional burners are replaced by ARCS (based on contractor and host site calculations). This reduces the CO₂ emissions (greenhouse gas) by eight percent.

FY 1993 Accomplishments

- Achieved 4,000 hours with half-scale burners (over five months) at steam reformers temperature without significant degradation.
- Completed design of burner controls.
- Obtained approval of design, field test plan, safety plan, and all requirements for installation of burners in host site (Air Products) reformers.

Planned Product

- Development of a high temperature ARCS for industrial heaters.

Program FundingDOE Historical Spending (\$ in millions)

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Develop and Test (OIT ¹)	0.190	0.970	0.600	0.600
Total DOE	0.190	0.970	0.600	0.600

¹ Office of Industrial TechnologyCost-Sharing

Cost-sharing by the contractor was five percent in the first phase. Continued contractor cost-sharing by Alzeta and the host site is now at 24 percent, and is expected to be 40 percent in the demonstration phase.

Flow Diagram

Projects	1992	1993	1994	1995	1996	1997
Prototype Demo Design/Contract System	<div style="text-align: center;"> <p>P _____</p> <p>D _____</p> </div>					
Conduct Field Test						

Coding:

D = Initiate field demonstration

P = Achieve proof-of-concept

IMPROVED COMBUSTION EFFICIENCY - GENERAL COMBUSTION

Tactical Objective

To conduct applied research to provide combustion processes knowledge. To develop simulation models that can be used to design advanced combustion systems.

Issues

The research program is designed to answer the following questions:

- Can the increased turbulence in the new low NO_x burners provide the mechanism to limit toxic emissions?
- Can natural gas and refinery process gas be burned in process heaters without forming toxic species (e.g., aldehydes at low levels of NO_x)?
- Can industry be encouraged to reduce its reluctance to adopt new burner technology or utilize new design codes that offer chemical kinetics and fluid dynamics?

Major Goals

The program has the following goals:

- Quantify the level of emissions from a typical refinery using natural gas and process gas, and develop a measurement system that meets all EPA quality control requirements. Emissions will be characterized with respect to natural gas as the fuel of reference;
- Identify factors responsible for producing air toxics from combustion of gaseous fuels; and
- Develop strategies to minimize emissions of air toxics from combustion of gaseous fuels.

Strategy (Total DOE FY 1994: \$ 2.110 Million)

Cost-Sharing Target: 50%

The program approach is to use the recently completed Burner Engineering Research Laboratory (BERL) to advance natural gas combustion research. BERL utilizes advanced laser diagnostics to measure turbulence, temperatures, heat transfer, chemical species, and mixing processes. Several burners -- firing simulated refinery process gas -- will be used to measure the chemical species present in the exhaust plumes, the location of this within flame boundaries, and the efficiency of the combustion event using laser diagnostics. Mechanisms will be defined that cause the formation of different species, and these chemical kinetics will be incorporated into a detailed model that simulates the process. Finally, the technology will be transferred to the advanced natural gas burner development activity.

Impact (Near-Term)

- Provides energy savings over conventional natural gas burners that use exhaust gas recirculation to provide NO_x control.
- Reduces emissions of toxic species, especially aldehydes and aromatics that are known carcinogens.
- Reduces NO_x emissions.

FY 1993 Accomplishments

- Completed the BERL facility (it is being readied for initial burner evaluation by burner manufacturer).
- Achieved NO_x levels of five ppm and CO levels of less than 10 ppm by pulse combustion burner.

Planned Products

- Development of advanced code for burner development.
- Development of advanced optical diagnostic tools for in-situ measurement of process variables.

Program Funding**DOE Historical Spending (\$ in millions)**

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
BERL ¹ Facility	0.160	0.400	1.000	1.000
Spray Dynamic Process	0.400	0.600	0.000	0.000
Pulse Combustion Process	0.400	0.300	0.410	0.410
Catalytic Combustion	0.140	0.300	0.000	0.000
Cooperative Program with PERF ²	0.000	0.000	0.700	0.700
Total DOE	1.100	1.600	2.110	2.110

¹ BERL: Burner Engineering Research Laboratory² PERF: Petroleum Environmental Research Forum**Cost-Sharing**

Project cost-sharing by project includes GRI providing \$0.5 million in operating funds for the BERL facility. PERF is also cost-sharing 50 percent of the tasks.

Flow Diagram

Projects	1992	1993	1994	1995	1996
BERL User Facility					
• Protocols Validated					
• Hardware Demonstrations					
Petroleum Refining					
• Identify Species					
• Validate Diagnostic					

MATERIALS PROCESSING

Tactical Objective

To develop technology for Rapid Glass Refining (RGR) that has potential for application to conventional glass furnaces and emerging rapid melting technology.

Issues

Glass melting furnace technologies are prime targets for energy savings. The melting/refining step consumes 54 percent of all energy used to manufacture glass. The refining process is the time limiting step, and natural gas is the major fuel source.

Full implementation of Advanced Glass Melters (AGM) and Rapid Glass Refiners could reduce energy demand by 100 trillion Btu. The ability to utilize low cost, energy efficient technology at low capital requirements will enable municipalities to efficiently recycle waste glass. With an RGR, the time required to refine glass will be reduced from 24 hours to less than one hour. With the AGM, melting time can be reduced to minutes, rather than four to eight hours. The AGM/RGR system will be efficient at small furnace sizes (40 tons/day), reducing energy requirements by 50 percent. Retrofit application to large furnaces (180 tons/day and larger) could reduce heat losses by 50 percent.

Technical and economic potential for success is great in the retrofit area where depreciated equipment defers the majority of capital cost requirements for implementation of a new technology. With technical advances, the U.S. glass industry could close the materials loop for economic recycling, and at the same time, increase productivity of present commercial systems. Other nonenergy benefits will also accrue such as improving the environment.

Major Goals

- Show correlation of computer model and hot test data;
- Determine design parameters for pilot unit;
- Construct and test pilot scale (750 pounds/hour) validation of proof-of-concept;
- Determine scaleup parameters and design for field test; and
- Field test final design for endurance and economic data.

Strategy (Total DOE FY 1994: \$ 1.450 Million)

Cost-Sharing Target: 10-50%

- Phase I (completed in 1992): (1) validate the concept and provide design and engineering analysis of the proposed system; (2) design small test loop for molten glass, and specify process design criteria for experimental scale rapid glass refiner; (3) utilize computational fluid dynamics code to evaluate several two- and three-dimensional models of rapid refining; and (4) make technical and economic analyses and assess the market potential for technology.
- Phase II: (1) design, fabricate, and test 20-ton/day experimental scale test glass refining loop; (2) validate testing and data analysis of pilot scale components; (3) define design criteria and requirements for field test and commercial units; and (4) identify field test site and estimate cost.
- Phase III: (1) complete final design of the field test for AGM; (2) fabricate and install field test system; (3) complete shakedown and endurance test for nine months; (4) update system engineering and technical and economic data; and (5) provide commercialization business plan.

- Use technical goals as decision points for continuation. Use existing Fossil Energy Rapid Melting Furnace to reduce cost of pilot unit. Increase application and reduce time for industry conversion by supporting a field test on conventional furnaces (upon availability of funds).
- Coordinate large scale test with GRI AGM test.
- Require industrial cost-sharing to increase as risk is reduced.

Impact (Near-Term)

- Provides energy savings ranging from estimated 0.025 to 0.11 quad per year, depending on the mode of application.
- Reduces CO₂ emissions by 1.4 to 6.2 million tons per year.

Impact (Mid-Term)

- Replaces small furnaces to reduce energy consumption by 50 percent. Allows new entries into the glass recycling market, such as municipalities.

FY 1992 Accomplishments

- Designed and installed pilot scale rapid glass refiner.

FY 1993 Accomplishments

- Field tested RGR: reduced refining time from 24 hours (typical) to 2 hours.

Planned Products

Develop a commercially viable rapid glass refiner and design for application to AGM and conventional furnace retrofit.

Program Funding**DOE Historical Spending (\$ in millions)**

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Rapid Glass Refiner (VORTEC)				
Phase I (Prior to FY 1992)	-	-	-	-
Phase II	0.745	0.464	0.950	0.950
Phase III	-	-	0.500	0.500
Total DOE	0.745	0.464	1.450	1.450

Cost-Sharing (\$ in millions)

Cost-sharing targets are 10 percent for Phase I, 30 percent for Phase II, and 50 percent for Phase III. Vortec Corporation is the prime contractor and has pilot plant facilities at U-PARC in Harmarville, Pennsylvania. CertainTeed Corporation, a major supplier of fiberglass, is cost-sharing in the project. GRI is supporting research on advanced glass melting, a companion technology.

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
VORTEC Corp.	Rapid Glass Refiner Phase I	-	-	-
	Phase II	0.317	0.320	0.407
	Phase III	-	-	0.500
Total		0.317	0.320	0.907

Flow Diagram

Project	1993	1994	1995	1996	1997	1998
Rapid Glass Refiner	S D/G P T					

Coding:

D = Initiate field demonstration
 S = Select most promising concept for further development
 G = Go/no go decision
 T = Transfer technology or information for application
 P = Achieve proof-of-concept

FUNDAMENTAL CHEMICAL RESEARCH RELATED TO NATURAL GAS

Tactical Objective

To conduct fundamental investigations on the chemistry relating to catalysis of methane, and the factors affecting combustion of methane in flames, industrial combustors, and internal combustion engines.

Issues

The catalytic mechanisms for the synthesis of higher molecular weight hydrocarbons and other organic compounds from methane are not sufficiently well understood for the optimal use of methane as a resource for liquid hydrocarbon fuels and chemical feedstocks. More detailed information is required on methane dissociation reactions and molecular fragment recombination reactions over a wide range of temperatures, pressures, and catalytic surface compositions.

Chemical processes on surfaces during combustion are poorly understood and rarely investigated. Semi-empirical theories are needed to represent complex combustion reaction mechanisms by simplified, but fundamentally correct, representative metareactions. Such chemistry theories will be incorporated into fluid dynamic models of combustion.

Major Goals

- Characterize the activation of carbon-hydrogen (C-H) bonds by metals as a function of metal species and surface structure;
- Characterize the reactive pathways of radical intermediates in the oxidation and coupling reactions of methane on catalytic surfaces and develop predictive theories (similar to the Woodward-Hoffmann rules for organic chemistry) for heterogeneous catalysis;
- Develop semi-empirical theories for the representation of complex reaction mechanisms by prototypical metareactions, and for the temperature and pressure dependence of their rates; and
- Develop general theories, principles, and methods of measurement for characterizing the reactions of prototypical combustion species at surfaces, temperatures, and pressures characteristic of combustion systems.

Strategy (Total DOE FY 1994: \$ 12.7 Million)

Cost-Sharing Target: None

The program strategy will focus on supporting fundamental, experimental, and theoretical research at universities and National Laboratories. In general, proposals are unsolicited and are prepared by individual investigators. A major effort on fundamental combustion science is underway at the Combustion Research Facility, Sandia/Livermore Laboratories.

The underlying theme for basic research in these areas is to investigate new ideas and approaches that will allow the industry and DOE technological programs to expand. Titles of specific research projects are as follows:

- Combustion Research Facility Diagnostic Research: Four Wave Mixing
- Flame Chemistry: Modeling and Experiments
- Photochemistry of C-H Bond Activation
- Turbulent Reacting Flow Research
- Chemical Kinetics and Dynamics
- Carbon-Hydrogen Bond Functionalization Catalyzed by Transition Metals
- Analysis of Turbulent Reacting Flows

- Turbulent Combustion
- Transition Metal Catalyzed Conversion of CO, NO, and Organic Molecules to Fuels and Petrochemicals
- Kinetics Database for Combustion Modeling
- Mechanisms and Controlling Characteristics of Catalytic Oxidation of Methane
- State Resolved Studies of the Methyl Radical
- Computation and Experimental Study of Laminar Premixed and Diffusion Flames
- Homogeneous-Heterogeneous Combustion: Thermal and Chemical Coupling

Impact (Near-Term)

- Allows chemistry to be more readily incorporated into turbulence and mixing models through the use of semi-empirical theories for simpler and more reliable description of combustion and complex chemical processes.
- Allows design decisions on combustion devices for minimizing emissions of unwanted byproducts and maximizing combustion efficiency by characterizing surface combustion processes.
- Allows more efficient discovery of new catalytic systems for more optimal use of natural gas resources through theories for C-H activation and molecular fragment recombination at surfaces.

Planned Products

- Development of critical data, descriptive and predictive theories, and measurement methods for fundamental processes in catalysis and combustion. These will be conveyed to DOE technology programs through jointly sponsored workshops, contractor meetings, personnel exchanges, and reports, and to the broad technical community through publication in the archival, peer reviewed literature.

Program Funding

DOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Fundamental Chemical Research	4.1	4.3	12.7	12.7
Total DOE	4.1	4.3	12.7¹	12.7

¹ The natural gas-related research has been expanded from that presented previously. The initial restricted view of natural gas was based on its major component, typically 96 percent methane and included only C₁ chemistry. Natural gas contains minor amounts of heavier hydrocarbons, and the revised research support includes research related to the small hydrocarbons as well. The FY 1994 budget request includes \$6.0 million for the Secretary's initiative in enhanced utilization of natural gas.

Cost-Sharing

Not anticipated.

Flow Diagram

Not applicable.

FUNDAMENTAL ENGINEERING RESEARCH RELATED TO NATURAL GAS

Tactical Objective

To conduct fundamental studies on transportation and other processes involving natural gas, which may lead to improved design methodologies.

Issues

Improved analysis of flows in pipelines and heat exchangers with high heat fluxes.

Major Goals

This research is a facet of a broad-based engineering research program emphasizing heat and fluid transport, process diagnostics and control, and engineering analysis. Specific goals are:

- Determine dryout limits for heat exchanges applicable to power plants using heated tubes with natural gas as the heat source; and
- Improve modeling of pipeline flows of gases and liquids.

Strategy (Total DOE FY 1994: \$0.200 Million)

Cost-Sharing Target: None

The program strategy is to conduct studies combining computational modeling with experiments designed to test and refine the modeling methodologies. Specific research topics include Gas-Liquid Flows in Pipelines, and Dryout in Horizontal and Almost Horizontal Heated Tubes.

Impact (Near- and Mid-Term)

- Improves models of chemical, mass, and heat transfer processes suitable for systems applications, testing, and evaluation.
- Develops capabilities for enhanced design and operation of pipelines and power plants utilizing natural gas.

Planned Products

- Publication of scientific and technical reports in the professional literature.
- Development of patents.
- Completion of new technology transfer to the private sector.

Program FundingDOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Fundamental Engineering Research	0.200	0.210	0.200	0.200
Total DOE	0.200	0.210	0.200	0.200

Cost-Sharing

Not anticipated.

Flow Diagram

Not applicable.

ALTERNATIVE FUELS UTILIZATION - ENGINE OPTIMIZATION AND ATMOSPHERIC REACTIONS

Tactical Objective

To develop next generation engines and fuel systems dedicated to and optimized for alternative fuels. To establish a credible database which can be used to project ultimate destinies and specific environmental impacts of automotive exhaust components.

Issues

The provisions of AMFA and Executive Order 12759 provide for: (1) operation of the state-of-the-art alternative fuel vehicles (AFVs) in Federal, State, and local fleets, and demonstration of AFV viability; (2) generation of a credible database for objective comparisons of fuel/vehicle performance; and (3) acceleration of widespread commercial introduction into the marketplace.

Major Goals

- To accelerate the Federal fleet conversion program. One half of vehicles purchased in 1994 (about 20,000) will be alternative fuel capable (fuel flexible, dedicated, dual/biofuel) rather than the 7,500 as defined in the current Executive Order 12759 and EPACT. Conventionally fueled models will be converted to AFVs if unavailable from manufacturers.

Strategy (Total DOE FY 1994: \$ 3.6 Million)

Cost-Sharing Target: 50%

DOE strategy will include working with the General Services Administration (GSA) and acquiring AFVs for Federal fleet using DOE funds for incremental costs; coordinating Federal agency AFV education and training; promoting agency awards for AFV goal achievement; and conducting joint planning with industry on refueling infrastructure.

Impact (Near-Term)

- Establishes government as a leader in moving the Nation toward alternative fuels.
- Leverages government and industry funds: fuels infrastructure and AFV production facilities investment (requiring billions of dollars) to be made by industry.
- Provides small business assistance through information and training programs.

Impact (Mid-Term)

- Provides air quality benefits as a result of widespread utilization of AFVs.
- Increases U.S. industry advantage and competitiveness in marketing AFVs worldwide.

FY 1992 Accomplishments

- Introduced first CNG vehicles into Federal fleets.
- Identified leading CNG absorbents and established target parameters.
- West Virginia University Transportation Vehicle Emission Laboratory began nationwide operations.

FY 1993 Accomplishments

- Identified and designated the first "Clean Cities."
- Expanded Federal alternative fuel vehicle fleet to over 7,000.
- Extended State and local grant program to 22 school districts in 18 States.

Planned Products

- CNG - hydrogen mixture effects on emissions.
- Establishment of mechanic certification criteria and curricula.

Program Funding

DOE Historical Spending (\$ in millions)

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Engine Optimization	2.5	3.1	3.1	3.1
Atmospheric Reactions	1.0	1.0	0.5	0.5
Total DOE	3.5	4.1	3.6	3.6

Cost-Sharing

Cost-sharing contribution: in funding and in-kind services is 50 percent.

Flow Diagram

Projects	1992	1993	1994	1995
Engine and Systems Development	C	S	T	I
Photochemistry Experiments and Modeling	E		D	M

Coding:

- C = Continue traditional modification of petroleum engines for adaptation to alternative fuels
 S = Start development of ultra-low emission vehicle systems for ethanol- and propane-burning engines
 T = Terminate traditional engine modification program; relinquish development to industry
 I = Initiate competitive program to develop optimized single-fuel engines and systems
 E = Initiate experimental photochemistry program to identify reactive species
 D = Database coordination for interactive experimental program
 M = Develop kinetic and mechanistic models for atmospheric impact calculations

PROCESS HEATING AND COOLING (RECUPERATORS)

Tactical Objective

To develop High Pressure Heat Exchange Equipment Systems for natural gas/steam reforming that will have improved conversion ratios and greater throughput.

Issues

This program is designed to answer the following questions:

- Can advanced ceramic materials be identified that will be viable in the aggressive environment of a methane reformer?
- Will the catalysts used for the reformation operate satisfactorily at the planned 2,000°F in lieu of the present practice of 1,500°F?
- Can new design technologies (including ceramic to metal joining) be developed that will allow the fabrication of critical components for the reformer?

Major Goals

The goal of the program is to develop improved chemical reactor vessels that will transmit high temperature heat while sustaining a significant pressure differential.

Strategy (Total DOE FY 1994: \$ 0.400 Million)

Cost-Sharing Target: 45%

The program strategy is to assemble an industry team (consisting of an architect and engineering firm, a National Laboratory, and a ceramic producer) to design, conduct laboratory tests, fabricate a prototype, and locate a host site for a demonstration.

Impact (Long-Term)

- Develops equipment to save 0.46 quad of energy per year. The equipment resulting from this development will have export potential to syngas producers, and could be used on offshore platforms and remote sites to convert flare gas to methanol. The improved chemical reactor vessel will reduce the atmospheric emissions from the combustion of flared gas.

Planned Products

- Development of syngas production reactor vessels.
- Development of flared gas-to-methanol conversion equipment.

Program Funding**DOE Historical Spending (\$ in millions)**

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Develop and Test (OIT ¹)	0.554	0.497	0.400	0.400
Total DOE	0.554	0.497	0.400	0.400

¹ Office of Industrial Technology**Cost-Sharing**

Cost-sharing by industrial teams for present development is 45 percent. Additional cost-sharing will be obtained from the host site company.

Flow Diagram

Projects	1992	1993	1994	1995
Equipment Development				
Demonstration and Testing				

SPACE CONDITIONING EQUIPMENT

Tactical Objective

To develop highly efficient Thermally Activated Heat Pumps (TAHPs) that use natural gas to heat and cool buildings.

Issues

Heating, cooling, and refrigeration equipment in buildings currently consume 14 quads of source energy, or 50 percent of all building energy consumption. Air conditioning is also the single leading cause of electric system peak loads and is one of the Nation's major current users of CFC. The space conditioning equipment program addresses technology and market issues of equipment to provide heating, cooling, and refrigeration for residential and commercial buildings. Major categories of equipment addressed include: (1) TAHP that uses fuel energy to drive a heat pump; (2) air conditioning and refrigeration systems for residential and commercial applications; and (3) distribution and control of HVAC thermal energy.

The TAHP effort focuses on technologies that target various heating and cooling market segments such as residential, commercial, and heating and cooling dominated segments. Absorption systems and engine driven systems have inherent cogeneration capabilities for added market potential and for greater energy savings. Absorption systems eliminate the use of CFCs.

Economic Competitiveness for Residential Equipment: The DOE TAHP program advances will counteract RD&D efforts by foreign governments. Specifically, Japan's Ministry of International Trade and Industry (MITI) and the Japanese HVAC industry have started a major new RD&D program for development of thermally activated residential heat pumps. The MITI program will develop absorption and internal combustion engine heat pumps. The goals and technical approach to be used in the Japanese absorption program appear to follow exactly the current DOE advanced cycle absorption heat pump program started in 1982.

Economic Competitiveness for Commercial Equipment: In 1967, U.S. companies were virtually without foreign competition and had 100 percent of absorption chiller sales. Japanese manufacturers now dominate world sales of absorption chillers and continually made small incremental improvements on U.S. pioneered single and double effect chiller technology. Today, Japanese companies have more than 90 percent of worldwide sales. Advanced absorption chiller technology should restore the U.S. industry to a technological leadership position and allow U.S. manufacturers to regain a significant market share from the Japanese.

Indoor comfort issues are indirectly part of the heating and cooling equipment RD&D program. Comfort issues and technologies include low input heating equipment (that provide less cycling in newer residences), improved diffusers, variable speed fans and compressors (that can better maintain humidity levels), and equipment noise level reduction.

Major Goals

- Introduce into the market residential natural gas heat pumps with a heating coefficient of performance (COP) of 1.7. This performance is more than double the efficiency of gas furnaces meeting the 1992 National Appliance Energy Conservation Act minimum efficiency standard, and is more than 70 percent better than the highest efficiency furnace. Residential gas absorption heat pumps will also eliminate ozone depleting CFC refrigerant use and reduce electric utility summer peak loads;
- Introduce into the market advanced "triple effect" absorption gas-fired chillers with a COP of more than 1.4. This performance is a 30-50 percent higher efficiency than equivalent Japanese double-effect chillers, and will reduce electric utility peak loads and eliminate CFC refrigerant use; and

- Develop advanced residential heat pumps (non-CFC with a COP of 2.0) and commercial rooftop heat pumps; and further improve large commercial chillers.

Strategy (Total DOE FY 1994: \$ 7.80 Million)

Cost-Sharing Target: 60%

The heating and cooling equipment program addresses technology and market issues of equipment for space heating, cooling, and refrigeration in residential and commercial buildings. The TAHP program will counteract RD&D efforts by foreign governments. The Advanced Absorption Chiller Technology should restore the U.S. industry to a technological leadership position and allow U.S. manufacturers to regain a significant market share from foreign competition. The objectives of the Advanced Absorption Technology program for residential and large commercial applications are:

- Achieve the commercial introduction of the Nation's first gas-fired residential absorption heat pump through laboratory development and joint venture commercialization with a major equipment manufacturer;
- Achieve the commercial introduction of a high efficiency absorption chiller for large commercial buildings; and
- Develop critical components such as an absorber/generator, solution pump, materials, and controls.

Impact (Near-Term)

- **Energy Security:** Reduces potential energy use 50 percent in space heating and 30-40 percent in air conditioning and refrigeration. Significant reductions in the use of oil for space heating also are possible. The program will establish the base technologies for achieving these reduction levels and transfer the results to industry for commercialization.
- **Economic Competitiveness:** Counteracts major RD&D efforts by foreign governments that, coupled with aggressive technical and market advances by multi-national foreign firms, present a significant competitive threat to U.S. jobs and technical leadership.
- **Institutional Barrier Reduction:** Assists the private sector in reducing the risk of developing new concepts of energy efficient equipment. Working with major manufacturers' efforts assures and lends credibility to market introduction of newly developed products.
- **Environmental Integrity:** Eliminates CFCs, improves air quality because of reduced exhaust emissions, increases efficiency of building HVAC equipment, and reduces adverse impacts on global climate by more efficient burning of fossil fuels.
- **Customer Acceptance:** Improves efficiency, reliability, and durability of building equipment, which will then be accepted by consumers for new or replacement equipment. Gas and electric utilities can reduce peak loads, utilize facilities more efficiently, and reduce the need for new plant construction.

FY 1993 Accomplishments

- Completed a licensing agreement between Carrier Corporation and Phillips Engineering for the manufacturing of the residential Generator Absorber Heat Exchange (GAX) Ammonia/Water Absorption heat pump. Carrier Corporation will manufacture the heat pump in the United States. DOE/Oak Ridge National Laboratory (ORNL) will continue to work with Carrier to complete the development phase and technology transfer. Manufacturing is expected to begin in 1996.

- Initiated a cost-shared program with York International to "fast-track" the development and demonstration of a commercial size absorption chiller using lithium bromide/water in a high temperature, triple-effect system developed by ORNL.
- Developed, at ORNL, a novel quaternary ammonia/water/salt mixture for residential absorption heat pumps. This fluid will improve the heating and cooling performance of absorption heat pumps.
- Initiated a "National Plan for a Generator Absorber Heat Exchange Absorption Heat Pumps", and gas cooling. Participants in the program are Carrier Corporation, GRI, American Gas Cooling Center, and several individual gas utilities.

Planned Products

- Completion of field test of a first generation residential gas absorption heat pump and technology transfer to private industry in 1995.
- Introduction of a commercial high efficiency absorption chiller for large commercial buildings by 1996.

Program Funding

DOE Historical Spending (\$ in millions)

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Advanced Absorption	2.80	2.93	6.25	6.25
Stirling Engine Driven Heat Pump	0.60	0.60	0.00	0.00
Large Chemical Chillers	0.83	1.00	1.00	1.00
Natural Gas Heating and Cooling	0.00	0.00	0.55	0.55
Total DOE	4.23	4.53	7.80	7.80

Cost-Sharing

Cost-sharing target for this program is about 60 percent.

Flow Diagram

Projects	Completion
Base Program	
Space Conditioning Equipment: Complete field test of first generation residential absorption heat pump and technology transfer.	FY 1997
Enhanced Program	
Space Conditioning Equipment: Develop and fully characterize a new working fluid for small absorption heat pumps.	FY 1996
Test first laboratory model of advanced absorption laboratory unit.	FY 1997
Achieve target performance levels with advanced absorption laboratory unit.	FY 1995
Establish course series, and cooperative education program in absorption science and engineering.	FY 1995

ADVANCED TURBINE SYSTEMS

Tactical Objective

To develop high efficiency, low NO_x industrial gas turbines to meet future power generation needs.

Issues

DOE has estimated that an additional 200,000 megawatt (MW) of new generating capacity will be required by the year 2010. In addition, it is estimated that a significant part of the existing 700,000 MW of electric generating capacity will require replacement during the same time period. According to some projections, the total new installed capacity will be as much as 400,000 MW.

The economic and environmental conditions and restraints currently imposed on power generation systems are more severe than in the past. These conditions are expected to become even more challenging in the future. Projections indicate that natural gas-fueled turbines, in both simple-cycle and coupled with steam turbines in combined-cycles, will capture a significant portion of the domestic and international power generation market over the next two decades.

Combined-cycle systems fueled with natural gas are available in utility units at efficiencies as high as 52 percent based on LHV. Fueling such systems with synthesis gas from coal or biomass gasifiers can result in efficiencies of 40-42 percent using currently available technology.

Combustion turbine systems offer low capital costs, quick installation, the potential for utilizing plentiful domestic fuels such as natural gas, biomass, and coal, and the potential for efficiencies above 60 percent accompanied by significant reduction in CO₂ and NO_x emissions. However, an aggressive research and development program is needed to assure that U.S. manufacturers will have a lead position in domestic and international markets.

Major Goals

- **Environmental:** reduce emissions to levels significantly less than the current standards when operated with natural gas or gasified coal (NO_x less than eight ppm);
- **Performance:** improve efficiency to better than 60 percent on a LHV basis for central power applications, with an equivalent improvement for industrial system in combined-cycle configurations;
- **Combustion and Fuels:** develop a turbine system capable of operating on natural gas and/or coal or biomass fuels;
- **Reliability and Maintainability:** equal to or better than present practice; and
- **Cost:** reduce capital and operating and maintenance costs, to provide 10 percent decrease in electricity costs.

Strategy (Total DOE FY 1994: \$ 28.46 Million)

Cost-Sharing Target: 34%

- **Program Definition/Planning Studies:** Conclude system studies to define technical issues and provide a better understanding of program needs. Areas of consideration include: (1) improved combustion for increased firing temperatures and low NO_x; (2) improved materials and cooling technology for increased firing temperatures as well as alternate fuel requirements; (3) turbine modifications for advanced augmented flow systems; (4) future capability to operate on coal or biomass-based fuels; and (5) total system integration needs for various cycles.

- Initiate basic science support from universities.
- Initiate materials and manufacturing technology programs.
- Initiate ultra-high efficiency gas turbine technology program utilizing multiple contractors, including system studies and component development aimed at improving the efficiency of gas-fired turbine cycles. Components include: (1) combustors; (2) turbine blades (materials/cooling); (3) high pressure ratio compressors/intercooling; and (4) increased mass flow expanders.

Impact (Near-Term)

- Provides a technology base that gas turbine manufacturers can use to commercialize advanced gas turbine systems with improved efficiencies and reduced emissions.

Impact (Mid-Term)

- Significantly reduces CO₂ and NO_x emissions when operated on natural gas, which is very attractive to both utilities and the public. Utilities will achieve emission levels less than one-tenth of the current New Source Performance Standards.
- Improves efficiency of gas turbine combined-cycle technology to 60 percent, up from the best available gas technology (BAT) of 48-52 percent. Presently, the industry average efficiency for coal-fired utilities is 33 percent.
- Achieves installed costs of gas turbine system competitive with current BAT. The cost of current BAT is \$750-\$875/kW.
- High efficiency gas turbines could significantly decrease long-term greenhouse gas emissions and also help increase U.S. technology exports.

FY 1993 Accomplishments

- Completed the ceramic component design study (Phase 1).
- Initiated laboratory evaluations (Phase 2).
- Initiated the ceramic component testing and processing.
- Initiated construction of component test rig.
- Completed initial testing of ceramic combustor liners.
- Hosted the First Annual Joint Fossil Energy-Energy Efficiency ATS Program Conference.
- Awarded 10 contracts under the First Round of University Support Contracts.
- Awarded four contracts to gas turbine manufacturers for development of concepts for both utility and industrial manufacturers.
- Formed a Materials Support Group and hosted the initial ATS materials planning meetings with manufacturers and the public.
- Initiated the Morgantown in-house support work including pulse combustion.

- Initiated support for the Collaborative Advanced Gas Turbine Program.
- Completed the Morgantown Advanced Turbine Combustion Facility.

Planned Products

- Completion of studies relating to advanced high temperature gas turbine systems capable of operating on natural gas and a wide range of gaseous coal and biomass-derived fuels (September 1994).
- Completion of design, construction, and testing of components critical to advanced gas turbine systems including the turbine aerodynamic blading, blade cooling, bearing and rotating group, casing, and combustion system (September 1998).

Program Funding

DOE Historical Spending (\$ in millions)

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Innovative Cycle Development	0.30	5.80	14.00	12.00
Technology Base (utility plus industrial)	0.40	4.50	9.96	8.96
Utility System Development	0.00	0.00	0.00	0.00
Industrial/System Development	2.20	2.50	7.50 ¹	7.50
Total DOE	2.90	12.80	31.46	28.46

¹ Includes ceramic components system work previously listed.

Cost-Sharing

The program is an eight year, \$706.6 million effort (1993-2000) and will be completed in four elements: (1) innovative cycle development (October 1994); (2) utility development (complete October 2000); (3) industrial development (October 2000); and (4) technology base (October 2000).

To ensure maximum efforts, the program will be accomplished by leveraging the funding and resources of all interested parties. The participants will be selected competitively. Overall program cost-sharing is expected to be 34 percent.

The ATS Program is jointly funded and managed by Fossil Energy and Energy Efficiency. A Steering Committee is composed of representatives of Fossil Energy, Energy Efficiency, EPRI, GRI, and EPA. This Committee assures that work under the ATS Program is complementary to other work supported by these funding organizations. The Steering Committee is also responsible for coordinating ATS Program work with that supported by other Federal, State, and private funding organizations, and acts as the liaison with industry groups.

Flow Diagram

Projects	1993	1994	1995	1996	1997	1998	1999	2000
Cycle Development Studies			G					
Utility System Development			S		S	D		P
Industrial System Development			S	D/S	S	D		P
Technology Base Development		T	T	T	T	T	T	T

Coding:

D = Initiate field demonstration

S = Select most promising concept for further development

G = Go/no go decision

T = Transfer technology or information for application

P = Achieve proof-of-concept

CONTINUOUS FIBER CERAMIC COMPOSITES

Tactical Objective

To develop advanced structural materials with improved high temperature, wear resistant, noncorroding characteristics that open up new opportunities because of their ability to perform in environments and under operating conditions that would destroy currently available metals and ceramics.

Issues

The development program is designed to improve the processing of these new materials in industries. In addition, the most favored applications are to be identified. There are few uncertainties surrounding development of advanced structural materials. Historically, the development of advanced materials, such as stainless steel, have opened up vast new opportunities for industrial market growth.

Major Goals

The goal of the program is to develop in U.S. industry the primary processing methods for reliable and cost-effective fabrication of continuous fiber ceramic composites (CFCCs) that will open up new application opportunities for use in industrial service.

Strategy (Total DOE FY 1994: \$ 9.00 Million)

Cost-Sharing Target: 24%

Assemble 10 industrial teams, including 42 different companies, universities, and National Laboratories, to develop the various material and processing systems for fabricating these new desirable materials.

Impact (Long-Term)

Based on the initially investigated applications:

- Decreases annual national energy consumption by 2.16 quads;
- Eliminates the emission to the atmosphere 0.9 million tons/year of NO_x, and 117.5 million tons/year of CO₂; and
- Qualifies the U.S to penetrate a \$20 billion market by the year 2020.

FY 1993 Accomplishments

- Designed a nonlubricated CFCC valve guide that would eliminate 25 percent of the particulate emissions of a diesel engine.
- Designed and tested a high output CFCC component that doubles the efficiency of radiant burners in drying applications.
- Achieved the ability to create a functionally gradient material layer (from silicon carbide to alumina) in a single step.
- Reduced the number of processing steps by half while at the same time material porosity was reduced by 60 percent.
- Improved material shape capability while increasing material strength by 40 percent.
- Increased material reliability by 40 percent while achieving significant material strength increase.

- Identified CFCC components that would increase the power generation efficiency of a coal-fired power plant from 35 percent to 47 percent with a 25 percent reduction in emissions.
- Increased material conductivity by 25 percent.
- Increased material strength by 50 percent by changing preform fabrication process.
- Increased CFCC material strength by a third while increasing the material processing rate by a factor of 10.

Planned Products

- Development of high pressure heat exchange systems, radiant burner tubes, gas turbine components, aluminum remelting and heat recovery, and diesel engine components.

Program Funding

DOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Develop and Test (OIT ¹)	6.70	6.90	7.50	9.00
Total DOE	6.70	6.90	7.50	9.00

¹ Office of Industrial Technology

Cost-Sharing

Cost-sharing by industrial teams in the initial phases is 24 percent. Higher amounts will be obtained in later phases of the program.

Flow Diagram

Projects	1992	1994	1996	1998	2000	2002	2004
Process Development	S P/T						
Pilot Scale Development	D P/T						

Coding:

D = Initiate field demonstration
 S = Select most promising concept for further development
 T = Transfer technology or information for application
 P = Achieve proof-of-concept

COGENERATION

Tactical Objective

To insert ceramic components into critical locations of stationary gas turbines for cogeneration service, achieving considerable fuel savings and reduced emissions.

Issues

Gas turbines are used internationally for electrical service, cogeneration, mechanical power drives, and offshore power generation. Nationally, there is about 65,000 MW of operating gas turbine capacity. Upgrading this capacity through routine overhaul of existing equipment or use of ceramics in new gas turbines will have significant impact on the fuel burned, emissions generated, and overall Gross National Product (GNP).

Key to this project is the vast existing knowledge generated on prior ceramic programs such as DOE's Advanced Technology Application Program, NASA's HITEMP, and Defense Advanced Research Projects Agency's Integrated High Performance Turbine Engine Technology programs. Critical issues include modifying existing engines, and ensuring durability of ceramics for 10,000- to 20,000-hour lifetimes. Benefits of ceramic components include the following: more than 40 percent thermal efficiency (over 16 percent lower fuel consumption); ultra-low NO_x potential with ceramic combustor (68 percent less NO_x than best domestic equipment currently available, lower CO, and less than 20 ppm unburned hydrocarbons); engine cost reductions by replacement of cooled single crystal and directionally solidified parts with uncooled ceramics; and lower cost per installed kW of capacity.

Major Goals

- Design ceramic components with appropriate seals and transitions to metallic supports;
- Redesign gas-fired engine hot sections including the combustor transition pieces and the first and second stage blades and nozzles;
- Screen each component with rig and hot-spin tests; and
- Perform 4,000-hour commercial engine tests using the newly designed ceramic components.

Strategy (Total DOE FY 1994: \$ 7.70 Million)

Cost-Sharing Target: 35%

The program consists of three phases and features industry led development teams, including ceramic component manufacturers, end users of gas turbines, and university and National Laboratory support activity.

- Phase I: Engineering/Preliminary Design Study.
- Phase II: Laboratory Evaluations -- includes ceramic evaluation; development and testing for vane, blade, and combustors; engine rig performance tests; and final engine design.
- Phase III: Engine Tests -- includes component production, engine shakedown tests, 4,000-hour engine tests, and data production and reporting.

Impact (Near-Term)

- Develops new gas turbine product that will be available to market by the year 2001.

- Reduces NO_x and other emissions by up to 68 percent.
- Introduces heat engine sales that will have a major impact on GNP.
- Increases electricity production per unit without increasing fuel burned.

Impact (Mid-Term)

Provides the following potential benefits in the year 2010:

- Energy savings: 0.45 quad;
- Decreased emissions: 80 percent reduction from 1990 level;
- Possible sales: U.S. (\$2.7 billion), export (\$6.3 billion); and
- World market opportunity during 2000-2020: \$115 billion.

Planned Products

- Development of a new generation of gas turbines for cogeneration, utility, mechanical drive, and small power production applications (2001).

Program Funding

DOE Historical Spending (\$ in millions)

Projects	FY 1992 Actual	FY 1993 Anprop.	FY 1994 Request	FY 1994 Approp.
Assessment (Battelle)	0.10	0.10	-	-
Engineering Studies, Laboratory Development, 4,000-Hour Tests (TBD ¹)	2.10	3.10	4.50	7.70
Total DOE	2.20	3.20	4.50	7.70

¹ TBD: To be determined

Cost-Sharing

This project is heavily endorsed by industry. Actual cost-sharing is 35 percent overall. Initial engineering study is supported by the following corporations: General Electric, United Technologies, General Motors Corporation (GM) (Allison), Garrett Aerospace, Caterpillar (Solar Turbines), Norton/TRW, GTE, Textron/Lycoming, Carborundum, ORNL, Westinghouse, American Ceramic Engine, University of Dayton, and Garrett Ceramics.

Flow Diagram

Projects	1993	1994	1995	1996	1997	1998
Assessment	_____T_____T_____T_____T_____T					
Phase I: Engineering Study	____S_____					
Phase II: Laboratory Testing	_____G_____					
Phase III: 4,000-Hour Testing	_____P_____					

Coding:

- S = Select most promising concept for further development
G = Go/no go decision
T = Transfer technology or information for application
P = Achieve proof-of-concept

HEAT ENGINE DEVELOPMENT

Tactical Objective

To develop light and heavy duty engine technologies in partnership with U.S. automakers that are needed to meet future emissions standards, improve fuel economy, and increase alternative fuel use.

Issues

Not available.

Major Goals

- Light Duty Engine: develop and verify endurance of high efficiency (30 percent improvement), low emission and multi-fuel capable ceramic gas turbine components and engine concepts in simulated automotive conditions. Technology also is applicable to small turbine engine for HV auxiliary power unit; and
- Heavy Duty Engine: develop high efficiency (20 percent improvement), low emission, alternative fuel (e.g., methanol and natural gas), and advanced propulsion (e.g., hybrid) technologies for heavy transportation equipment, primarily trucks and buses.

Strategy (Total DOE FY 1994: \$ 4.20 Million)

Cost-Sharing Target: 28%

The approach is to support the U.S. auto industry to develop and market advanced emission control technologies. In addition, DOE will develop alternative fuel capable engines and propulsion systems departing from the current diesel engine technology.

Impact (Mid-Term)

- Develops conventional light duty engine technology to help reduce oil use at least 300,000 barrels per day by the year 2010 (available in 1998).
- Reduces NO_x, particulates, and other pollutants to levels below Federal and State requirements for both conventional and advanced engines in light and heavy duty vehicles.
- Reduces heavy duty petroleum consumption of at least one million barrels per day in the year 2010 because of increased efficiency and use of alternative fuels (in combination with other programs).
- Enhances U.S. world leadership in both light and heavy duty propulsion systems. Increases market penetration in overseas truck markets.

FY 1993 Accomplishments

Not available.

Planned Products

Not available.

Program Funding**DOE Historical Spending (\$ in millions)**

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Light Duty Engine Development	3.18	2.13	2.34	2.45
Heavy Duty Engine Development	0.98	1.61	1.75	1.75
Total DOE	4.16	3.74	4.09	4.20

Cost-Sharing

Cost-sharing target is 28 percent.

Flow Diagram

Not available.

ALTERNATIVE FUELS UTILIZATION

Tactical Objective

To encourage the development and widespread use of natural gas as a transportation fuel and simultaneously encourage the production of natural gas powered motor vehicles.

Issues

Transportation accounts for more than 60 percent of U.S. oil consumption, and imports of oil account for more than 40 percent of U.S. oil supplies. Natural gas is composed mostly of methane. Although it can be liquefied, it is most commonly used in CNG transportation vehicles. Currently, natural gas is used in approximately 30,000 vehicles in the U.S., and in almost one million vehicles worldwide. Congress has recognized that displacement of energy derived from imported oil with alternative fuels will help improve energy security and air quality. Using natural gas also has the potential to improve air quality in highly populated urban areas. The U.S. has large natural gas reserves, and the most sophisticated natural gas production and delivery system in the world.

This project is being carried out under the authority of AMFA as amended by EPACT. To meet its objectives, AMFA provides vehicle manufacturers with incentives to produce AFVs. The Act also mandates demonstration and testing of alternative fuels in a variety of vehicles and calls for several studies for further understanding of alternative fuels. Several government agencies are participating in the program. Specifically, DOE is working with GSA, DOT, and EPA, as well as other agencies, to carry out the provisions of AMFA. State and local governments and industry are also active participants.

AMFA encourages automotive manufacturers to produce AFVs by offering them corporate average fuel economy (CAFE) incentives for these vehicles, beginning with model year 1993. This incentive provides manufacturers of AFVs with defined credits that will make it easier to meet the CAFE standards by assigning a high fuel economy value to these vehicles. Incentives for Federal agencies to acquire these vehicles through GSA include allowing an agency to count only half the number of its AFVs against its total vehicle allocation.

Major Goals

DOE is managing three demonstration and testing projects required by AMFA. These include the following:

- Procure Federal passenger automobiles and light duty trucks, in conjunction with GSA, and place them into service in Federal fleets;
- Conduct a heavy duty truck project with commercial fleets; and
- Test alternative fuel transit buses in support of DOT's Federal Transit Administration (FTA) Alternative Fuel Initiative Program and alternative fuel transit buses operated by State and local agencies.

To support these projects, a National Alternative Fuels Data Center has been established at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, to acquire, analyze, and disseminate all data generated during these demonstration and testing projects. The Center will also analyze complementary data from other alternative fuels programs. In addition, a transportable, heavy duty engine emissions testing laboratory at West Virginia University has completed its first year of operation in support of the heavy duty truck and transit bus projects.

AMFA also requires conduct of several studies to improve understanding of AFVs. Some of these studies will analyze and determine the following:

- AFV performance, fuel economy, emissions, safety, and operating and maintenance costs;
- Federal regulations in need of amendment to stimulate the production and introduction of electric vehicles into the marketplace;
- Impact of including alternative fuel credits in calculating corporate average fuel economy on the average price of home heating to residential consumers;
- Cost and feasibility of producing methanol from domestic natural gas resources; and
- Air quality, climate changes, and other environmental impacts associated with production, storage, distribution, and use of alternative fuels, including an extended forecast of the changes under various scenarios.

Strategy (Total DOE FY 1994: \$ 24.12 Million)

Cost-Sharing Target: 25%

Natural gas vehicle penetration strategy is threefold: (1) acquire significant numbers of light duty vehicles for the Federal fleet; (2) support the DOT/FTA bus program; and (3) initiate a nationwide commercial heavy duty truck program. All three activities are ongoing, with data from light duty bus and truck fleets currently under analysis at the Center. Industrial access to this data, plus public access to general information on alternative fuels, will provide adequate leverage to sustain the natural gas fuel movement toward maturity.

Impact (Near-Term)

NGVs acquisition schedule is as follows:

- 2,500 NGVs into the Federal fleet in FY 1993; 10,000-15,000 by the end of FY 1995.
- 200 NGV buses now operating on CNG/LNG; 1,000-2,000 by the end of FY 1995.
- 150 heavy duty trucks now running on CNG; 200-500 by the end of FY 1995.

In support of these fleets, gas producers and utilities continue to provide key support in installation and operation of natural gas refueling facilities.

Impact (Mid-Term)

- Assists other agencies in AFV acquisitions/conversions.
- Provides AMFA data to interested parties through NREL database access.
- Provides follow-on technical support to agencies and civilian fleets that convert to AFVs.

FY 1993 Accomplishments

- Acquired first group of CNG vehicles (600 pickup trucks; 95 vans).
- Increased NREL data center users to 400-500.
- Continued to operate the West Virginia University mobile heavy duty dynamometer, second unit construction started.

Planned Products

- Addition of 12,500 AFVs to the Federal fleet, FY 1993-1994.
- NREL-AMFA database, made available to public.
- Acceleration of Federal acquisition of and conversion to AFVs, which will result in 25 percent fleet penetration by FY 1996.

Program Funding**DOE Historical Spending (\$ in millions)**

Performer	Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
NREL ¹	ATA ² Truck	0.30	0.40	0.70	0.70
	Light Duty Engineering Support	0.70	1.38	1.50	1.50
	NGV Database	0.80	1.20	1.20	1.20
	SCAQMD ³ Fleet	0.40	0.80	0.60	0.60
	Houston Metro LNG	0.10	0.10	0.00	0.00
	EPA-RTP ⁴ Testing	0.20	0.20	0.50	0.50
NIPER ⁵	Tinker AFB ⁶ Support	0.20	0.30	0.20	0.20
	Tulsa CNG Bus	0.09	0.12	0.12	0.12
WVA Univ.	Mobile Dynamometer	2.30	3.50	2.60	2.60
ORNL ⁷	Heavy Duty CNG Engines	0.20	0.30	0.50	0.50
ANL ⁸	SAE ⁹ NGV Challenge	0.10	0.10	0.20	0.20
BNL ¹⁰	NGV Absorbents	0.30	0.40	1.00	1.00
Federal Fleet Purchase		0.00	6.00	15.00	15.00
Total DOE		5.69	14.80	24.12	24.12

¹ NREL: National Renewable Energy Laboratory² ATA: American Trucking Association³ SCAQMD: Southern California Air Quality Metropolitan District⁴ RTP: Research Triangle Park⁵ NIPER: National Institute for Petroleum Energy Research⁶ AFB: Air Force Base⁷ ORNL: Oak Ridge National Laboratory⁸ ANL: Argonne National Laboratory⁹ SAE: Society of Automotive Engineers¹⁰ BNL: Brookhaven National Laboratory

Cost-Sharing (\$ in millions)

- The Office of Alternative Fuels of Energy Efficiency has lead responsibility for introduction of NGVs into the Federal fleet.
- Through AMFA, DOE is transferring funds to GSA for the incremental costs of NGVs above those for stock vehicles. GSA funds baseline costs from its normal budget.
- DOE is aggressively participating in cost-shared NGV programs in State operated fleets. Funds already have been committed to fleet activities in Oklahoma, West Virginia, and Texas, and others are under consideration.
- DOE's principal field offices and laboratories [Morgantown, Pittsburgh Energy Technology Center (Pittsburgh), National Institute for Petroleum Energy Research (NIPER), BNL, ORNL, NREL, ANL] are now developing detailed NGV acquisition schedules.

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
NREL-GSA	AMFA	3.00	4.10	4.50
ANL ¹	SAE Challenge	0.10	0.10	0.20
WVA Univ.	Mobile Dynamometer Laboratory	2.30	3.50	1.60
Total		5.40	7.70	6.30

¹ ANL: Argonne National Laboratory

Flow Diagram

Projects	1993	1994	1995	1996	1997	1998
DOE - AMFA	D _____ P					
DOE - USPS ¹ Trucks	D _____ P					
DOE-USAF ² Tinker AFB ³	D _____ P					
DOE - National School Bus Fleet	D _____ P					

¹ USPS: United States Postal Service

² USAF: United States Air Force

³ AFB : Air Force Base

Coding:

D = Initiative field demonstration

P = Achieve proof-of-concept

FUEL CELLS FOR POWER SYSTEMS

Tactical Objective

To develop and apply fuel cell power plant technology for use in electric utility, industrial, and commercial sectors with 50 to 60 percent efficiencies and producing economic and environmental benefits.

Issues

Although advanced fuel cell systems achieved high efficiencies of 50 to 60 percent in development testing with gaseous fuels, they must be scaled up to commercial size power plants and demonstrated to have acceptable capital cost and long operating life.

The current Fossil Energy fuel cells program has been developing systems for operation on natural gas and coal. Integration of pilot demonstration plants of up to 11 MW on natural gas has been accomplished with a PAFC power plant. However, no large scale integrated system tests (above 100 kW) have been performed with more advanced molten carbonate or solid oxide fuel cell technologies.

Major Goals

The goals of the fuel cells program, in support of EPACT, are to: (1) support technology base development of fuel cell systems to provide highly efficient, environmentally superior technology for the generation of electrical and thermal energy for electric utility, industrial, commercial and residential markets; and (2) strengthen the national economy by providing technologies that improve U.S. international competitiveness in this new manufacturing industry, and by generating export sales for technology and products. Specific goals are:

- Near-term (to year 2000) - demonstrate and commercially introduce high efficiency, gas-fueled, multi-kilowatt, onsite powerplants and low MW electric utility powerplants at competitive costs;
- Mid-term (to year 2010) - significantly penetrate all markets for high efficiency gas-based systems, and commercially introduce coal-fueled, multi-MW powerplants at competitive costs; and
- Long-term (to year 2030) - establish commercial availability of advanced, ultra-high efficiency, integrated fuel cell systems.

These systems are among several advanced technologies currently under development that offer the prospect of reducing criteria pollutants well below current New Source Performance Standard levels, reducing noncriteria pollutants such as CO₂ and acid rain precursors, and reducing thermal emissions to the environment. These reductions are achieved through the ultra-high efficiency and the inherently low emissions of fuel cell systems. First generation PAFC systems have reached commercial status and market entry units are attempting to overcome cost barriers typical of new products. Advanced MCFC and SOFC stacks have been successfully operated at the 20 to 120-kW scale. Higher system efficiencies and lower costs are forecast for the second generation systems, which will be introduced using natural gas and later operated on gas and coal in multiple end use sectors.

Strategy (Total DOE FY 1994: \$ 51.8 Million)

Cost-Sharing Target: 30-50%

Beginning in FY 1994, the fuel cells program is included as part of DOE's overall Gas Research Program. It is evident throughout the fuel cell industry that gas-fueled fuel cells will be developed before coal-fueled fuel cells, and that gas-fueled fuel cells will most likely be placed into use years before a coal-fueled fuel cell system could be fully developed. Because research conducted by the Fossil Energy fuel cells program is applicable to both coal and gas-fueled fuel cells and since the fuel cell program is currently developing gas-fueled applications, it was decided that the program should be grouped within the Gas Program.

The strategy is to support development, integration, scaleup, and commercial scale demonstration of molten carbonate and solid oxide fuel cell power plants with increasing levels of cost sharing. In addition, the program manager will facilitate technology transfer to the private sector by stimulating interactions between manufacturers and potential users. Activities will be continued for basic and applied research on materials, processes, and components applicable to fuel cell systems to achieve steady progress in improving these technologies. This effort provides supporting technology as well as evaluation of improvements.

The advanced research subactivity supports the program objectives by studying critical enabling science and technology topics related to research on fuel cells, to better understand the basis of the underlying processes involved, and to explore novel concepts. Fuel cells are known for their superior characteristics as super clean power systems. The results of the investigations are used by those who develop, design, manufacture, and operate fuel cell systems including the MCFC and SOFC systems discussed above. Advanced research of superclean fuel cell power systems seeks to capitalize on their intrinsic high efficiency and environmentally benign characteristics, emphasizing research on electrochemistry, catalysis, interconnections, and materials interactions for molten carbonate, tubular, planar, monolith solid oxide, and advanced devices.

Impact (Mid-Term)

- Provides ultra-high efficiency, fuel flexible fuel cell power plants that will provide economic benefits, aid in securing future energy supplies, and environmental benefits.
- Provides international trade benefits because of power plant exports.

FY 1993 Accomplishments

- Operated a 20-kW coal-fueled MCFC stack on Dow Gasifier.
- Tested two 120-kW MCFC stacks, achieved 55 percent efficiency.
- Tested and thermal cycled two 20-kW MCFC area stacks.
- Fabricated and field tested two 25-kW SOFC generator systems.
- Scaled-up cell length to 100 centimeters and addressed material issues critical to systems development.

Planned Products

- Demonstration of a 1-2 MW MCFC power plant fueled by natural gas (September 1995).
- Demonstration of a 1-2 MW SOFC power plant fueled by natural gas (September 1997).
- Initial commercial production of a natural gas-fueled MCFC power plant (September 1997).

Program Funding

Program implementation is through the Morgantown. Most of the activities are through cost-shared contracts with private industry interested in commercializing these power plants. Some supporting research is also performed by the National Laboratories.

DOE Historical Spending (\$ in millions)

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	1994 Approp.
Solid Oxide Fuel Cell	16.7	18.5	18.0	18.0
Molten Carbonate Fuel Cell	28.6	31.2	29.8	32.4
Phosphoric Acid Fuel Cell	3.9	0.0	0.0	0.0
AR&TD	1.6	1.5	1.4	1.4
Total DOE	50.8	51.2	49.2	51.8

Cost-Sharing

Cost-sharing in major activities ranged from 30 percent to slightly over 50 percent in FY 1991 and FY 1992. Activities to scaleup molten carbonate and solid oxide systems continued in FY 1993.

The DOE Fossil Energy program is coordinated with GRI and EPRI fuel cells programs through periodic meetings and informal communication. The GRI and EPRI programs emphasize application to gas and electric utility industries and provide synergistic support of the DOE program, which emphasizes development of critical technologies.

Flow Diagram

Projects	1993	1994	1995	1996	1997	1998
Molten Carbonate Fuel Cell Development						
Technology Development ¹	P	P				
Pilot Scale Plants ¹	P					
Demonstration Plants ¹			D D			
Commercial Availability ²					D	
Solid Oxide Fuel Cell Development						
Technology Development ¹	P					
Pilot Scale Plants ¹		D	D			
Demonstration Plants ¹					D	
Commercial Availability ²						

¹ Cost-shared ² Privately funded

Coding: D = Initiate field demonstration P = Achieve proof-of-concept

FUEL CELLS FOR TRANSPORTATION

Tactical Objective

To utilize natural gas in compressed or liquid form, to reform natural gas to hydrogen, or to produce other fuels (e.g., methanol) for use in fuel cell vehicles (FCVs) for transportation applications.

Issues

The introduction of FCVs could result in reduced oil imports, an improved national economy, and lower pollutant emissions. Fuel cells can address environmental and energy supply concerns because they can run on hydrogen generated from alternative fuels such as methanol, ethanol, and natural gas -- all fuels that can be produced domestically. FCVs emit essentially no NO_x, particulates, or sulfur oxides, and significantly reduce emissions of hydrocarbons and CO which are major components of urban air pollution.

The U.S. consumes about as much natural gas as it produces, therefore, massive additional quantities would need to be produced for any significant reduction of petroleum use in the transportation sector. This includes utilization of natural gas to produce methanol fuel for FCVs. Methanol is a preferred fuel because of its high reforming efficiency, high storage density, and low reforming temperature. Additional infrastructure requirements also need to be addressed if any fuel other than petroleum-based hydrocarbon fuels are to be utilized in large quantities.

Natural gas in liquid form could not be transported through existing pipelines. Therefore, liquefied natural gas (LNG) would be transported by train, truck, or ships from LNG manufacturing sites to end use locations. Because the energy density of LNG is lower than other liquid fuels, greater volumes would have to be transported from the manufacturing site to bulk storage sites.

Large natural gas reformers have been developed for electric utility applications of fuel cells and are currently being used in demonstration projects. DOE is undertaking the development of advanced reformers that are capable of converting ethanol, methanol, and natural gas into hydrogen for use in PAFC or PEM fuel cells. The objective of the DOE reformer development effort is to adapt this technology to the much smaller and compact size needed for onboard vehicle applications. If successful, this would allow natural gas to be used with present day fuel cell systems.

In the long term, SOFCs may be capable of reforming natural gas and other hydrocarbons internally without the need of a separate external fuel processor. When fully developed and scaled up for vehicle applications, SOFCs will be able to operate directly on natural gas and other carbon-based fuels.

Major Goals

The major goals of the transportation fuel cells program are:

- Develop and evaluate fuel cell systems in the U.S. transportation sector;
- Provide data and information for industry to make decisions on the merits of developing commercial fuel cell systems as power sources for future transportation applications; and
- Reduce U.S. petroleum consumption significantly and improve air quality.

The following are the specific research objectives:

- Develop and demonstrate PAFC in an urban transit bus as a near-term application;
- Develop PEM fuel cell as a mid-term option for cars, vans, buses, and locomotives;

- Develop advanced reformers to convert carbon-based fuels to hydrogen for use by fuel cells;
- Develop improved hydrogen storage systems for onboard vehicle use with fuel cells;
- Evaluate SOFC as a potential long-term option; and
- Develop fuel cell powered rail locomotive.

Strategy (Total DOE FY 1994: \$ 6.40 Million)

Cost-Sharing Target: 20-40%

- Near-term efforts are directed at PAFC as the only suitable currently developed technology for transportation applications. The urban transit bus system was selected as the entry point for application of fuel cells for several reasons. A bus is large enough to accommodate a first generation fuel cell design, and the long service life of transit buses allows amortization of the initial high cost of installation over a longer period than for passenger cars. The regularity of the transit route structure permits testing under controlled conditions, and use of the technology in urban areas will accentuate the environmental benefits of fuel cells. Finally, a transit system provides for a centralized maintenance and refueling operations. The result will be a fuel cell powered bus system with performance equivalent to diesel buses, but with more than 99 percent reduction of exhaust emissions. The technology will be ready for urban buses by 1996.
- Locomotive applications require technical and economic feasibility studies to explore design flexibility, confirm efficiency and emission projections, demonstrate satisfactory operation, and evaluate maintenance costs. The approach is to retrofit conventional locomotives using existing fuel cell technology and demonstrate operation on selected railroads in a seven to nine year time frame.
- For cars and vans, the program is directed at PEM fuel cell that can achieve suitable power density. Over the last five years, the technology base has been developed to the point where the performance necessary for transportation applications can be achieved at an acceptable cost with a hybrid PEM fuel cell/battery system. A new membrane was recently developed with lower electrical resistance enabling higher current densities to be carried. Decreased platinum loadings on the electrocatalyst and less expensive separator plates also have been developed. These advances should make the PEM fuel cell economical for use in cars and vans. However, additional fundamental research and development is required for cost reduction, performance optimization, and engineering scaleup. The technology will be ready for demonstration in the late 1990s.
- Advanced reformer research will identify reformat requirements for PAFC and PEM fuel cells and examine system tradeoffs (e.g., reformer size, weight, efficiency, quality of reformat, life, cost, transient response capability, and start up time). Steam reforming, partial oxidation, or combinations of these processes will be investigated. One objective of the program is to develop advanced fuel processing systems to reform methanol, ethanol, natural gas, and other hydrocarbons into hydrogen for use in transportation fuel cell systems. A second objective is to develop better systems for onboard hydrogen storage. Development of advanced reformer and hydrogen storage technologies will provide fuel flexibility for fuel cell powered vehicles; reduce system size, cost, and startup time; and increase transient response capability.
- The SOFC system offers the best long-term prospects because it operates with internal reforming and does not require a separate reformer or peaking power source. However, the system is at the earliest stages of development. The SOFC RD&D will be focused on developing materials to reduce the fuel cell operating temperature, simplify fabrication, and improve system reliability and ruggedness.

Impact (Near-Term)

- Improves environment through utilization of natural gas/fuel cell powered vehicles.
- Displaces imported oil and utilizes available supplies of natural gas.

Impact (Mid-Term)

- Produces methanol from natural gas (methanol can be reformed to generate hydrogen for use in inter- and intra-city buses powered by fuel cells).
- Allows natural gas reforming offboard for use as hydrogen source for direct hydrogen fuel cell vehicles.

FY 1992 Accomplishments

- H-Power Corporation completed the first year of a three-year contract to design and build three fuel cell powered urban transit buses. At the end of FY 1992, H-Power completed the major subsystem designs and started fabrication of the bus structure and the 50-kW PAFC system.
- GM (Allison Gas Turbine Division) completed the second year of a 32-month RD&D contract (20 percent cost-shared) to develop the PEM fuel cell as a complete power source system for transportation applications. Improvements in membranes and electrodes were developed, state-of-the-art 5-kW PEM fuel cell stacks were built and tested, and significant progress was achieved in the methanol fuel processing and control technologies required for a complete system.
- DOE initiated a 30 month contract (11.5 percent cost-shared) in May 1992, with Arthur D. Little, Inc. (ADL), to develop the capability for reforming methanol, ethanol, or natural gas into hydrogen for use in transportation fuel cell systems, and to develop advanced systems for onboard hydrogen storage. This project will provide fuel flexibility for fuel cell powered vehicles and will also reduce system size and cost, reduce startup time, and increase transient response capability.
- Catalyst development work at Argonne National Laboratory has identified a highly promising catalyst formulation for the partial oxidation reforming of methanol and another potential catalyst formulation for the steam reforming of ethanol. Further work to characterize the stability and performance of these and other suitable catalysts will continue.

FY 1993 Accomplishments

- Issued a National Program Plan for Fuel Cells in Transportation.
- Conducted a Fuel Cells for Transportation Strategic Planning Meeting (participants represented 10 laboratories, two universities, and NASA).
- Successfully completed Phase 1 of the PEM fuel cell program with GM (demonstrated an integrated 10-kW subscale PEM system for light duty vehicle applications).
- Met all performance requirements during testing of the 50-kW PAFC and reformer system for the Fuel Cell Urban Transit Bus.
- Initiated a new procurement for research and development of a direct hydrogen-fueled PEM fuel cell for light duty vehicle applications.
- Initiated Peak Power Management Devices procurement for the fuel cell-powered bus applications.

Planned Products

- Field testing of small fleets of prototype PAFC powered buses.
- Proof-of-concept testing of a full size PEM powered vehicle.
- Proof-of-concept testing for advanced reformer and hydrogen storage systems.
- Evaluation of proof-of-concept fuel cell locomotive.

Program Funding**DOE Historical Spending (\$ in millions)**

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Reformer RD&D (ADL ¹)	0.20	0.20	0.30	0.30
PAFC Battery Bus Program (H-Power)	0.50	0.50	0.50	0.50
PEM Fuel Cell RD&D (GM ²)	2.27	2.27	3.00	3.00
Fuel Cell Locomotive (TBD ³)	-	-	1.00	1.40
Direct Use of Hydrogen Onboard (TBD)	-	0.33	0.67	0.67
Peak Power Management (TBD)	-	0.07	0.17	0.17
Core PEM RD&D (TBD)	-	0.33	0.33	0.33
ES&H ⁴ (NREL ⁵)	-	-	0.03	0.03
Total DOE	2.97	3.70	6.00	6.40

¹ ADL: Arthur D. Little, Inc.² GM: General Motors Corporation³ TBD: To be determined⁴ ES&H: Environment, Safety and Health⁵ NREL: National Renewable Energy Laboratory**Cost-Sharing (\$ in millions)**

All current FY 1993 activities are cost shared by industry.

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
H-Power	PAFC Bus Program	0.700	0.330	0.330
GM/Allison	PEM Fuel Cell RD&D	1.750	1.360	1.800
ADL	Reformer RD&D	0.090	0.070	0.108
Total		2.540	1.760	2.238

Flow Diagram

Projects	1993	1994	1995	1996	1997	1998	1999
Advanced Reformer Development	G		D				
PEM Development		G	S	G	D	P	
PAFC/Battery Bus Program		D	T				
Fuel Cell Locomotive	S				G		D

Coding:

D = Initiative field demonstration

S = Select most promising concept for further development

G = Go/no go decision

T = Transfer technology or information for application

P = Achieve proof-of-concept

MICRO-COGENERATION FUEL CELLS FOR BUILDINGS

Tactical Objective

To develop fuel cell power generation systems that are cost effective and highly efficient in supplying electric and thermal needs of buildings. To achieve high power generating efficiency of 40 to 50 percent relative to conventional generation efficiency of 36 percent.

Issues

Significant advances in fuel cell technology and materials science over the past few decades have not addressed what is perhaps the greatest potential for fuel cells, namely, cogeneration in the residential and small commercial markets with power demand of between 15 and 200 kW. Current fuel cell technology in these size ranges is about 20 to 25 percent more efficient than electric generation alternatives, even without considering the additional use of fuel cell waste heat for hot water and space conditioning.

A variety of fuel cells are being developed and they are usually classified according to the type of electrolyte used in the cells: (1) polymer electrolyte fuel cell (PEFC); (2) alkaline fuel cell; (3) PAFC; (4) MCFC; and (5) SOFC. Fuel cells of importance for near-term power generation and commercialization in the building sector are PAFC, PEFC, and SOFC.

Major issues to be addressed in fuel cells as applied to buildings are the type of fuel cells to be used, the technical merits, and the cost of electricity produced. For PEFC, the temperature capability of current membrane technology is insufficient for heat recovery or for reforming natural gas fuel. For PAFC, the present cost per kW is about \$3,500 compared with \$1,000 per kW for a conventional coal-fired generator. Other issues related to building applications are reliability for stand alone operation and minimum maintenance, durability for longer life, multiple function controls, and household safety. When the fuel cell is used in the cogeneration mode producing both power and heat it can achieve overall efficiencies as high as 80 percent.

Fuel cells have been identified by the President's National Critical Technologies Panel as one of the 22 technologies considered essential for the U.S. to develop and utilize in order to achieve economic prosperity and maintain national security.

Major Goals

- Introduce into the market economical commercial size (25-150 kW) fuel cells for buildings by the year 2010. Fuel cells using phosphoric acid and/or PEM technology, with conversion efficiencies of 60 percent or better, can supply electrical and thermal needs to several buildings. When used for electric generation and water heating, this technology can achieve system efficiencies of 80 percent and can save substantial primary energy when replacing conventional electric generating systems.

Strategy (Total DOE FY 1994: \$ 0.0 Million)

Cost-Share Target: 50%

The overall strategy is to lower costs and improve reliability (assisted if necessary by Federal incentives) and to achieve expeditious commercialization of residential and commercial fuel cells. The strategy also emphasizes: rapid attainment of technology advances through basic and applied research and development; use of pilot scale facilities and demonstration projects to test technical, economic, environmental, and institutional parameters; and identification of viable fuel cell technology programs from which to gain valuable information.

Program activities will be accomplished in three phases. Phase I includes definition of technology requirements and application, assessment of economic performance and system cost, identification of technology needs, codes, regulation, and development of the RD&D program plan. Phase II activities

include fuel processing, and power conditioning. Phase III is comprised of stack modifications, design, fabrication, and system testing.

Impact (Mid-Term)

- Provides energy security: the potential exists for energy production well beyond the capability of present generating systems. The siteability and modularity of fuel cells will aid in the reduction of high loss transmission lines as they are spread across the Nation today. The use of fuel cells has the potential to reduce the energy required to provide essential services by 50 percent or more compared to current practices.
- Enhances economic competitiveness: advances in fuel cell technologies has, for the present time, given the edge to foreign countries that are using U.S. developed technology to manufacture and sell fuel cells. Although the U.S. is a leader in specific technologies, the micro-cogeneration fuel cell program will open substantial markets for siteable small scale (25-150 kW) fuel cells for building applications.
- Reduces institutional barriers: government supported research assists the private sector in reducing the risk of developing new concepts of energy efficient equipment. Working with major manufacturers and suppliers of natural gas assures and lends credibility to market introduction of newly developed products.
- Provides environmental integrity: fuel cells utilization, as a means of generating electricity, will help achieve the stringent emissions standards on combustion systems required by the CAAA over the next 20 years. New standards will require electric industries to ensure better efficiency of combustion systems and scrubbing of exhaust gases. The growing concerns regarding environmental problems will accelerate the development and implementation of fuel cell technology worldwide.
- Ensures customer acceptance: improved efficiency, reliability, and durability of cost-effective fuel cells will result in consumer acceptance for new or replacement hardware. Gas and electric utilities can reduce peak loads on central plants, reduce transmission and distribution systems, and utilize facilities more efficiently, thereby reducing the need for new plant construction.

Planned Products

- Completion of the industry cost-shared development of a laboratory breadboard fuel cell, either PAFC or PEM technology, in the range of 25-150 kW for testing and evaluation.

Program Funding

DOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Fuel Cells for Buildings	-	0.0	2.5	0.0
Total DOE	-	0.0	2.5	0.0

Cost-Sharing

Industry cost-sharing is expected to be 50 percent.

Flow Diagram

Projects	Completion
Base Program	
Fuel Cell: Complete development and laboratory testing of breadboard system of first generation fuel cell for micro-cogeneration in building applications	FY 1997

Projects	1993	1994	1995	1996	1997
Phase I	<div></div>				
Phase II					
Phase III					

GAS-TO-LIQUIDS CONVERSION

Tactical Objective

To demonstrate technology for economical conversion of methane and other light hydrocarbon gases to liquids that can be used as light transportation fuels or chemical feedstocks, consequently increasing the available sources of supply for liquid transportation fuels and reducing the demand for crude oil-derived liquid transportation fuels.

Issues

Domestic supplies of natural gas are abundant. However, some gas resources are remote from gas transportation systems or contain large amounts of nonmethane gases making some resources uneconomical to market as natural gas. Such resources may be shut in or flared where permitted. Methane and other light hydrocarbon gases are also low value byproducts of crude oil upgrading and refining, and other conversion processes. The ability to convert these low value gases to high value liquids could have significant favorable economic and energy efficiency impacts.

Currently, processes for conversion of gas-to-liquids have poor efficiency and economics, operate at severe conditions requiring multiple steps (e.g., methane-to-methanol-to-gasoline, and syngas), and require large capital investments and operating costs. Development of advanced processes to convert methane gas to liquids requires a better understanding of catalytic and kinetic effects to control conversion and selectivity for producing desired products at acceptable yields.

One route toward developing a better understanding of catalytic effects and kinetics is the study of biological organisms that convert methane to methanol in nature. Better understanding of these systems could lead to improved catalysts and processes that produce high yields of desired products under moderate process conditions.

Another major factor in control of selectivity, yield, and costs in conversion systems involves prompt separation of desired products from reactants. This ensures that the reaction will not be hindered from proceeding toward completion, or will not degrade desired products to undesired products. New separation methods may provide a substantial improvement toward enhancing selectivity, increasing yields, and reducing costs.

Major Goals

The goal of this program is to convert methane to liquids or chemicals in a simple one- or two-step process under moderate operating conditions of pressure and temperature. This goal can be achieved by eliminating intermediate conversion steps thereby reducing process equipment and operating under moderate conditions to avoid exotic and expensive materials of construction that add to capital and operating costs required by current technology.

Strategy (Total DOE FY 1994: \$ 3.628 Million)

Cost-Sharing Target: 40-50%

The research strategy is carried out through two coordinated activities, one focusing on the conversion of natural gas-to-liquids and the other on conversion of light hydrocarbons (primarily methane) that are derived as byproducts of other hydrocarbon processing methods, including refining and coal conversion.

- **Natural Gas-to-Liquids:** The natural gas-to-liquids conversion research executed at Morgantown is a multidisciplinary effort focused on the development of an economic, direct conversion process that will convert natural gas to higher value liquid fuels, and provide a means of transporting natural gas from remote locations to the marketplace. Activities include theoretical and experimental investigations in catalytic, noncatalytic, and biological conversion processes directed toward specific research

objectives: (1) derive fundamental information and concepts about chemical reactions during conversion; (2) enhance conversion rates and selectivity; and (3) improve separation and recovery of the product.

- **Process Derived Gas Processing Research:** The gas processing research executed at Pittsburgh is focused on developing the scientific and engineering knowledge base for industry use in manufacturing hydrocarbon fuels and chemicals from process derived gases. Currently, the three most advanced direct conversion technologies are: (1) partial oxidation; (2) oxyhydrochlorination; and (3) oxidative coupling. The conversion of methane using enzymes is also being investigated. This program seeks to accomplish innovative improvements over the state-of-the-art conversion technologies through staged development from laboratory scale to bench scale and finally to the proof-of-concept scale.

Impact (Near-Term)

Leads to the discovery, proof-of-concept, and demonstration of new chemistry for direct conversion of methane rich gases to liquid fuels.

Impact (Mid-Term)

Encourages or promotes construction of commercial plants based on new direct conversion processes.

FY 1992 Accomplishments

- Discovered a promising new catalytic approach to the direct production of methanol-rich oxidates from natural gas. This new catalytic process, if successfully developed, will be effective in the conversion of light alkanes to alcohols or other oxygenates.
- Identified catalysts that produce ethylene and ethane from methane in about 10 percent yields and 100 percent selectivity. Studies have shown that higher oxygenated catalysts exhibit better catalytic properties than lower oxygenated catalysts.
- Discovered that highly substituted porphyrin catalysts were active for methane conversion. (Activity follows the electron withdrawing ability for the highly substituted porphyrins.)
- Selected seven new projects to investigate novel concepts for direct conversion of light hydrocarbon gases to liquid fuels.

FY 1993 Accomplishments

- Determined that the presence of water during oxidative methane coupling decreases the concentration of multiple exchange sites and thereby decreases total oxidation.
- Investigated conversion of methane to C₂ products and formaldehyde over silicas and determined that two different parallel mechanistic pathways exist for the conversion of surface activated methane.
- Demonstrated that the SO_{4.2}/Sr/La₂O₃ catalyst exhibit good stability in the temperature range of 500-600 °C, and is one of the most active and selective oxidative coupling catalyst for converting methane to C₂ products ever reported.
- Made progress in the synthesis of new catalytic materials promising much greater activity than earlier generation catalysts for oxidizing methane, ethane, and propane; demonstrated improved results for propane and ethane.

- Scaled-up the biomimetic work and identified potential industry partners for application of this technology for commercial processes.
- Developed a stable and highly selective copper-based catalyst for conversion of methane to methyl chloride; initiated a bench-scale continuous flow reactor for use in optimizing process conditions.

Planned Products

- Completion of exploratory research, evaluation of biomimetic catalyst alternatives, and identification of promising concepts (Morgantown/Pittsburgh).
- Completion of proof-of-concept research on oxyhydrochlorination process (Pittsburgh).
- Demonstration of proof-of-concept of a biomimetic catalyst process with industry (Morgantown).
- Completion of exploratory research and evaluation of novel concepts selected from FY 1992 Program Research and Development Announcement (PRDA) (Pittsburgh).
- Selection of promising process concepts for cost-shared proof-of-concept testing in integrated process development units (Morgantown/Pittsburgh).
- Completion of proof-of-concept testing in integrated process development units (Morgantown/Pittsburgh).
- Selection of promising process concepts for cost-shared demonstration of commercial feasibility (Morgantown/Pittsburgh).
- Completion of cost-shared demonstration with industry of direct conversion processes at scale sufficient for industry to evaluate commercial prospects and proceed with construction of commercial plants (Morgantown/Pittsburgh).

Program Funding

DOE Historical Spending (\$ in millions)

Performer	Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Morgantown					
Lehigh University	Novel Catalyst Research	0.135	0.150	0.155	0.155
LBL ¹	Characterization of Gasification Catalyst	0.110	0.200	0.175	0.175
INEL ²	Catalyst Conversion Control	-	0.030	0.000	0.120
LLNL ³	Novel Catalyst Biological Research	0.200	0.150	0.150	0.150
Morgantown	Novel Catalyst Assessment	0.507	-	-	-
Sun R&M ⁴	Biomimetic Catalyst Development	0.427	1.000	1.000	1.000

DOE Historical Spending (continued)

Performer	Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Colorado University	Membrane Reactor Studies	0.169	0.197	0.000	0.000
TBD ⁵	Module Feasibility	-	-	0.000	0.000
Morgantown	Assessment and Economics	-	0.230	0.100	0.076
Total Morgantown		1.548	1.957	1.580	1.676
Pittsburgh					
Amax	Selective Oxidation	-	-	0.160	0.180
SNL ⁶	Light Hydrocarbon Gas Conversion	0.225	0.200	0.200	0.225
Amoco	Partial Oxidation/OCH ⁷	-	0.600	0.302	0.362
Dow Corning	Oxyhydrochlorination	-	-	-	0.025
Pittsburgh	OCH Research	0.600	0.500	0.318	0.200
Pittsburgh/TBD	Gas-to-Liquids Research	0.826	0.700	-	-
University of Delaware	Superacid Catalysts	-	-	0.080	0.100
MIT ⁸	Light Hydrocarbon Gas	-	-	0.120	0.160
SRI ⁹	Novel Catalysts for Methane	-	-	0.160	0.210
Worcester Poly Tech	Methane Coupling	-	-	0.170	0.200
Ultamira Institute	Direct Aromatization	-	-	0.085	0.130
IGT ¹⁰	Gasoline from Methane	-	-	0.155	0.160
TBD	OCH Pilot Demonstration	-	-	0.000	0.000
Total Pittsburgh		1.651	2.000	1.750	1.952
Total DOE		3.199	3.957	3.330	3.628

¹ LBL: Lawrence Berkeley Laboratory² INEL: Idaho National Engineering Laboratory³ LLNL: Lawrence Livermore National Laboratory⁴ Sun R&M: Sun Refining and Marketing Co.⁵ TBD: To be determined⁶ SNL: Sandia National Laboratories⁷ OCH: Oxyhydrochlorination⁸ MIT: Massachusetts Institute of Technology⁹ SRI: SRI International¹⁰ IGT: Institute of Gas TechnologyCost-Sharing (\$ in millions)

All candidate program activities involve cost-sharing. The activities are closely coordinated with GRI, which is a cost-sharing participant in several of the projects. Cost-sharing excludes the in-house portion of research at Morgantown and Pittsburgh as well as some of the fundamental and exploratory research conducted by National Laboratories. The extent of cost-sharing varies from contract-to-contract, with an overall average of 40 percent.

Cost-Sharing (continued)

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
Morgantown				
LBL	Gasification Catalyst	-	-	-
Lehigh University	Novel Catalyst	0.035	0.035	0.035
LLNL/GRI	Novel Catalyst Biological Research	0.100	0.100	0.100
INEL	Catalyst Conversion	-	-	-
Morgantown	Novel Catalyst Assessment	-	-	-
Sun R&M	Biomimetic Catalyst Development	0.458	2.000	2.000
Colorado University	Membrane Reactor Studies	-	0.125	0.000
TBD	Module Feasibility	-	-	0.000
Morgantown	Assessment and Economics	-	-	-
Subtotal Morgantown		0.593	2.260	2.135
Pittsburgh				
SNL	Light Hydrocarbon Gas Conversion	0.225	0.200	0.250
University of Delaware	Superacid Catalysts	-	-	-
Amax	Selective Oxidation	-	-	-
Dow Corning	Oxyhydrochlorination	-	0.397	0.900
Pittsburgh	OCH Research	-	-	-
Pittsburgh/TBD	Gas-to-Liquids Research	-	-	-
MIT	Light Hydrocarbon Gas	-	-	-
SRI	Novel Catalysts for Methane	0.002	0.001	0.002
Worcester Poly Tech	Methane Coupling	0.017	0.008	0.018
Amoco/ANL	Partial Oxidation/OCH	0.092	0.323	0.369
Ultamira Institute	Direct Aromatization	-	-	-
IGT	Gasoline from Methane	-	-	-
TBD	OCH Pilot Demonstration	-	-	0.000
Subtotal Pittsburgh		0.336	0.929	1.539
Total		0.929	3.189	3.674

Natural Gas-to-Liquids Research: Activities in FY 1993 include projects at two National Laboratories (LLNL, LBL), one university (Lehigh University), one industrial firm (Sun Refining and Marketing Co.), as well as continued in-house assessments at Morgantown on catalysts and system economic issues. The LLNL project is a collaborative research activity which includes participation by GRI, and the project with Sun Refining and Marketing Co. includes cost-shared funding by both GRI and the performing company.

Process Derived Gas Processing Research: Activities in FY 1993 include continued in-house research at Pittsburgh on the oxyhydrochlorination process and systems evaluations, one National Laboratory project at SNL on biomimetic catalysis, one continuing project with industry (with Dow Corning), and eight projects selected from PRDA. One of the industrial projects targets aspects of the oxyhydrochlorination process and includes cost-sharing by GRI and the performer. The project with industry will be cost-shared at a 50 percent level by Dow Corning for the oxyhydrochlorination process. New exploratory research activity in light hydrocarbon gas processing will be initiated through the above mentioned procurement.

Flow Diagram

Projects	1994	1995	1996	1997	1998	1999
Basic Mechanism Study and System Evaluations	G _____ T					
Noncatalytic Conversion Concepts	G _____ S _____ P					
Biological and Biomimetic Concepts	_____ P					
Testing of Biomimetic Catalytic Concepts	_____ T _____ P					
Testing of Novel Catalytic Concepts and Reactors	_____ G _____ P					
Process Development and Testing of OCH Technology	_____ S _____ P					
Exploratory Gas Processing Research	S _____ P					
High Priority Concepts	_____ D _____					

Coding:

D = Initiative field demonstration
 S = Select most promising concept for further development
 G = Go/no go decision
 T = Transfer technology or information for application
 P = Achieve proof-of-concept

GAS INTEGRATED RESOURCE PLANNING

Tactical Objective

To develop a comprehensive primer on gas IRP, which will be directed toward State public utility commissions and gas utility staff.

Issues

Utilities are beginning to use gas IRP as a new planning instrument to compare the costs and benefits of electricity supply and demand options as shown in 1990 which was the first year when most gas utility IRP plans were filed. There are 15 States with some form of gas IRP requirement either in practice or under development. Gas DSM programs have been developed in response to PUC requirements in 10 States. Development of gas DSM and IRP have been hampered by limited information on technical and market potential, and disagreement on appropriate economic tests and levels of avoided gas costs.

Major Goals

- Prepare information on gas IRP for State public utility commissions so they can make informed technical decisions. Specific research objectives are twofold: (1) focus specific information on the unique characteristics of the gas utility industry; and (2) identify where IRP can be applied.

Strategy (Total DOE FY 1994: \$ 0.500 Million)

Cost-Sharing Target: None

- Investigate analyses of various approaches used for economic tests in States and discuss issues on appropriate levels of avoided gas costs.
- Determine regulatory, structural, and geographic factors affecting the level of DSM activity for gas utilities.
- Compare gas planning processes and utility assessments of technical and market potential, and offer suggestions on preparation of plans for commissions and gas utilities.
- Examine integration of gas efficiency options into existing gas supply planning models and methods used to evaluate DSM program options, and analyze fuel substitution policies and technical issues.
- Conduct a comparative analysis of IRP and DSM plans being submitted by 15 gas utilities that are leaders in the field.

Impact (Near-Term)

- Increases gas IRP at the State level with more informed decisionmaking with handbook availability.
- Encourages gas DSM plans to be implemented by more utilities in different arrangements, such as collaborative projects, utility initiated projects and under PUC orders.

FY 1993 Accomplishments

- Completed draft of the Gas IRP Primer.

Planned Products

- Distribution of a primer through the National Association of Regulatory Commissioners to State public utility commissions (hybrid and gas utilities will receive copies if they are interested).

- Evaluation of the gas IRP status in accordance with Section 115 of EPACT.
- Development of other planning tools, as needed, to assist local distribution companies and utility companies in implementing gas IRP.

Program Funding

DOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Primer for Gas Integrated Resource Planning	0.200	0.300	0.500	0.500
Total DOE	0.200	0.300	0.500	0.500

Cost-Sharing

Not anticipated.

Flow Diagram

Project	1993	1994	1995	1996	1997	1998
Primer for Gas Integrated Resource Planning	_____T					

Coding:

T = Transfer technology or information for application

GAS DEMAND-SIDE MANAGEMENT TECHNOLOGIES

Tactical Objective

To prepare a status report on the potential efficiency and costs of residential gas efficiency technologies for gas utility DSM programs.

Issues

Gas DSM programs are in the early stages of implementation in 10 States as directed by State PUCs. According to a 1990 national survey conducted for the National Association of Regulatory Utility Commissioners, lack of technical and market information has been hampering the implementation of DSM programs.

Major Goals

- Collect and analyze information on gas end use technologies that are not being performed on a national level by others; and
- Assess the possibility and range of savings in gas DSM programs.

Strategy (Total DOE FY 1994: \$ 0.0 Million)

Cost-Sharing Target: None

Using the 1990 survey, the leaders of gas DSM programs will be contacted for information on technologies installed in their programs. Comparisons of existing gas industry technologies and information sources will be completed.

Planning for and conduct of the first National Gas Demand-Side Management Conference will be initiated. This conference is designed to disseminate the gas IRP information and successful DSM experience to the regulatory organizations and utility industry.

Impact (Near-Term)

- Benefits gas DSM programs because of nationally available technical information.
- Increases application of gas IRP as a result of access to technical information by staff of State PUCs.

Impact (Mid-Term)

- Provides a status report on the potential efficiency and costs of residential gas efficiency technologies that are being installed and/or will be installed for gas utility DSM programs.

Planned Products

- Preparation of a comparative listing of gas DSM technologies.
- Planning and identification of sponsors for the first National Gas DSM Conference in 1993.
- Planning and conducting of the first National Gas DSM Conference in 1993.

Program Funding**DOE Historical Spending (\$ in millions)**

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Comparison of Gas DSM Technologies and Planning of National Gas DSM Conference	0.025	0.025	0.000	0.000
Total DOE	0.025	0.025	0.000	0.000

Cost-Sharing

Not anticipated.

Flow Diagram

Not applicable.

MUNICIPAL SOLID WASTE

Tactical Objective

To demonstrate beneficial use of both municipal solid waste and other organic wastes by converting these to methane.

Issues

A community scale test is necessary to demonstrate that anaerobic digestion technology can efficiently convert combined MSW and sewage sludge into methane. The disposal of both tuna sludge and MSW is a major problem for American Samoa. Applicability of anaerobic digestion, high solids reactors for converting MSW, tuna sludge, and similar wastes into methane need to be determined. In addition, improving the timely generation, capture, and beneficial use of landfill methane, will increase application of this technology.

Major Goals

The projects now underway have the following goals:

- Design, build, and operate a community scale anaerobic digestion system for combined digestion of MSW and sewage sludge;
- Develop a high solids digestion system for combined digestion of MSW and tuna sludge for American Samoa; and
- Understand the gas migration and emissions from landfills, increase its capture and beneficial use, and develop techniques for increased gas production from organic matter in landfills.

Strategy (Total DOE FY 1994: \$1.700 Million)

Cost-Sharing Target: 20-40%

The approach is to utilize the experience from previous anaerobic digestion pilot experiments to develop a community based system with industry cost-sharing and a host community participation. Laboratory data will be obtained to develop a design for a pilot scale system for high solids digestion of MSW and sewage sludge for use in American Samoa. In addition, DOE will collaborate with other partners to understand emissions from landfills and increase gas production. All these efforts are aimed at increasing the production of methane from municipal waste and promoting its beneficial use.

Impact (Near-Term)

- Reduces emissions from landfills and increases capture of the estimated 0.5 quad/year of methane that is available from landfills.
- Develops anaerobic digestion technology with a potential for contributing 0.5 quad/year of energy.

FY 1993 Accomplishments

- Completed construction of 1,000-liter test reactor.
- Started testing in the 1,000-liter test reactor.
- Collected gas emission data at the Illinois site.

Planned Products

- Production of natural gas for beneficial use.

Program Funding**DOE Historical Spending (\$ in millions)**

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Anaerobic Digestion System	0.794	0.100	0.100	0.100
High Solids	0.360	1.125	1.300	1.300
Landfill Gas	0.246	0.300	0.300	0.300
Total DOE	1.400	1.525	1.700	1.700

Cost-Sharing

Cost-sharing for the community scale system is expected to be a minimum of 50 percent for the entire project. For the American Samoa project, cost-sharing in excess of 10 percent from the participating industries is expected. Cost-sharing of about 50 percent is expected from State organizations and industry for the landfill gas projects.

Flow Diagram

Projects	1993	1994	1995	1996	1997
Pilot Scale System for American Samoa					
Landfill Gas Emissions Data for Illinois Site					

MATERIALS DEVELOPMENT

Tactical Objective

To develop an industrial technology base in advanced materials for engines, and to optimize the use of alternative fuels in vehicles.

Issues

The issues in this program are the result of workshops with industry which identified critical needs. The research program is designed to meet critical materials needs related to fuels and emissions. Issues that require investigation are as follows:

- Critical evaluation of catalytic materials for use with alternative fuels to enable more efficient reduction of emissions and to improve the durability of catalysts;
- Identification and supporting development of lean burn catalyst technology that would be applicable to two-stroke and diesel engines;
- Evaluation of durability of all composite high pressure natural gas cylinders and assessment of their worthiness for extended vehicle applications;
- Development of onboard, nondestructive evaluation (NDE) technology for continuous monitoring of conditions for safe operation using natural gas;
- Development of protocols to standardize catalyst testing, aging, and reporting methods;
- Evaluation of technology required to improve durability and permeability of onboard and infrastructure storage tanks for alcohol fuels; and
- Identification of alcohol compatible materials and materials technology that will lower the processing costs of alcohols from biomass technology.

Improved materials of all types, as available, will be exploited so that their inherently superior properties will make the greatest contribution to improved energy efficiency, reduced environmental degradation, and greater utilization of alternative fuels.

Major Goals

The major goals of multi-phase project tasks now in progress are:

- Evaluate new and used catalysts obtained from industrial partners to assess mechanisms by which deterioration is occurring;
- Establish test facilities to evaluate catalyst durability and testing protocols;
- Obtain and modify AFVs from industry participants;
- Evaluate feasibility of utilizing spinoff technology to develop NDE methodology;
- Develop partnership and obtain cost-sharing funding to initiate NDE program in FY 1993;
- Conduct a government/industry/academia workshop to determine alternative paths and technologies applicable to solution of problems related to biomass processing materials; and

- Develop accelerated research and development follow-on plan.

Strategy (Total DOE FY 1994: \$0.0 million)

Cost-Sharing Target: 50%

The program goal is to develop an industrial technology base on materials for alternative fueled engines. Program emphasis is on carrying out the research and development within the industry and companies that can best utilize the technology in their products. The intent is to involve industry in every phase of the program from the planning process to conducting the research and, ultimately, to utilizing technology improvements resulting from the program.

Impact

- Reduces NO_x and particulate levels from two-stroke engines to meet ultra clean car levels.
- Eliminates aldehyde emissions from AFVs by 90 percent.
- Extends catalyst durability to 100,000 miles.
- Reduces cost of biomass processing of alcohols by at least 25 percent.
- Reduces operating costs of CNG vehicles while improving safety reliability factors.
- Develops double durability of infrastructure systems for storing alcohols.

FY 1993 Accomplishments

- Started cooperative research with industry.
- Initiated analysis of new and used industry-government cooperative research program (over 60 percent matching funds) on NDE of composite and compressed natural gas cylinders
- Completed workshop on materials and corrosion protection for biomass processing plants (research plan was developed in cooperation with ORNL and NREL).

Program Funding

DOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Alternative Fuels Compatible Materials Program	1.00	0.80	3.00	0.00
Total DOE	1.00	0.80	3.00	0.00

Cost-Sharing

FY 1993 cost-sharing was \$1 million (50 percent) in industry matching funds through the cooperative research and development agreement (CRADA) for catalyst activities established under Low Emission Partnership program. The planned FY 1994 cost-sharing level is also \$1 million (50 percent).

Flow Diagram

Not applicable.

ELECTRIC AND HYBRID VEHICLES

Tactical Objective

To assist U.S. industry in developing and demonstrating the viability of an HV technology base, which is needed to enable the design, production, and future use of HVs as a competitive transportation alternative.

Issues

The transportation sector of the U.S. economy depends almost totally on petroleum as an energy source. In 1990, 64 percent of oil used in the Nation was consumed by the transportation sector and personal vehicles accounted for more than 60 percent of this use. Approximately half of the petroleum consumed in the U.S. is imported, which contributes heavily to the U.S. balance of payments deficit and results in an already demonstrated vulnerability to petroleum supply disruptions. Energy use projections indicate that our petroleum dependence will continue to worsen despite continuing improvement in vehicle fuel efficiency. National security considerations compel us to develop ways to reduce such reliance on foreign petroleum.

In addition, as local and regional governments attempt to clean the air in our cities, they focus increasingly on transportation solutions. Global environmental consequences resulting from the current widespread use of internal combustion engines in personal vehicles provide further impetus. The internal combustion engine operating on petroleum based fuels is a major source of emissions and the first line of attack has been to improve its efficiency and reduce its emissions. Success in both areas has been significant in the last decade, but further emission reductions are being required as annual vehicle miles traveled continue to grow. Current technology alone is not projected to meet increasingly strict emission requirements in some areas.

A partial solution could be to optimize the engine to use alternative fuels such as natural gas or nonpetroleum fuels, which are derived from extensive indigenous and renewable sources such as alcohols from coal or biomass.

Another technology option could be 100 percent electric vehicles (EVs). As technological improvements increase the range and acceptance of EVs, development of HVs will proceed in parallel, providing consumers and regulators with more than one future reduced emission alternative for meeting different driving requirements.

HVs, which use more than one method to convert stored energy to propulsion energy, can offer distinct advantages for transportation. Unlike vehicles that can operate only with liquid fuels, HVs can be extremely efficient onboard energy converters, resulting in high mileage performance as well as low emissions. Unlike vehicles that can operate only with battery stored power, HVs offer a significantly extended range and easy refueling using existing infrastructure, thus improving consumer acceptance.

Successful commercialization of HVs should have energy security, environmental, and economic benefits significant enough to warrant this government/industry development initiative. Estimates of these benefits are derived from projections of HV market penetration, which depend on future and uncertain technical and economic competitiveness with conventional and other alternative vehicle systems. Developing the new market segment also can provide a boost to U.S. industrial competitiveness, by improving the manufacturing base and providing products that can compete in a rapidly growing domestic and world market for "green" (or environmentally sound) vehicles. In addition, the development of advanced technologies and components for HVs could provide the type of "high value added" element to our industrial base that results in benefits far beyond the field in which the element is first introduced.

HVs that use a combination of electric and internal combustion engine systems could offer flexibility to meet differing transportation market requirements. In HVs, range is greatly extended over that of EVs by increasing the energy density of the storage subsystem, typically with liquid fuels.

Major Goals

HVs hold the promise of significantly reducing transportation energy requirements, which is critical to reducing petroleum imports and reducing vehicle emissions. HVs use a combination of electric and internal combustion engine systems offering the extended range consumers require of vehicles as well as rapid refueling potential similar to that of conventional vehicles.

The acceleration of HV commercialization can be accomplished by supporting U.S. industry in its more rapid development and deployment of HV propulsion systems while industry occupies itself with developing advanced body and structural systems (e.g., including aerodynamics, lightweight and composite materials, and tires); internal systems (e.g., including heating and cooling systems requiring lower parasitic power draws); and infrastructure systems. More specifically, DOE intends to:

- Collaborate with industry to identify and test potential near- to mid-term technologies related to advanced HV propulsion systems;
- Coordinate a national technology development effort to address the potentials identified; and
- Cofund the early technology development with industry.

Major program goals are to:

- Accelerate the development and use of HV technologies to meet pressing national goals of energy efficiency and environmental acceptability;
- Reduce U.S. petroleum use in transportation sector before the year 2010, and improve the competitiveness of the U.S. industry in advanced vehicle propulsion;
- Accelerate the integration of a viable set of technologies for use in HVs;
- Integrate improved and reliable propulsion, control, and energy storage technologies while maintaining the HV cost within an acceptable range and otherwise meeting market requirements for performance and safety; and
- Support early development of HV propulsion systems through the initial demonstration phase.

Strategy (Total DOE FY 1994: \$4.8 Million)

Cost-Sharing Target: 50%

The main thrust of the HV program will be to support competitive U.S. industry "teams" in developing and demonstrating hybrid propulsion system prototypes that are progressively more responsive to the market requirements for HVs. These teams will be funded under cost-shared contracts through several phases of development to further their hybrid propulsion concepts. This will yield a range of demonstration vehicles for evaluation and testing.

DOE proposes to closely involve industry in the planning and implementation of the HV Program and to incorporate past and continuing output of related technical programs such as the Fuel Cell Program, the Advanced Heat Engine Program, and the U.S. Advanced Battery Consortium Program. The HV Program also will benefit from continuing research and development by such industry associations as GRI and EPRI.

The overall strategy for the Program involves accelerating HV realization by supporting multiple competitive

development projects for hybrid propulsion system. This strategy is intended to reduce front-end risk by allowing competing industry "teams" to use existing and near production technologies that are considered company proprietary.

Driving elements of the HV Program strategy are:

- Forming industry teams wherein each member brings specific expertise to the HV development effort;
- Realizing a government/industry cooperative effort that shares the cost, risk, and direction of the development effort, but gradually shifts the responsibilities solely to HV industry participants;
- Coordinating with (and continuously feeding from) a number of other DOE/industry technical development activities;
- Actively incorporating HV infrastructure components early in the development process; and
- Prompting the participation of these segments of private industry that are key to HV technology commercialization.

There are clear advantages to a program strategy that anticipates using the existing manufacturing infrastructure in the U.S. to manufacture, assemble, market, distribute, and maintain the product being introduced. The HV Program has included all of the major U.S. auto manufacturers in planning and anticipates that they will have a major role in HV development. In this way, the Program will gain access to the required expertise and experience while involving large U.S. corporations that can raise the necessary capital. The capital needs have been estimated to be several hundred million dollars for pre-acquisition of final HV production machinery and multiple billions of dollars for HV product commercialization.

A final element of the HV Program strategy is to emphasize the practicality of the HV concept by focusing on the potential for commercializing specific candidate HV concepts. This encourages the manufacturers and their supplier base to share the investment in the program and to fashion their development programs within a long-term market perspective rather than resting on the mere satisfaction of some program milestones.

Impact (Near-Term)

- Accelerates HV technology development.
- Allows development, demonstration, and testing of HV propulsion prototypes.

Impact (Mid-Term)

- Assists the U.S. automobile manufacturers in commercialization and production of HVs.
- Improves the potential for development of advanced HV systems.
- Provides energy security, and environmental and economic benefits.
- Increases U.S. industry competitiveness.

FY 1993 Accomplishments

Not available.

Planned Products

The HV Program will be divided into phases for each of the multiple propulsion system development projects. Each phase will be fully defined in cooperation with the individual development teams prior to commencement of the development work. Agreed upon work plans are expected to be integrated with or complemented with the normal automotive industry development steps leading to a production vehicle. Each step will provide the program with a continuation decision point based on a review of performance evaluation criteria.

The Program products are:

- Definition and preliminary modeling of the system(s) to be pursued.
- Testing of individual components.
- Development of integration schemes and the necessary controls.
- Testing and identification of proper combination to achieve the program goals.
- Production of demonstrable test vehicles.

Program Funding

The Program's funding requirements are estimated to be \$100 million per team over five years for two to four competitive teams. Industry will provide at least one-half of that funding. Industry partnerships also will be structured to ensure that the program output will be one or more new automobiles that U.S. industry can produce and that will have sufficient market acceptance to make production financially attractive.

The DOE-funded portion of the HV Program will be conducted mainly through contracted efforts with commercial suppliers and manufacturers for development of advanced technologies. The contractors will develop improved propulsion subsystems for applications in HVs. The major propulsion system prototype development contracts will be competitively awarded to multiple teams, based on proposals submitted in response to a request for proposal (RFP).

DOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
System Development	0.0	4.2	4.8	4.8
Total DOE	0.0	4.2	4.8	4.8

Cost-Sharing

Each of the industrial teams will be required to significantly involve a vehicle manufacturer and fuel supplier under a cost-sharing agreement with the Midwest Research Institute. It is anticipated that the vehicle manufacturer on each team will take the primary responsibility for developing a commercially viable HV, for which a specific strategy will be detailed in each team's response to the RFP. The fuel supplier will be cognizant of the infrastructure requirements of alternate fuels proposed. Cost-sharing by industry will be at least 50 percent, and participation of DOE's National Laboratories and nonprofit organizations will be encouraged; participation of small businesses will be required.

Flow Diagram

Projects	1993	1994	1995	1996	1997	1998
Program Definition
System Integration Review						
Vehicle Confirmation and Approval						

INTERNATIONAL ENERGY AGENCY CENTER FOR GAS TECHNOLOGY INFORMATION

Tactical Objective

To promote the widespread commercialization of gas-related technologies by providing a continuing international forum where an effort to increase information dissemination and international cooperation and collaboration concerning gas technologies can take place.

Issues

International Energy Agency (IEA), founded in 1974, is the energy forum for 21 industrialized countries. Among its other activities, IEA helps member countries set up collaborative projects for RD&D of energy related technologies. In October 1990, IEA sponsored a conference in Lisbon, Portugal, on emerging natural gas technologies. The outcome of the conference was the recommendation that an International Center for Gas Technology Information be established. In response to IEA's recommendation, DOE and the Danish Ministry of Energy agreed to present a joint proposal for the formation of the Center. DOE asked GRI to be the focal point for forming the Center.

There is a growing awareness on the part of the international natural gas community of the need for better access to information about gas technologies, and for analyses aiming at enhancing RD&D cooperation and technology transfer in gas supply, transportation, and utilization. Many of the interested participants need to gain access to a comprehensive source of information in order to better coordinate investments in RD&D, more rapidly and broadly disseminate both research results and early marketplace experience with new technologies, and facilitate the adoption of proven technologies over wider geographic markets.

Today, a variety of organizations collect information about energy and technology, but none of these organizations exclusively focus on natural gas technology. Furthermore, there is no international clearinghouse to facilitate the exchange of such information among participants and potential users of technology. There are substantial efforts underway throughout the world to improve the technologies of gas production, transportation, and utilization. An inventory of new technological concepts awaits introduction into the marketplace, and experience is being gained with field testing and early introduction of new practices and equipment. The body of information gained in these activities is being communicated, but usually only in bilateral exchanges among the most active participants.

Development of this information source will require a proactive effort to bring the most active current participants into the dialogue, to organize the available inventory of technological experience, and to develop communication networks that reach a global audience of potential gas technology users which do not have extensive RD&D activities. In addition, it will require original analyses to consider the requirements for adaptation of emerging technologies to applications in new economic, cultural, and climatological situations.

Major Goals

Assessments of the global natural gas resources, collection of general gas production and consumption data, and projection of supply and demand are currently being provided by a variety of commercial, national, and international organizations. Rather than duplicating these efforts, the Center will focus its analytical activities on emerging problems and on opportunities in the marketplace that are amenable to the application of gas-related technologies.

The Center will perform three basic functions: technology information exchange, technology analysis, and technology transfer. The technology information exchange function will provide members and other subscribers access to information concerning important gas technology advancements. The technology analysis function will identify the problems, opportunities, and needs of the gas industry and its customers that can be addressed through technology. Finally, the technology transfer function will facilitate and

expand applications of gas technologies through a continuing international forum where information and experience about new and emerging technologies can be exchanged by both existing and potential users.

More extensive and better targeted international cooperation and collaboration in RD&D will enable individual members of the Center to transfer gas technologies and practices more effectively into the global marketplace. The focus will be on new and emerging technologies and their applications.

The Center does not contemplate funding or managing any RD&D projects. The IEA Center will be a nonprofit organization funded by those member countries desiring to participate. Policy guidance and strategic direction will come from the International Executive Committee of sponsoring IEA members. Gas Technology Information, Inc., a joint corporation of GRI and the Danish Technology Center, will be the legal entity acting as the Operating Agent for the Center.

Strategy (Total DOE FY 1994: \$0.875 Million)

Cost-Sharing Target: TBD

Through establishment of the Center offices and interaction with the Executive Committee, the Center will develop visibility in the international community as soon as is practicable. An early workshop on specific topics involving the role of gas technologies will help to identify the Center's central role in a network of government and industry entities interested in gas technologies. Reports of initial studies performed by the Center on critical issues will make a contribution to immediate policy and business decisions concerning gas, and identify needs and opportunities for technology development and deployment. Specific strategies of the Center include the following:

- Focus on emerging problems and on opportunities in the marketplace that are amenable to the application of gas technologies.
- Review forecasts of the worldwide energy situation, relating future forecasts to the need for natural gas technologies.
- Facilitate the commercialization of gas technologies through a continuing international forum where information is exchanged between existing and potential users.
- Build on the success of other IEA information centers such as Energy Technology Data Exchange, Coal Research Center, Heat Pump Center, and CADDET.
- Initiate a proactive effort to create a technology inventory and interactive communications system, by seeking out unpublished results and bringing active technology developers into the dialog.
- Conduct analytical studies on topics selected in consultation with the Executive Committee.
- Disseminate the results of the studies to sponsors and others as agreed upon by the Executive Committee.
- Conduct workshops to discuss specific issues for technology transfer of program results, or to discuss the development of cooperative RD&D products to be financed independently by interested participants.
- Proactively promote the transfer of gas-related technologies by providing information on the evaluation of the effectiveness of new gas technologies in specific applications.
- Conduct workshops and training courses to inform potential users of the capabilities of new technologies.
- Form an international advisory body on technology transfer.

Impact (Near- and Mid-Term)

- Provides for technology information exchange, technology analysis, and technology transfer.
- Results in conduct of studies and workshops to encourage better transfer of gas technology related information.
- Enhances awareness about U.S. technology.
- Introduces U.S. technology into overseas markets.

FY 1992 Accomplishments

- GRI and leaders in the U.S. gas industry encouraged the U.S. to take the lead in establishing the Center.
- Participating IEA Member Countries designated GRI and the Danish Gas Technology Center to operate the Center.
- The Center was jointly established by GRI and the Danish Gas Technology Center.

FY 1993 Accomplishments

- Participated in the Interim Executive Committee meeting with the major goals of finalizing the Center Implementing Agreement and approving a permanent program budget.

Planned Products

The following are the interim studies and workshops currently planned by the interim Executive Committee of the Center (FY 1994):

- "Assessment of the Potential Applications for Gas-Based Space Conditioning Technologies," a study to assess the technical, economic and environmental characteristics of gas-based space cooling technologies, and evaluate their potential for contributing to future regional/global requirements for space conditioning services.
- "Assessment of the Significance of New and Emerging Gas-Based Technologies to the Energy Requirements of the Commonwealth for Independent States, Central, and Eastern Europe," a study to evaluate the potential of new and emerging gas technologies to increase energy efficiency and economy, and reduce the environmental consequences of providing energy services to Central and Eastern Europe.
- "The Role of Gas-Fired Electric Power Generating Technologies," a workshop to discuss the future role for natural gas fuel technologies for electric power generation. The emphasis of the workshop will be on advantages of advanced gas technologies in a variety of cultural and technical settings.
- "Impacts of Technology on Global Gas Resource Estimates," a workshop to reassess conventional estimates of the global natural gas resource base, giving consideration to recent and prospective improvements in technologies and practices of exploration, development and recovery.
- "Feasibility Study," a study to define the scope, contents, procedures, and other basic characteristics of the technology information exchange services of the Center.

Program Funding**DOE Historical Spending (\$ in millions)**

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
IEA Center for Gas Technology Information	-	0.500	0.875	0.875
Total DOE	-	0.500	0.875	0.875

Cost-Sharing

The Center will be cofunded by GRI, DOE, and the Danish Gas Technology Center. When the participating countries make program funding available, the Operating Agent, with supplemental support from the governments of the United States and Denmark, will initiate the preliminary work program while negotiations are underway on the formal Implementing Agreement for the permanent program.

Ten countries thus far have agreed to fund or have indicated that they expect to participate in the interim program. They are the United States, Denmark, Japan, Italy, Spain, Portugal, Belgium, France, Germany, United Kingdom, Russian Federation, and Netherlands. Six of these, Japan, Italy, Spain, Portugal, the United States and Denmark, already have signed agreements. Possible associate members for the future are Indonesia, Olade (a Latin and Central American energy organization), Poland, Republic of Korea, and the Ukraine.

Flow Diagram

Not applicable.

4.3 DELIVERY AND STORAGE AREA

4.3 DELIVERY AND STORAGE AREA

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OFFICES: FE: FOSSIL ENERGY

EIA: ENERGY INFORMATION ADMINISTRATION

IS: INTELLIGENCE AND NATIONAL SECURITY

4.3 DELIVERY AND STORAGE AREA

AREA SUMMARY

Mission

The natural gas Delivery and Storage Program is designed as a joint effort with industry and States to advance technologies and methodologies that will increase the efficiency and reliability of the natural gas system. DOE's program will: (1) foster more efficient use of gas storage; (2) demonstrate the reliability of peak-load deliverability of natural gas; and (3) assist in the development of an information system for natural gas data that is accurate, reliable, and timely. Through integration with industry research programs, DOE's gas Delivery and Storage RD&D Program will increase utilization of natural gas.

Mandates

The gas delivery and storage technology program will comply with all applicable Federal, State, and local laws and regulations, and DOE regulations and policies. Requirements of immediate relevance include the CAAA, EPACT, Congressional funding requirements, and the Administration's natural gas policy directives.

Program Relationships

Within DOE, the principal responsibility for research in gas delivery and storage lies within the Office of Oil and Gas Processing, Office of Fossil Energy. The Delivery and Storage Program is a new initiative for FY 1994 and has been developed in response to DOE's new natural gas strategy, which emphasizes a "systems approach" to conducting RD&D efforts. The strategy addresses all aspects of the gas system from the wellhead to burnertip. The program is to be implemented by Morgantown. DOE's natural gas plan also emphasizes joint government/industry RD&D programs to develop efficient and reliable delivery and storage technologies. Planned research will build on the deliverability and storage findings and recommendations in the NPC report, *The Potential for Natural Gas in the United States (1992)*; the FERC/DOE study, *Natural Gas Deliverability Task Force Report (1992)*; and the Energy Information Administration (EIA) report, *Natural Gas Production Capacity for the Lower 48 States (1992)*, and procedures for estimating pipeline deliverability.

GRI has planned research in the natural gas delivery and storage area which will complement the DOE program. The objective of GRI sponsored delivery and storage RD&D is to develop technologies to ensure more reliable, safe, cost-effective, and efficient gas delivery and storage. Program elements of GRI's gas storage research include: deliverability enhancement, storage operations optimization, delivery, and new storage development. Joint funding with GRI will be initiated whenever GRI RD&D addresses strategic issues consistent with the DOE program.

Situation Analysis

Current Situation and Key Trends

Gas delivery and storage are the critical link between supply (producers) and demand (consumers). The transmission and storage industry is currently in the midst of the most significant restructuring in its history. The industry, which has been regulated from wellhead to burnertip, is undergoing changes that will enhance competition by leaving choices for supply and services in the hands of providers and purchasers. The NPC study estimated that, as of 1991, the U.S. had the capability to deliver to consumers about 24 Tcf annually and approximately 120 Bcf of natural gas on a peak day. This additional capability above the 1991 actual consumption of 19.2 Tcf and estimated peak day consumption of 102 Bcf allows for use of this capacity by nonfirm customers on peak days. In addition, it provides flexibility in the delivery system, adds reliability, and enables the system to support a growing U.S. gas market.

Gas demand is seasonal and can lead to underutilization on interstate pipelines during off-peak periods. Reduction in seasonal fluctuations of gas usage may lead to higher utilization of pipeline transmission, with potential gains in the utilization and storage facilities. The U.S. has a total storage capacity of approximately eight Tcf, and about four Tcf of that total is the operating (working) volume. Technology advances to enhance the reliability of the gas system through efficient, timely, and accurate information, and the construction and utilization of new gas storage facilities are necessary for natural gas to realize its full potential.

Passage of EPACT and CAAA and reform of the Public Utility Holding Company Act will provide opportunities for increased use of natural gas in all market areas. Consumption of natural gas is expected to increase substantially through the year 2010, to a level ranging from 21 to 24 Tcf. Peak day consumption will increase from eight to 25 percent over 1991 levels due to an increase in firm load requirements, including growth in the electric generation and cogeneration markets. In addition, regional flow patterns will shift, reflecting the decline of the Southwest as a supply source and the increasing importance of the Rocky Mountain region and Canada.

The energy industry forecasts that the Nation's total electric power generation requirements will increase by about one-fifth in the next decade, and that natural gas will supply as much as 40 percent of that increase. EIA forecasts gas demand in the industrial market to increase 15 to 20 percent by the year 2000. The American Gas Association (AGA) is advocating a program to increase U.S. natural gas consumption by 2.5 Tcf by 1995, which includes a potential one Tcf increase in gas use for electric power generation by 1995.

To serve the increasing demand and address the regional shift in sources of supply, new storage and delivery facilities will need to be constructed. NPC estimates that by 2010, if the 24 Tcf consumption level is realized, peak-day deliverability will need to increase 14 percent to 137 Bcf per day. In addition to market growth, recent declining wellhead deliverability will cause gas storage to become a more critical issue. If wellhead deliverability continues to decline, storage will be used to meet an even larger portion of the seasonal demand.

DOE Position

The natural gas delivery and storage technology program represents a new initiative for FY 1994. Development of technologies leading to cost-effective expansion of storage capacity, and enhanced deliverability, is an integral element of the program and is aimed at increasing end user confidence in gas as a reasonable and reliable energy source. DOE believes that the timely dissemination of accurate and reliable State production data, the measurement and monitoring of gas flows through the pipeline system, storage/user needs, storage revitalization and improvement, and reservoir management, and the development of a national deliverability capacity model are critical in assuring continued efficient and reliable gas industry performance.

The main drivers for Fossil Energy and EIA in initiating this program are the FERC/DOE Natural Gas Deliverability Task Force Report and FERC Order No. 636, both issued in 1992. The delivery program will start to implement the recommendations of the Task Force Report relating to natural gas deliverability: standardization of information; review, development, and dissemination of data; implementation of electronic data recording and interchange; and planning and coordination for peak periods and emergencies. The main conclusion from this joint study with industry is that information on natural gas (production, storage, and deliverability) is often fragmentary and late. The information infrastructure that now serves the gas industry was built for the regulated industry in the 1950s, 1960s, and 1970s. Accurate and timely information will be the lifeblood of emerging and rapidly changing competitive gas markets. There is a need for better and new reporting on the State level (hardware and software needs). Key elements of the information change will include:

- Refocusing much of the information to serve those who buy and sell both natural gas and pipeline capacity; and
- Receiving crucial information much faster (real time monitoring) and tying the information to market institutions where parties actually buy and sell gas or capacity.

Order 636 restructured pipeline service obligations. It requires the separation of pipeline companies' sales, transportation and storage services to allow customers to contract only for that mix of services they need. It allows the development of a secondary market for released pipeline capacity, encourages the development of market hubs, and requires electronic bulletin boards to provide on-line access to information regarding available capacity. All of these changes are expected to enhance competition in the natural gas market and promote better policy and investment decision by both the public and private sectors.

The program is partitioned into the delivery and storage project areas. The delivery program projects are: Upgrade of Producing State Data Gathering and Dissemination Systems, Real Time Monitoring and Automated Systems, National Deliverability Capacity Model, and EMERGE Natural Gas Database and Geographic Information System. The storage projects are: Energy and Natural Resource Information Management System (ENRIMS) Underground Storage Applications, Match Gas Storage to End User Requirements, Storage Revitalization and Improvement, and Reservoir Management. Planned research activities for FY 1994 form the foundation for the DOE's RD&D program for FY 1995 and the outyears. DOE's research program is designed to be cost-shared with industry, with industry's share increasing as research efforts move towards the demonstration phase.

During FY 1991-1993, DOE/Morgantown has maintained a cooperative research effort with major natural gas utilities using geologic modeling and reservoir simulation to address aspects of deliverability, reservoir management, and storage optimization. Numerical simulators have been updated to incorporate surface facilities modeling, thus increasing the systems approach capability used to address storage and delivery technology issues. In FY 1994, Morgantown plans to begin a series of CRADAs with natural gas utilities to develop a methodology to address the major issues of storage field deliverability and reservoir management.

Key Planning Assumptions

- Prospects for expanded natural gas use will be influenced by many factors, including: its perceived current and future availability to customers; its price relative to other energy prices; an acceptable rate of return-on-investment; and the availability of capital to develop new sources and advanced communication technologies, and to construct required storage and expanded distribution systems.
- The domestic natural gas resource base is sufficient, but requires an adequate storage and distribution system to meet increased demand and provide reliable supplies in the long-term. Although conventional gas resources will continue to play a dominant role, resources now considered unconventional -- low permeability sandstones, shales, coals -- will capture an increasing share of the market by the year 2010.
- Natural gas demand will increase by 25 percent to 24 Tcf/year by the year 2010. Substantial future increases in natural gas consumption are expected in the electric power generation sector.
- The environmental advantages of natural gas will encourage its greater use. However, environmental constraints associated with siting, permitting, and construction of exploration and production facilities, gas storage, LNG and pipeline projects, and power plants will become more stringent.

- Federal, State, and local environmental regulations will expand in depth and scope. Full impact of reauthorized Federal statutes and new regulations being implemented on the gas industry is unknown. Implementation of the CAAA is expected to encourage gas demand in the industrial, electric utility, and transportation sectors.

Key Customer Considerations

Gas Industry:

Producers: Producers will benefit by being able to sell gas year-round with summer volumes going into storage rather than having to shut-in production wells. Producers benefit from the accurate measurement of gas volumes that they ship by pipelines to end users.

Pipeline Companies (Pipelines): Pipelines are seeking improved deliverability. Pipelines benefit from increased efficiency, resulting from automated controls and measurement systems, that lower operational costs and increase their rate-of-return on investments. Pipelines support regulatory reform that encourages companies to increase storage capacity.

Local Distribution Companies: These companies are concerned with increasing the reliability, flexibility, and deliverability of gas services. They benefit from improved operational control that results from accurate and real time measuring and monitoring of gas in their pipeline systems.

Gas Storage Operators: This group is facing increased and more complex responsibilities for managing storage operations under Order 636 which requires that storage be unbundled from other pipeline services. They will want financial rewards to be commensurate with the increased risks.

Gas Marketers: Marketers are seeking improved information and data on pipeline capacity and availability on a real time basis, and will benefit from an electronic natural gas information network system that increases their ability to provide efficient gas services.

Major Gas Consumers: Electric utilities, independent power producers, and industrial gas consumers want reliable supply and price stability to help facilitate long-term planning and to preclude supply interruptions. In addition, they desire economically efficient technologies for gas-fueled electric generation.

Environmental Groups: These groups are pressing for reduced emissions. Increased utilization of natural gas in the electric generating sector is responsive to the CAAA.

Research and Educational Community: These organizations seek to expand Federal funding for their RD&D efforts and to participate with DOE in the demonstration of technologies.

Equipment Vendors: These companies seek to develop and market equipment that will reduce costs and improve efficiency for pipeline operations and storage facilities.

Investment Community: Lenders and investors are concerned with reducing the risks of financing natural gas-related activities. Capital is needed to construct the required storage and distribution systems.

Congress: Industry driven RD&D programs with GRI and other nonfederal sources receive more Congressional support than Government-only funded research. Cost-sharing of 40 to 50 percent is sought. Congress is concerned about reliability of natural gas to consumers and the burden of costs.

Department-Wide Program

Strategic Objectives and Strategies

Near-Term (By the Year 2000)

1. Identify and evaluate the feasibility of alternative technologies suitable for gas storage and delivery applications.
2. Identify strategic market areas for new and growing for natural gas use, projected gas demand, and the storage capacity/delivery required for these areas. Assess potential geologic formations for their development as storage reservoirs in these markets areas.
3. Investigate field development strategies for new and expanding gas storage fields.
4. Identify communication system technology leading to development of a national electronic gas deliverability system. DOE plans to:
 - a. Identify and address aspects that will lead to improved storage/delivery technology to establish confidence in gas deliverability;
 - b. Evaluate alternative gas storage methods that have the potential to meet the expected demand increase from major gas consumers;
 - c. Define and improve system aspects of gas storage/delivery technologies and participate in gas storage/end use demonstration tests to establish the reliability of peak-load deliverability; and
 - d. Identify market growth areas, projected demand and potential storage sites.

Mid-Term (By the Year 2010)

1. Demonstrate new storage and delivery technologies to optimize the economics of gas storage and delivery. DOE plans to:
 - a. Participate in gas storage/end user demonstration tests to establish the reliability of alternative storage methods; and
 - b. Develop technologies that address the constraints associated with natural gas storage in aquifers thereby facilitating the construction of new aquifer storage capacity.

Key Performance Indicators

Near-Term (By the Year 2000)

- Completion of the National Deliverability Capacity Model and dissemination of analytical capability.
- Demonstration and dissemination of the ENRIMS underground storage application capability for evaluating changes in the development and use of storage, and the interconnections among storage areas and pipelines.
- Demonstration of natural gas as a reliable fuel source by using storage reservoirs to supply gas during peak-demand periods for the power generation market through actual tests and demonstrations.

- Completion of the design and demonstration for a national electronic natural gas deliverability information network system.

Mid-Term (By the Year 2010)

- Improved reservoir management techniques to mitigate the effects of gas migration from storage reservoirs, demonstrated in research and verification tests.
- Alternative storage methods identified in areas where conventional underground storage is not feasible, and feasibility/verification tests evaluated for these methods.
- Producing States connected through an online system to a national electronic natural gas deliverability information network.
- Improvement in gas reliability and monitoring of gas supplies from the wellhead to the burnertip through the national electronic gas deliverability information network system.

Strategic Issues and Obstacles

- Private sector resources are not adequate in RD&D of advanced natural gas delivery and storage technologies. The natural gas industry continues to focus on short-term return-on-investment which inhibits necessary investment in new storage and delivery technologies.
- Many customers do not have confidence in the reliable deliverability of natural gas as a long-term energy source. In many cases, new customers can find it difficult, complicated, and sometimes impossible to buy gas.
- Conventional underground formations amenable to storage applications are limited in certain market areas.
- Current peak-day demand, pipeline bottlenecks, and limited deliverability to certain markets could lead to delivery problems during severe cold spells near the end of the storage withdrawal season.
- The current transition under Order 636 has not yet resulted in a streamlined process of approval for storage and pipeline projects. Hence, development of adequate transmission and storage capability to meet the forecasted growth in demand for natural gas continues slowly.

FY 1992-1994 Crosscut Budget SummaryBudget by DOE Office (\$ in millions)

DOE Office	FY 1992 Actual	FY 1993 Appropriated	FY 1994 Request	FY 1994 Appropriated
Fossil Energy (FE)	0.070	-	3.440	1.000
Intelligence and National Security (IS)	0.125	0.100	0.100	0.100
Total DOE	0.195	0.100	3.540	1.100

Budget by Project (\$ in millions)

DOE Program	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Delivery¹	0.125	0.100	1.790	0.100
Upgrade of Producing State Data Gathering and Dissemination Systems (FE)	-	-	1.000	0.000
Real Time Monitoring and Automated Systems (FE)	-	-	0.490	0.000
National Deliverability Capacity Model (EIA/FE) ²	-	-	0.200	0.000
EMERGE Natural Gas Database and Geographic Information System (IS)	0.125	0.100	0.100	0.100
Storage	0.070	-	1.750	1.000
ENRIMS Underground Storage Applications (EIA/FE) ²	-	-	0.200	0.100
Match Gas Storage to End Users Requirements (FE)	-	-	0.500	0.350
Storage Revitalization and Improvement (FE)	0.070	-	0.500	0.350
Reservoir Management (FE)	-	-	0.500	0.050
Morgantown In-House Research (FE)	-	-	0.050	0.150
Total Delivery and Storage Area	0.195	0.100	3.540	1.100

¹ Note that there is deliverability RD&D funded in FY 1993 (\$0.250 million), but it is included in the Resource and Extraction Area for the FY 1994 Plan.

² Project is funded by Fossil Energy.

UPGRADE OF PRODUCING STATE DATA GATHERING AND DISSEMINATION SYSTEMS

Tactical Objective

To increase consumer confidence in the availability and deliverability of natural gas supplies into the gas delivery system by providing more accurate and timely data on natural gas production at the State level (Most information on gas production and delivery into the pipeline system is collected at the State level).

Issues

Accurate and timely natural gas production information is critical to assure gas reliability and increase gas use. The quality of natural gas deliverability data will play a significant role in the development of an efficient, national, competitive market for natural gas. The theoretical premise of a competitive market is that prices are set when commodity supply and demand curves intersect. The market participants' opinions about natural gas supply are based in part on deliverability data. Inadequate deliverability data may lead to inaccurate estimates of supply, causing mispricing in the market. This results in economic inefficiency and misallocation of resources.

The FERC/DOE Task Force Report on natural gas deliverability stated that the present system of information gathering by States is not capable of providing timely and accurate data on gas production. Improved data will lead to better decisions about production levels by natural gas producers, gas supply procurement plans by LDCs and industrial consumers, and emergency and curtailment plans approved by government bodies.

The FERC/DOE Task Force report identified a number of concerns and issues that the Federal and State agencies and LDCs need to resolve in order to increase natural gas reliability. Initially, an assessment of the data collection and reporting systems needed by the States (hardware, software, and programs) is necessary.

Major Goals

This project is a follow-up to the "Natural Gas Production Reporting System Study" subproject initiated in FY 1993 under the Resource and Extraction program (see Follow-Up Research per NPC Gas Study project). Major goals of this activity are to conduct an assessment of the requirements necessary to upgrade the individual State data collection and dissemination systems, and to provide assistance to the States to accomplish those upgrades.

Strategy (Total DOE FY 1994: \$0.0 million)

Cost-Sharing Target: 50%

Assess needs and develop requirements for States to upgrade individual gas production data gathering systems, and to continue work commenced in FY 1993. Initiate demonstration programs to implement those upgrades.

Impact (Near-Term)

- Provides States with a model to follow in upgrading their gas production data collection and reporting system.
- Increases States' operational understanding of gas deliverability and their commitment to improving gas reliability.

Impact (Mid-Term)

- Demonstrates the ability of States to collect and report accurate and timely gas deliverability data to ensure reliability of service to an expanded customer base.

FY 1993 Accomplishments

None. New program for FY 1994.

Planned Products

- Development of data gathering and dissemination system for use at the individual State level.

Program Funding**DOE Historical Spending (\$ in millions)**

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
State Reporting Upgrade (FE)	-	-	1.0	0.0
Total DOE	-	-	1.0	0.0

Cost-Sharing

Cost-sharing goal is 50 percent.

Flow Diagram

Not applicable.

REAL TIME MONITORING AND AUTOMATED SYSTEMS

Tactical Objective

To provide new and advanced technologies for use in the gas transportation sector that will increase efficiency, reduce operating costs, and improve information gathering and dissemination for operators and customers. This is consistent with the Administration's vision for a National Information Super Highways program.

Issues

Accurate information on the pipeline operations and gas volumes being moved are required for customers who now only use the transportation services offered by pipelines. Furthermore, pipelines need the same information about the gas they transport, and the inputs and takes from their systems to efficiently operate their systems and manage their contracts.

Operational necessity and competitive requirements dictate that the technology of measurement and pipeline operation improve. However, under rate-of-return regulation, the transmission sector has little incentive to invest in technology development. Thus, there is a role for government to support development of technology in this area. Cost reductions gained through improved efficiency of operations can be passed on to customers to reduce overall cost of gas and stimulate demand.

Major Goals

Develop new and improved operational and measuring technology for pipeline transportation services. These devices will improve the efficiency of operation to allow the transmission sector to provide services at a reasonable and competitive cost.

Strategy (Total DOE FY 1994: \$0.0 Million)

Cost-Sharing Target: 50%

DOE's approach is to provide the basis for establishment of a national electronic communication network that will provide real time information on natural gas flows and pressures from critical locations at production and storage facilities, interstate and intrastate pipelines, local gas distribution companies, and major end users of natural gas.

Impact (Near-Term)

- Develops an energy flow device that enables pipelines to measure the energy content of the gas that they are transporting without removal or destruction or interference in normal operations. Further, the development of real time measurement devices for pipeline operations will satisfy the needs of industry and regulatory agencies such as FERC.

Impact (Mid-Term)

- Develops automated systems for pipelines and storage facilities that combine accurate measurement with automated operation. Thus, these systems improve operational efficiency and lower the operation costs of this sector of the industry.

FY 1993 Accomplishments

None. New program for FY 1994.

Planned Products

- Development of a nondestructive energy flow measurement device within the pipeline. Cost-effective, automated real time measurement and operational systems.

Program FundingDOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Real Time Monitoring Projects (FE)	-	-	0.49	0.00
Total DOE	-	-	0.49	0.00

Cost-Sharing

Cost-sharing goal is 50 percent. Cofunding is anticipated with GRI.

Flow Diagram

Not applicable.

NATIONAL DELIVERABILITY CAPACITY MODEL

Tactical Objective

To develop a model for estimating the capability of the U.S. to deliver natural gas to customers, linking wellhead productive capacity with pipeline capacity on a State-to-State basis.

Issues

The FERC/DOE Natural Gas Deliverability study notes the need for estimates of national delivery capability. Although there are procedures for estimating wellhead productive and pipeline capacities, there is no system linking both wellhead and pipeline capacity. This methodology will allow the evaluation of the overall system to deliver natural gas, including considerations of wellhead and pipeline capacity constraints.

Major Goals

- Develop a PC-based system for the analysis of domestic gas deliverability for analytical use throughout DOE; and
- Study the current capability and the impact of projected changes in supply and demand patterns and planned pipeline expansion on the capability of the system to meet domestic requirements.

Strategy (Total DOE FY 1994: \$0.0 million)

Cost-Sharing Target: None

The program strategy includes the following: (1) development of a supply and demand profiles database on a regional basis; (2) update of the pipeline capacity database to include most current capacity information and planned projects; and (3) evaluation of the NPC procedure to estimate deliverability and enhancement as necessary to fit DOE application.

Impact (Near-Term)

- Enhances ability of DOE to address questions relating to the gas industry's ability to deliver natural gas on a regional basis.
- Complements the GSAM to provide the capability to evaluate seasonal and peak day supply and consumption and other issues at a more desegregate level than is considered in the GSAM model.

Impact (Mid-Term)

- Provides the capability to model and simulate regional gas production and end use deliverability to new markets.

FY 1993 Accomplishments

None. New program for FY 1994.

Planned Products

- Development of PC-based analysis capability to address national and regional deliverability issues.
- Initiation of annual EIA summary report on domestic natural gas deliverability capability.

Program Funding**DOE Historical Spending** (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
National Deliverability Capacity Model (EIA/FE)	-	-	0.200	0.000
Total DOE	-	-	0.200	0.000

Cost-Sharing

Not anticipated.

Flow Diagram

Not applicable.

EMERGE NATURAL GAS DATABASE AND GEOGRAPHIC INFORMATION SYSTEM

Tactical Objective

To enhance DOE's capability for assessing the impact of natural gas emergencies, and when needed, to provide information for developing a Federal and State government response strategy.

Issues

DOE must be able to quickly assess and evaluate the extent of natural gas emergencies or potential emergencies to help determine if Federal or State assistance should be offered. The development of an information system to support this effort would significantly increase operational readiness. Formulating and testing various emergency response options offered by industry and Federal and State governments is a critical requirement of emergency response planning. An information system that can help to support this requirement will provide a higher level of preparedness.

Issuance of Order 636 has led to unbundling of pipeline services and gas transportation requirements from producers to consumers. These changes will require DOE to carefully monitor and evaluate system stresses for possible negative impacts on supplies and deliverability. As natural gas supply and demand are brought into balance, it is expected that industry emergency response flexibility will decline. System disruptions will need to be monitored and analyzed more closely for their impact on deliverability.

Major Goals

To finalize the development of the EMERGE natural gas database and Geographic Information System (GIS), incorporating production and consumption data, a network flow model, and improved mapping capability.

Strategy (Total FY 1994: \$0.100 million)

Cost-Sharing Target: None

The development strategy is carried out in cooperation with EIA. The approach will focus on the refinement of the existing EMERGE databases and GIS, and the incorporation of seasonalized production and consumption data into a network flow.

- Refine EMERGE pipeline maps for higher resolution including new pipelines, compressor stations, and interconnections.
- Incorporate cities and township files to redefine local distribution company service territories and customer profiles.
- Seasonalize production, consumption, and storage data. Inventory targets will be developed and storage data will be linked to key pipeline interconnects.
- Integrate pipeline reservation database, receipt and delivery points, and contract demand with LDC service territory database.
- Develop a network analytical capability using standard network data structures and mathematical programming software.

Impact (Near-Term)

- Enhances DOE's ability to quickly define and understand the scope of a major natural gas emergency as it relates to transmission and distribution.
- Makes available computerized geographic situation analysis to senior management.

Impact (Mid-Term)

- Develops ability to simulate and link a production disruption with the transmission/distribution system.

FY 1992 Accomplishments

- Developed a service area boundary database for LDCs.
- Developed a natural gas end user database, including thematic maps by LDC service areas.
- Integrated the natural gas database and the GIS database to form the EMERGE system.

Planned Products

- Refinement of pipeline mapping system resolution that incorporates new systems and the U.S. intrastate and Canadian pipelines.
- Enhancement of LDC database, including a township file.
- Development of network capability, beginning with logical linkages of downstream activities and ending with incorporation of producers into the network.
- Incorporation of EMERGE into DOE's Emergency Operations Center (EOC) to interface with existing information systems.

Program Funding**DOE Historical Spending (\$ in millions)**

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
EMERGE Development (IS ¹)	0.125	0.100	0.100	0.100
Total DOE	0.125	0.100	0.100	0.100

¹ Office of Intelligence and National Security

Cost-Sharing

Not anticipated.

Flow Diagram

Projects	1993	1994	1995	1996
Refine System Maps/Data	S/G/D T			
Enhance LDC Database and Township File	T			
Network/Data Linkage	S G T			
Seasonalize Data	S T			
Incorporate into EOC	S G D T			

Coding:

S = Select most promising methodology
 G = Go/no go decision
 D = Initiate test exercise
 T = Transfer information for application

ENRIMS UNDERGROUND STORAGE APPLICATIONS

Tactical Objective

To promote greater confidence in the natural gas delivery system by developing an information system that will provide the capability to evaluate domestic storage capacity and deliverability on a site specific basis. To document and assess the use of new technologies in the development and management of storage, and the role of storage in meeting variable demand patterns.

Issues

Information regarding storage is increasingly important as a result of the unbundling of storage services from pipeline transportation services. Fossil Energy needs a system to easily track and evaluate the progress of the storage and deliverability initiative.

EIA has been developing a natural gas data analysis system that can provide general analytical capabilities for mapping, cross-reference of data, and data presentation. Currently, the system has extensive information on pipeline locations (based on compressor station information), capacity, system information (pipeline interconnects), flow information by segment, and customer information by local distribution company. The system will be expanded to incorporate information on underground storage. The information will be included in the least segregated form available.

Major Goals

- Develop a PC-based system to evaluate changes and efficiency gains related to the development and use of storage in the national natural gas delivery system.

Strategy (Total DOE FY 1994: \$0.100 million)

Cost-Sharing Target: None

The approach is to establish a database of site specific information on storage facilities on a monthly basis, including geographical and geologic information regarding storage sites, capacity, operational information (number of wells, peak-day deliverability), ownership data, and withdrawal and injection information. The database will be merged into the EIA ENRIMS which allows for cross-referencing with pipeline connection information, pipeline capacity, and market information.

Impact (Near-Term)

- Provides DOE the capability to track and document the impact of DOE and other funding programs designed to improve the development and use of storage.
- Provides a readily accessible database of information relating to natural gas storage to customers outside of DOE.

Impact (Mid-Term)

- Provides a database of information relating to underground geology and gas storage technologies to international community.

Planned Products

- PC-based analysis capability coupled with the EIA ENRIMS system. This provides a user-friendly menu and flexible system for spatial display and data analysis. Additionally, this system provides access to an extensive amount of data that can be used to address other energy and environmental questions.

Program FundingDOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
ENRIMS Underground Storage Applications (EIA/FE)	-	-	0.200	0.100
Total DOE	-	-	0.200	0.100

Cost-Sharing

Not anticipated.

Flow Diagram

Not applicable.

MATCH GAS STORAGE TO END USER REQUIREMENTS

Tactical Objective

To develop new and cost-effective gas storage alternatives and improve existing gas storage systems. To identify and improve system aspects of gas delivery from the storage reservoir to the burnertip, leading to improved storage/delivery technologies to establish confidence in gas deliverability in strategic market areas.

Issues

Natural gas storage capacity must be increased near new and expanding market areas to service the forecasted increase in gas utilization. However, development of underground storage reservoirs (pools) is capital intensive. Technologies must be developed or improved to reduce the service charges by lowering capital and operating costs. Alternative gas storage methods must be developed for industrial and power generation use. A large share of the forecasted incremental market for natural gas is for electric power generation, a market requiring reliable, high delivery rates of gas. Specific needs for power generation must be addressed. Shipments of natural gas through large diameter, interstate pipelines are seasonal and lead to underutilization of the interstate transmission network during off-peak demand periods.

Major Goals

- Identify strategic market areas for new and expanding natural gas usage;
- Conduct research that will lead to the development of storage capacity to meet needs in new and growing market areas;
- Establish proof-of-concept for alternative storage methods;
- Develop systems to meet specific needs in gas delivery for power generation; and
- Promote contraseasonal markets through improved storage to lessen imbalance in pipelines.

Strategy (Total DOE FY 1994: \$ 0.350 Million)

Cost-Sharing Target: 50%

- Identify strategic market areas for new and growing natural gas usage. For these areas, identify, evaluate, and rank underground reservoirs for their potential as new storage pools or for expansion of existing capacity. Geologic modeling, engineering design, and economic feasibility studies will be completed.
- Conduct feasibility study of alternative gas storage methods such as low permeability/fractured reservoirs, thin-bedded salt formations, nonreservoir rock, chambers, and surface facilities.

Impact (Near-Term)

- Increases industry's understanding and commitment to the development of new storage capacity.
- Demonstrates the ability of gas storage to bridge the potential deliverability gap between gas supplies and strategic markets.
- Provides a gas delivery option to help independent producers to effectively market their gas supplies during periods of low demand.

Impact (Mid-Term)

- Assures end users of adequate natural gas supplies.
- Provides a mechanism for year-round production (sales) of gas, thus attenuating seasonal shut-ins.

FY 1993 Accomplishments

None. New program for FY 1994.

Planned Products

- Identification of reservoirs for new capacity development.
- Identification of reservoirs for capacity expansion in existing storage fields.
- Completion of feasibility study of alternative storage methods.
- Demonstration of natural gas as a viable fuel for the power generation market.

Program Funding

DOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Candidate Reservoirs/New Storage (TBD ¹ /FE)	-	-	0.250	
Alternative Storage Study (TBD/FE)	-	-	0.250	
Total DOE	-	-	0.500	0.350

¹ TBD: To be determined.

Cost-Sharing

Cost-sharing goal is 50 percent. Cofunding is anticipated with GRI.

Flow Diagram

Projects	1994	1995	1996	1997	1998	1999
Candidate Reservoirs/New Storage	_____ T _____ T _____					
Capacity Expansion Study	_____ T _____ T _____					
Alternative Storage Study	_____ S _____					
Alternative Storage Demonstration	_____ D _____ P _____ T _____					

Coding:

D = Initiate field demonstration
 S = Select most promising concept for further development
 T = Transfer technology or information for application
 P = Achieve proof-of-concept

STORAGE REVITALIZATION AND IMPROVEMENT

Tactical Objective

To develop and demonstrate cost-effective technologies and techniques that can revitalize injection/withdrawal rates or that can prevent injection/withdrawal rate losses from existing storage wells. To develop and demonstrate improvements, such as horizontal well and surface facility optimization for injection/withdrawal, from new or existing storage fields.

Issues

Revitalization of 17,000 existing U.S. gas storage wells is required to maintain system capability and to reduce overall storage and delivery costs to the end users. Enhanced injection and withdrawal of gas from new and existing storage fields must be developed and demonstrated to meet projected daily gas demands and provide peak-day deliverability, especially for the industrial and power generation markets.

Major Goals

- Develop technologies that will reduce costs to revitalize existing gas storage wells;
- Identify and verify technologies to improve injection and withdrawal of gas from new and existing fields; and
- Determine cost-effective gas storage field development strategies.

Strategy (Total DOE FY 1994: \$0.35 Million)

Cost-Sharing Target: 50%

- Conduct a deliverability revitalization project to evaluate new/improved techniques, such as propellant fracturing and chemical treatment methods for existing wells. Multiple candidate wells will be selected for field verification tests.
- Develop a methodology through geologic modeling and reservoir simulation studies of selected storage fields to improve storage field development. Investigate field development strategies, such as increasing injection/withdrawal rates using horizontal wells and optimizing surface facilities, for reducing development costs.

Impact (Near-Term)

- Improves confidence in storage/delivery from new and existing storage fields in order to meet deliverability demand.
- Reduces the costs of service by developing a more efficient storage system.

Impact (Mid-Term)

- Develops new gas storage.

FY 1993 Accomplishments

None. New program for FY 1994.

Planned Products

- Development of new guidelines on deliverability revitalization technology and techniques for existing gas storage wells.
- Development of improved technology for enhancing gas storage field deliverability.
- Completion of new storage field development strategies.

Program FundingDOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Gas Storage/Horizontal Well Study (Morgantown In-House/FE)	0.07	-	-	
Deliverability Revitalization (TBD ¹ /FE)	-	-	0.30	
Geologic/Reservoir Simulation Studies (Morgantown In-House/CRADA/FE)	-	-	0.20	
Total DOE	0.07	-	0.50	0.35

¹ TBD: To be determined

Cost-Sharing

Cost-sharing goal is 50 percent. Cofunding is anticipated with GRI.

Flow Diagram

Projects	1994	1995	1996	1997	1998	1999
Deliverability Revitalization	S	D	P	T	S	D
Horizontal Well Field Test in Nonconventional Reservoir		S		D	P	T
Geologic Reservoir Studies	S	T		S	T	
Deliverability Enhancement Study		S		T		

Coding:

D = Initiate field demonstration
 S = Select most promising concept for further development
 T = Transfer technology or information for application
 P = Achieve proof-of-concept

RESERVOIR MANAGEMENT

Tactical Objective

To develop and demonstrate technologies and techniques that will reduce the costs associated with the operation and maintenance of natural gas storage.

Issues

Migration of injected gas out of the storage reservoir needs to be prevented to reduce the cost of storage field operations. Low cost methods that improve the accuracy of inventory verification are needed to optimally manage stored natural gas. Wellbore integrity should be maintained throughout the life of storage operations with minimum follow-on costs.

Major Goals

- Demonstrate cost-effective techniques to minimize gas migration from storage field;
- Reduce costs associated with the management of underground gas storage fields;
- Replace base gas with a less expensive inert gas; and
- Provide cost-effective reservoir management tools to industry.

Strategy (Total DOE FY 1994: \$ 0.05 Million)

Cost-Sharing Target: 50%

- Conduct a gas migration study of problem field(s) concluding with a field verification test(s) of the effectiveness of horizontal wells, surfactant/foams, or other technologies to reduce the costs associated with gas migration.
- Provide in-house expertise on surfactant/polymer systems in direct support of field verification test(s).

Impact (Near-Term)

- Provides new and improved, cost-effective techniques for detecting and inhibiting gas migration from the storage area.

Impact (Mid-Term)

- Reduces the cost of storage by substituting base gas with less expensive inert gas.
- Provides more accurate verification of inventories.

FY 1993 Accomplishments

None. New program for FY 1994.

Planned Products

- Development of remedial procedures and/or techniques to contain gas migration.
- Technology transfer of methodology for replacing base gas with a less expensive inert gas.
- Development of methodology for improved inventory verification.

Program Funding**DOE Historical Spending (\$ in millions)**

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Gas Migration Verification Test (TBD ¹ /FE)	-	-	0.40	
Gas Migration Study Support (FE)	-	-	0.10	
Total DOE	-	-	0.50	0.05

¹ TBD: To be determined**Cost-Sharing**

Cost-sharing goal is 50 percent. Cofunding is anticipated with GRI.

Flow Diagram

Projects	1994	1995	1996	1997	1998	1999
Gas Migration Verification Test	T	S	D		P	T
Gas Migration Study Support (Morgantown In-House)	S		T			
Storage Automation		S	D		T	
Base Gas Replacement		S	D		T	

Coding:

D = Initiate field demonstration

S = Select most promising concept for further development

T = Transfer technology or information for application

P = Achieve proof-of-concept

4.4 ENVIRONMENTAL/REGULATORY IMPACT AREA

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OFFICES: FE : FOSSIL ENERGY
 ER : ENERGY RESEARCH

4.4 ENVIRONMENTAL/REGULATORY IMPACT AREA

AREA SUMMARY

Mission

The mission of the Environmental/Regulatory Impact Program is to: (1) reduce inefficient regulations that impede market operations; (2) promote consistent cost-effective, and innovative regulations based on improved scientific information affecting all areas of the gas system; and (3) ensure availability of low cost environmental technology to industry. These efforts will increase the marketability and use of natural gas, therefore providing the Nation with economic, environmental, and energy security benefits. Sound regulations and improved technologies will enable industry to reduce the burden of compliance and meet the expected growth in electric generation.

Mandates

Policy Mandates

- "Technology for America's Growth, A New Direction to Build Economic Strength" (February 22, 1993): Outlines new criteria to govern U.S. technology policy.
- Pollution Prevention Act of 1990: Promotes pollution prevention at the source.
- Montreal Protocol (1987 and 1990): Mandates phasing out the use of all CFCs and most halons by the year 2000.
- United Nations Framework Convention on Climate Change (June 1992): Commits the U.S. to stabilizing greenhouse gas emissions to 1990 levels by the year 2000 and beyond.

Legislative and Regulatory Mandates

- FERC Order 636 (April 1992): Significantly reforms regulation of interstate pipelines to create comparability of service for all gas supplies. Still subject to court review.
- EPACT: Promotes natural gas use in transportation and electric generation; requires IRP for natural gas; and encourages research and development activities for gas technologies.
- Wellhead Decontrol Act of 1989: Eliminated all wellhead price controls by January 1, 1993.
- NEPA (as amended): Regulates environmental impacts of government sponsored activities.
- RCRA (as amended): Regulates drilling wastes, produced water, other exploration and production wastes, surface impoundments, and site remediation. Reauthorization is due in 1993.
- CWA (as amended): Regulates produced water and drilling waste discharges onshore and offshore, as well as access to and operations in wetlands. Reauthorization is due in 1993.
- Safe Drinking Water Act of 1984 (SDWA) (as amended): Regulates underground injection of produced water for disposal or enhanced recovery. Reauthorization is due in 1993.
- CAAA: Regulates air emissions from exploration and production sites, pipelines, and end user facilities. Increasingly stringent standards are being phased in for NO_x, SO₂, CO, and other emissions. Also encourages alternative fuels use in vehicles.

Program Relationships

The gas system is subject to market and environmental regulations at many levels. Market regulations can either support or discourage the ability to discover, produce, store, transport, distribute, and use gas. Removing market barriers and promoting sound regulatory policy will result in a more efficient gas system that will balance expected increases in gas consumption with sufficient gas supplies. FERC has made substantial progress in reforming an extraordinarily complex regulatory structure. DOE works with FERC on regulatory issues that have an impact on gas utilization and corresponding RD&D programs. Recent regulatory and legislative changes that have occurred on the Federal level represent a new regulatory framework and provide a catalyst for States to reevaluate their regulation of natural gas. Dialog and collaboration among State and Federal regulators, industry, environmental groups, DOE, and other customers are important parts of regulatory RD&D program planning and implementation.

Environmental regulations governing all areas of the gas system should be based on the best available scientific data, and consideration of potential costs and benefits. DOE frequently provides comments on regulations proposed by EPA that may affect gas supply. DOE staff also serve on State and Federal interagency workgroups. DOE, DOI, and EPA work cooperatively with organizations, such as the Interstate Oil and Gas Compact Commission, to improve State programs that regulate the environmental aspects of gas exploration and production, and to ascertain the effect that State regulatory programs have on gas resource recovery. EPA has instituted the Green Lights, Golden Carrots, and Energy Star (product labeling) Programs in an effort to reduce greenhouse gas emissions.

In environmental policy, DOE works to improve scientific understanding of environmental risks associated with gas production, transmission, and use. By conducting studies to determine the impact of produced waters on the environment, for example, DOE helps regulatory officials at the Federal and State levels promulgate appropriate and effective regulations. EPA and DOI are the primary Federal agencies issuing environmental regulations affecting gas supply and use. EPA and DOE cooperate in areas of mutual interest, including: energy efficiency and conservation, pollution prevention, technology transfer, and development of environmentally sound manufacturing technologies.

To explore the States' role in developing the natural gas market, DOE and National Association of Regulatory Utility Commissioners (NARUC) sponsored a National Conference on Natural Gas in April 1993. This conference examined the opportunities and challenges at the State level that have occurred through several actions, including: wellhead deregulation, new FERC policies governing pipeline transportation and supply services, CAAA and other environmental issues, the use of gas in vehicles and for electric generation, and other Federal and State actions that are changing the regulatory environment. DOE and NARUC sponsored the first conference in 1992. In conjunction with the 1992 conference, DOE solicited public input on issues related to State regulation of the gas industry in a Federal Register notice that was issued in August 1992. DOE is continuing its efforts to understand the role of the States and to communicate and coordinate with State agencies, the gas industry, and the public about gas regulation.

State agencies play a major role in regulating the environmental aspects of gas operations by issuing permits or by granting approvals for the siting and operation of exploration, production, processing, storage facilities, pipelines, and power plants. State environmental actions impact waste management, air emissions, effluent discharges, and construction projects that affect fish and wildlife and involve environmentally sensitive areas such as wetlands. DOE helps States to exchange information and discuss areas of mutual interest by sponsoring meetings and workshops, with organizations such as the National Governors Association and the Interstate Oil and Gas Compact Commission, to discuss energy siting processes, exploration and production, and permitting and enforcement activities. State public utility commissions are increasingly interested in integrated resource planning and environmental externalities, in addition to their traditional regulatory activities.

In recent years, industry and professional organizations have increased their efforts to assist individual companies to improve environmental performance and reduce environmental compliance and mitigation costs. DOE works cooperatively with these organizations to avoid duplication and to leverage resources. For example, in March 1993, DOE, EPA, the American Petroleum Institute, GRI, and others cosponsored the first Society of Petroleum Engineers (SPE) conference on environmental issues related to gas and oil exploration and production (attendance was over 1,000).

DOE is working with other Federal agencies to fulfill the commitments made under the United Nations Framework Convention on Climate Change. DOE will help to devise a mitigation strategy that will accomplish the Administration's goal to stabilize greenhouse gas emissions to 1990 levels by 2000 and beyond. Gas has a featured role in the strategy because of its environmental advantages over other fossil fuels, and because of the economic benefits of substituting lower priced gas for higher priced, greenhouse gas producing alternatives. DOE is conducting a study in conjunction with the European Community to develop an approach for valuing environmental and other impacts resulting from electric power generation.

Situation Analysis

Current Situation

With the reauthorization of RCRA, CWA, and SDWA, wellhead deregulation, pipeline restructuring and open access transportation with FERC Order 636, coupled with reform in the electricity market due to amendments to the Public Utility Holding Company Act, the focus of the regulatory and policy agenda is shifting to transportation service and State regulatory issues. The Federal Government's goal is to identify and remove Federal and State impediments to cost-effective gas use and to adopt regulations, where necessary, that are flexible enough to capture new market opportunities. The issuance of Order 636 and the passage of EPACT will have a significant impact on the natural gas market.

FERC Order 636

Order 636, as clarified and modified by Orders No. 636-A and 636-B, requires significant changes to services provided by interstate natural gas pipelines. The changes ensure that pipelines provide transportation service equal in quality for all gas supplies, whether customers purchase gas from the pipeline or from another supplier. Other major requirements under Order 636 include: a rate design change that shifts all fixed costs to firm customers; deregulation of pipeline gas sales; mitigation measures designed to balance costs and risks of restructuring; and establishment of a secondary market for transportation capacity.

For the most part, Order 636 promotes cost-effective gas use by: fostering robust competition in gas supply services; allowing efficient pricing of firm capacity and interruptible services; improving incentives to fully utilize available capacity; and permitting rapid adjustments to new market opportunities. By shifting many purchasing and balancing responsibilities to LDCs, Order 636 requires that State public utility commissions become more involved in gas operations by virtue of their oversight responsibilities. These new responsibilities come at a time when other State commission activities are growing, many of them related to CAAA implementation, electric generation regulatory reform, and integrated resource planning.

EPACT

In October 1992, Congress passed EPACT. In particular, EPACT provides the opportunity for increased gas use in transportation by encouraging the use of alternative fuel vehicles, and in electric generation by exempting wholesale power generators from the Public Utility Holding Company Act. EPACT also provides independent oil and gas producers some relief from the alternative minimum tax, which is expected to increase capital investment in gas production. EPACT also mandates IRP for natural gas. In addition,

EPACT requires that EPA develop emissions standards and test procedures for AFVs, and evaluate the success of clean fuels programs in controlling air pollution.

Other Legislation and Changes

In addition to changes resulting from Order 636 and EPACT, environmental considerations pose both opportunities and challenges for natural gas. Natural gas is generally perceived as cleaner than other fossil fuels because of low SO₂ and particulate emissions, and therefore, its use in industrial and electrical generation applications is expected to increase. Implementation of CAAA and recommendations from the National Academy of Sciences Report on Urban Ozone in 1991 may lead to further constraints on NO_x emissions from mobile and stationary sources. Requirements in the CAAA for decreasing automotive emissions according to Tier I and Tier II standards, present opportunities for NGVs. Adoption of California air quality standards by other States will tighten emissions standards even more rapidly than CAAA requirements.

There is concern within the exploration and production sectors that increasingly stringent environmental regulations will significantly hinder gas production due to higher compliance costs, without any measurable environmental benefits. This concern, combined with the possibility of diminishing access to production areas, could have a dampening effect on the amount of recoverable gas reserves in the United States. A number of Federal environmental statutes, discussed under legislative mandates, are scheduled to be reauthorized or to have new implementing regulations that may increase the compliance costs of or restrict production activities. In light of this, DOE has taken a proactive role in educating State and Federal government decisionmakers on the cumulative impacts that environmental regulations may have on U.S. gas reserves and production.

Increasingly, international issues related to trade and the environment may affect the development of the natural gas market. The North American Free Trade Agreement will continue the expansion of trade between the U.S., Canada, and Mexico. Already, Mexico has increased imports of U.S. gas because of concerns about reducing emissions of pollutants in border areas. In an effort to coordinate international RD&D, DOE is cosponsoring the establishment of the IEA Gas Technology Information Center, an international clearinghouse providing information to the global energy market on new gas technologies.

Furthermore, commitments made in the Montreal Protocol to phase out CFCs by the year 2000 could expand the use of gas absorption chillers, which do not contain CFC refrigerants. As evidenced by the international consensus reached at the Rio Summit in 1992, there is increasing international concern about the proliferation of greenhouse gases, which include CO₂ and methane. DOE is quantifying the environmental and economic impacts of increasing greenhouse gases. As nations are increasingly concerned about the environment, the international demand for environmental technologies for extraction and production operations and cleaner end use technologies is growing. However, the Federal Government may not be effectively assisting U.S. firms in pursuing this export market, through measures such as helping to identify export opportunities, reducing export barriers, and assisting the Departments of Commerce and State in their promotion programs.

Key Trends

To encourage cost-effective gas utilization, the direction of market regulatory reform has been to remove obstacles to a more efficient market system. The regulatory and policy agenda has changed considerably from the 1970s and 1980s when there was a misperception that natural gas was in short supply. In 1992, total gas consumption reached 19.8 Tcf, the highest level since 1980. Much of the credit for this increased gas use can be attributed to the changing regulatory structure that allowed the gas market to become less regulated and more competitive. Now there is a general consensus that the supply of natural gas is plentiful and available at competitive prices. The 1992 gas study of NPC, *The Potential for Natural Gas in the United States*, indicates that by the year 2010, 1,295 Tcf of gas will be available at competitive prices assuming adequate advances in technology and access to production areas. Because of existing

Federal and State policies and regulations that restrict gas demand, the future policy and regulatory agenda will focus on eliminating obstacles to gas consumption.

Public and regulatory bodies continue to press for more stringent environmental regulations in all energy sectors. Restrictions affect not only air, water, and solid waste, but also the siting and permitting of power plants, pipelines, power distribution systems, and exploration and production facilities. Regulations are rapidly becoming more restrictive not only in the levels of pollutants allowed, but also in the number of pollutants regulated. Some environmental statutes require protection of human health and the environment without consideration of potential economic or energy impacts. Comprehensive approaches to environmental protection, such as pollution prevention and life-cycle costing, have gained interest among industry and government agencies. The need for advanced, less costly, and more protective environmental technologies and practices is expanding in the industry.

Increasingly, conflicts are occurring between the desire to use more gas because of its relatively clean burning characteristics and the environmental restrictions placed on production, transportation, and use. Federal regulatory requirements usually do not allow industry the flexibility to determine how best to meet particular environmental performance goals. In addition, Federal regulatory requirements often do not account for the diversity of technologies, and the regional and site specific environmental and operational conditions. These conflicts highlight the need for more cost-effective environmental compliance technologies, information that will allow industry and Federal and State governments to manage risk more effectively, and energy impact analyses to provide decisionmakers with better information on the consequences of their actions.

Public and regulatory bodies are increasingly concerned about the following issues: (1) environmental risks associated with Naturally Occurring Radioactive Materials (NORM) in equipment and pipe discharges; (2) NO_x emissions are a target for reduction because of their contribution to ozone formation as highlighted by the December 1991 National Research Council report; and (3) the impact and potency of methane emissions is of widespread interest because of methane's role as a greenhouse gas.

DOE Position

The Administration supports increased gas use because of its beneficial qualities, namely: domestic abundance, clean burning properties, and relatively low price. Accordingly, government funding levels have grown to expand RD&D efforts for gas technologies, to expand government purchases of developing technologies for Federal fleets and facilities, and to enlarge the knowledge base of regulatory and environmental issues related to the production and use of gas.

As outlined in the 1993 report, *Technology for America's Economic Growth, A New Direction to Build Economic Strength*, the Administration's technology policy encourages greater coordination between industry and the government in RD&D, and promotes the elimination of inefficient regulations and technical barriers that impede efficient market development. Therefore, DOE will continue to identify technical and regulatory barriers to increased gas production and use, develop policies to remove these barriers, and coordinate with other Federal/State agencies and industry on the development and implementation of environmental regulations that balance the benefits of using gas with the environmental costs of developing gas resources. Regulatory policy must encourage innovation and efficient achievement of social objectives.

The Administration has indicated that expanding environmental RD&D programs is a high priority. But one agency can not be responsible for addressing every environmental problem. There needs to be a partnership between DOE, other Federal agencies, and the National Laboratories. DOE intends to continue its participation in identifying and promoting research and assessments to foster environmentally sound energy development. Advanced technologies will help reduce the cost and burden of regulations. Further, environmental goals are incorporated into all natural gas technology RD&D programs.

The present Fossil Energy program is directed only at upstream gas operations. A strategy for an environmental RD&D program relating to downstream operations will be developed in 1994; program efforts will commence in FY 1995. Downstream RD&D activities will focus on air toxics, waste minimization, and methane emissions.

NPC Study

At the request of the Secretary of Energy, NPC issued a comprehensive report in December 1992 entitled *The Potential for Natural Gas in the United States*. This report is the result of a two-year effort by over 200 individuals representing all segments of the natural gas industry (major and independent producers, transmission companies, LDCs, and marketers), end users, and Federal and State government officials. The Federal Government will work with the gas industry in its consideration of the issues and in addressing the recommendations summarized in the study.

NPC focused in part on assessing the effect of the regulatory development and environmental requirements on industry operations. Major recommendations related to the regulatory, policy, and environmental impact areas include:

- Federal, State, and local officials should allow competitive market forces to continue to develop and work. As the industry evolves, the role of regulation must shift away from efforts to control markets and move toward assuring that adequate information is available to all customers and that industry does not abuse its market power; and
- Government at all levels should create a balance between costs and benefits in the legislative and regulatory process for environmental and access issues, including direct recognition of the environmental benefits of gas as a clean burning fuel. Analysis indicates that, compared to a more balanced regulatory approach, stringent environmental requirements could decrease U.S. gas production by 2.0 to 2.3 Tcf per year by 2010, depending on the level of future economic growth.

Key Planning Assumptions

- Continued regulatory reform and industry restructuring to adjust to the increasingly competitive marketplace is necessary for the long-term growth of the industry.
- With the completion of wellhead deregulation, the focus of the Federal policy and regulatory agenda is moving to transportation services and end use issues.
- Changes are occurring at the State regulatory level as competitive forces pressure changes in gas and electric rate regulation, and environmental requirements place increased responsibility on States.
- By the year 2000, the pipeline certification and permitting process will be reformed such that sufficient capacity will exist to meet regional demand.
- Natural gas will maintain a competitive advantage for new markets due to its environmental advantages relative to other fossil fuels. However, environmental constraints associated with siting, permitting, and construction of exploration, production, and storage facilities, LNG and pipeline projects, and power plants likely will be more stringent.
- Federal, State, and local authority on environmental issues will expand in depth and scope. The full impact of reauthorized Federal statutes and new implementing regulations on the gas industry is still unknown. Implementation of the CAAA is expected to stimulate gas demand in the industrial and electric utility sectors, while making exploration, production, and transportation of gas more costly.

- State adoption of strict environmental standards will continue. CAAA and proposed adoption of California air quality standards by other States suggest that low emission vehicle technology, including CNG vehicles, will be encouraged. Zero emission vehicles in the worst nonattainment areas will increase electricity demand from clean sources.
- The contribution to global climate change from natural gas methane emissions will continue to be a major policy concern.
- Environmental externalities will continue to be considered by the States.

Key Customer Considerations

Public: The public recognizes the value of natural gas as a relatively clean, affordable, and secure domestic fuel source.

Federal Government: The Departments of State and Commerce support the objectives and goals of the DOE natural gas RD&D program because it offers trade opportunities and environmentally and economically sound technology options for gas-using countries. The Office of Management and Budget and EPA support DOE's aggressive RD&D program initiative because of its environmental benefits. DOI has close programmatic cooperation with DOE's gas program in its collection and evaluation of resource and reserve data.

Gas Industry: Even though the players in the natural gas system are quite diverse, they generally seek an expanded and more competitive gas market. The customers are as follows:

Producers: See regulatory relief and environmental compliance costs as important near-term issues.

Marketers: Both independent and affiliated (owned by distributors or pipelines) seek regulatory reform that would increase economic efficiency, expand growth, improve performance and reliability, enhance customer service, and alleviate problems such as how to fund RD&D and market entry.

Pipeline Companies: Support regulatory reform that facilitates construction of pipelines and facilities (new and expansion), and creates more efficient and flexible pricing. They seek regulatory and market stability, particularly now that Order 636 has eliminated their traditional role as marketer.

LDCs: Seek consistent and flexible Federal and State regulation and fair and timely cost recovery that would enable them to improve their marketing of gas. These companies are concerned with maximizing the reliability and flexibility of services, and would like to see innovative product development for new uses of gas.

Major Gas Consumers: Independent power producers, electric utilities, and industrial gas consumers believe that they benefit from reform of Federal statutes and regulations. They require adequate, reliable supplies, and price stability to facilitate long-term planning and to preclude supply interruptions. These groups will likely increase their use of gas to meet environmental regulations. Residential and commercial consumers are concerned that the changing regulatory framework could result in higher, more volatile gas prices and less reliable service.

Federal, State, and Local Regulatory Agencies: Regulatory agencies, such as FERC, EPA, and PUCs, generally support the development of a market-based natural gas system conditioned upon avoiding abuse of market power, protecting "captive" customers, and requiring environmental compliance.

Environmental Organizations: These groups continue to press for reduced emissions and consideration of environmental externalities in the selection of fossil fuels. They are generally proponents of energy conservation and zero emission technologies. They continue to view natural gas as the fossil energy resource of choice, but continue to support restrictive access to new resource developments.

State Governments: States govern gas utility rates, resource prorationing, and environmental issues within their jurisdictions. They are increasingly concerned with the disposal of produced waters and drilling fluids, and operating in environmentally sensitive areas. Consuming States want active government involvement to ensure supply availability and deliverability, while producing States are concerned about resource conservation and management. State geological surveys provide geological data for DOE's Gas Research Program. State regulators are concerned that the move toward a market driven gas system will result in increased costs and unreliable service. Many State governments now require IRP programs and DSM.

Foreign Governments: Interest in gas use is increasing internationally as energy demand grows and environmental concerns increase.

Congress: Congress has continued a strong interest in environmentally sound energy development and eliminating unnecessary statutory barriers to market development. It requires information on the cost and energy impacts of legislative proposals, as well as program information in support of the DOE budget.

Research Community: Research organizations (e.g., GRI and IGT), numerous colleges and universities, and National Laboratories seek to expand Federal funding for their RD&D efforts as well as contribute to the commercialization of environmental compliance technologies.

Investment Community: The investment community is concerned with reducing the risks of financing gas-related activities, such as commercializing end use technologies, and constructing required storage and distribution systems.

Department-Wide Program

The Office of Policy, Planning and Program Evaluation provides policy direction on issues related to natural gas and undertakes studies related to regulatory and statutory obstacles that unnecessarily impede the development of cost-effective gas use, impacts of emissions from vehicles and from the general use of fossil fuels, and broad economic impacts of activities proposed by the Administration or by Congress.

Energy Efficiency invests in RD&D activities for the utilization of natural gas technologies. Through partnerships with industry, Energy Efficiency develops and deploys innovative gas utilization technologies in the transportation, industrial, utility and buildings sectors. Program objectives include: analyzing combustion optimization and catalysts, emphasizing emission reductions for natural gas and other alternative fuels; developing industrial technologies to help manufacturers meet current and future environmental regulations and quality objectives; and developing methodologies for gas IRP and coordinating with the States. The environmental benefits of these utilization technologies are greater efficiency, and reduction in harmful air emissions (such as NO_x and CO₂) and other environmental effluents.

Fossil Energy's environmental efforts are only directed at upstream gas operations, and include five main activities: (1) data analysis to identify key environmental constraints to gas resource recovery; (2) outreach and technology transfer to improve environmental performance and to resolve key environmental constraints; (3) characterization of the health and environmental risks posed by gas exploration and production operations; (4) development and demonstration of technologies to improve the economics and environmental performance of gas exploration and production operations; and (5) study of Gulf of Mexico offshore and coastal discharges. Fossil Energy's gas program currently emphasizes RD&D in the areas of NORM, air emissions, and waste treatment, whereas produced water RD&D is primarily conducted in the petroleum program. At this time, there are no ongoing efforts in the areas of contaminated site cleanup and remote sensing for fugitive emissions and air toxics.

Energy Research conducts fundamental research on the role of methane in global climate change, primarily through two initiatives: (1) development of improved global circulation models as the basis for global climate studies; and (2) studies of background methane emissions from agricultural activities and natural sources such as rice paddies, boreal peat bogs, and ruminant animals.

EIA, through its data collection, analysis, and forecasting programs, provides current and future market trends for natural gas from the wellhead to the burnertip.

Priority issues for these offices will change over time as legislative and regulatory agendas evolve, new knowledge develops, opportunities arise, and available technologies and industry practices change.

Strategic Objectives and Strategies

Near-Term (By the Year 2000)

1. Identify, analyze, and recommend the removal of impediments to cost-effective gas utilization. DOE plans to:
 - a. Work with FERC to complete Federal regulatory reforms to permit increased gas use. Issues requiring the greatest attention are: implementation of Order 636, the development of a minimally regulated secondary market for pipeline capacity; and development of a streamlined certification and siting process for production, transportation, storage, and utilization facilities;
 - b. Work with FERC, PUCs, and NARUC to develop policies providing for efficient operation of the energy system and to ensure market opportunities for natural gas, such as a robust secondary market for pipeline capacity and incentive rate reform; and
 - c. Work with States to promote cooperative approaches to enhancing gas usage focusing on regulatory and environmental issues that affect access, production, storage, transmission, and utilization.
2. Provide industry with the tools to comply with environmental requirements in order to maintain and increase economic gas production. Reduce the cost of compliance with current and future requirements. Provide a sound scientific basis for regulation and mitigation measures. DOE plans to:
 - a. Develop lower cost environmental mitigation and waste management technologies and methods for gas exploration to meet current and future regulatory requirements;
 - b. Through various DOE programs, sponsor research and environmental science assessment on: global warming; air quality standards (both mobile and stationary sources); geologic hazards; aquifer protection; wetlands operations; and other air, water, and solid waste environmental concerns related to natural gas, including the role of NO_x , CO_2 , methane, NORM; and basic research on combustion and catalysis; and
 - c. Transfer environmental technologies and technical information to appropriate parties (e.g., Federal and State agencies, gas industry).
3. Enhance the capability to analyze the costs and energy impacts of proposed environmental laws and regulations on the gas industry. Obtain improved Federal and State regulations affecting gas production, transportation, distribution, and utilization networks. DOE plans to:
 - a. Work with regulatory bodies to establish improved criteria for environmental regulations based on such factors as risk assessment, cost/benefit analysis, and cumulative regulatory impact;

- b. Analyze the energy impact of environmental regulations and legislation, such as new regulations under the CAAA and reauthorization of RCRA, and ensure that such information is made available to environmental regulators and legislator; and
 - c. Formulate air and water quality standards and waste management requirements.
4. Maintain relationships with foreign governments and international organizations to continue the exchange of information and to expand trade and investment opportunities.
5. Develop regulations involving fuel provider fleets and private fleets required by EPACT, that accelerate the development of natural gas fuels for transportation.

Mid-Term (By the Year 2010)

1. Contribute to evaluations of environmental science and externalities for all fuel cycles to achieve the optimal total fuel-cycle cost mix for different energy uses affecting natural gas.

Under these strategies, DOE will use the following approaches: (1) listen to industry, regulators, associations, and other customers about their concerns and suggestions, and adjust to the changing concerns and priorities; (2) seek opportunities to incorporate environmental research into other technology RD&D efforts by DOE and others; (3) leverage program resources fully by collaborating with other concerned organizations (e.g., other Federal agencies, trade associations, and universities), and stimulating them to perform or help fund activities; and (4) promote Federal interagency cooperation and coordination.

Key Performance Indicators

Near-Term (By the Year 2000)

- Development of policies to ensure a minimally regulated secondary market for pipeline capacity, and a streamlined certification and siting process for production, transportation, storage, and utilization facilities.
- Completion of research and analysis that support States interested in reforming their gas regulatory programs. Number of conferences and workshops held with States and industry on regulatory issues.
- Completion of analysis of Federal and State barriers to the increased use of gas in electric generation.
- Initiation of efforts to address regional environmental constraints to gas supply. Expansion of analytical capability to assess relationship between environmental compliance and access constraints to gas resource recovery.
- Issuance of estimates of contribution by natural gas global methane concentrations by 1996.

Mid-Term (By the Year 2010)

- Reduction of pipeline methane losses by 25 percent, in cooperation with EPA.
- Increased market share by natural gas, due to coordination, streamlining, and reduction of Federal and State barriers to gas use.

Strategic Issues and Obstacles

- Increased gas use is dependent upon a fully mature market that caters to customer needs, balances demand and supply through market signals, and reliably serves end users. Full market maturation will not occur until industry restructuring and regulatory reform are completed.
- Continuing natural gas regulatory reforms (incorporating market oriented solutions) are needed, or use will not be economically efficient or be consistent with technology availability (consideration of new regulations may be necessary to achieve a significant increase in gas consumption).
- The gas industry needs to reexamine the internal working relationships among its components as regulatory reform and other market influences occur.
- Certain regulatory areas need to be studied to test if regulations can be removed and substituted by market oriented solutions.
- As changing gas and electric regulatory reforms at the Federal level place increased responsibility on States, DOE should develop a staff and resource capability to become more knowledgeable about State policy and regulatory developments. DOE needs to work closely with State officials to ensure that national objectives relating to gas are considered as part of the State decisionmaking process.
- Once the gas industry completes the restructuring resulting from Federal and State regulatory reform, and is well positioned to compete in the end use market, it will be necessary to identify unwarranted policy advantages that have been granted to coal and oil that distort end use competition and impede gas utilization.
- Regulations will pose one of the primary constraints on the competitive choices among fuels over the next 10 to 15 years. For example, application of externality regulations (SO_x, NO_x, and CO₂) on utility plants, and mobile and stationary source emission standards for improved air quality will help determine the future competitive advantages and disadvantages.
- The cumulative impact of compliance costs associated with uncoordinated Federal and State environmental regulations could constrain future production and utilization of natural gas.
- Access to Federal lands, including many areas in the Outer Continental Shelf and wetlands, is restricted by Federal and State policies.
- Market pricing of competing fossil fuels and nuclear energy may not reflect the total fuel-cycle cost of their production, use, and disposal. Environmental and other social benefits of gas utilization may not be explicitly recognized in decisionmaking concerning competing energy supplies.
- Scientific understanding is inadequate to guide efficient environmental regulation concerning the impact of energy use on the environment, including natural gas use.

Changes from Previous Plan

The systems approach also applies to the Environmental/Regulatory Impact Program. DOE is concerned about State and local government statutes and regulations as well as Federal Government barriers to increased production and use of gas. DOE promotes the coordination of all government level statutes and regulations and supports efficient, innovative regulations. DOE is prepared to work with State regulatory authorities to coordinate natural gas policy and regulatory approaches that will serve the interests of consumers, suppliers of natural gas, and the Nation's economic, environmental, and energy security goals.

Projects addressing NORM issues have been included in the 1993 Environmental/Regulatory Impact Program. In addition, more emphasis is being placed on outreach and technology transfer.

FY 1992-1994 Crosscut Budget Summary

Budget by DOE Office (\$ in millions)

DOE Office	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Fossil Energy (FE)	-	1.82	2.94	2.44
Energy Research (ER)	-	2.50	4.50	4.50
Total DOE	-	4.32	7.44	6.94

Budget by Project (\$ in millions)

DOE Program	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Gulf of Mexico Discharges (FE)	-	0.300	0.294	0.294
Environmental Data Analysis (FE)	-	0.343	0.440	0.440
Risk Assessment of Exploration and Production Operations (FE)	-	0.435	0.827	0.778
Technology Development to Improve Environmental Performance (FE)	-	0.206	0.856	0.500
Enhanced Technology Transfer ¹ (IEA Center) (FE)	-	0.494	- ¹	
Environmental Outreach and Technology Transfer (FE)	-	-	0.490	0.400
Program Management (FE)	-	0.042	0.029	0.024
Sources of Atmospheric Methane (ER)	-	0.500	0.500	0.500
Atmospheric Chemistry Research Associated with Natural Gas (ER)	-	2.000	4.000	4.000
Total Environmental/Regulatory Impact Area	-	4.320	7.436	6.936

¹ Funding for Enhanced Technology Transfer (IEA Center for Gas Technology Information) is transferred to the gas utilization budget in FY 1994.

GULF OF MEXICO DISCHARGES

Tactical Objective

To assess the environmental fate and effects of offshore Gulf of Mexico discharges of NORM, heavy metals, and organics in produced water and produced sands; the recovery of impacted wetlands and open bay produced water discharge sites in coastal Louisiana and Texas; and the economic impacts of offshore and coastal discharge requirements on present and future operations in the Gulf of Mexico region.

Issues

Offshore and coastal gas production may result in the discharge of produced water and sand. Produced waters include water contained in the hydrocarbon bearing formations which are brought to the surface with the extraction of hydrocarbons. These waters generally have dissolved salt concentrations higher than those in seawater, contain dissolved and dispersed hydrocarbons and related nonhydrocarbon organic compounds, and contain elevated concentrations of certain trace metals and NORM. Produced sand consists of slurried particles, unconsolidated formation sands and other particles, such as scale, that may be generated during production. There is a concern that discharge of these materials to offshore and coastal environments may result in significant impacts to human health and the ecosystem.

Major Goals

Increase the base of scientific knowledge concerning:

- The fate and environmental effects of organics, trace metals, and NORM in water, sediment, and biota near several offshore facilities;
- The characteristics of produced water and produced sand discharges as they pertain to organics, trace metals, and NORM variably found in association with the discharges;
- The recovery of four terminated produced water discharge sites located in wetland and high energy open bay sites of coastal Louisiana and Texas;
- The economic and energy supply impacts of existing and anticipated Federal and State offshore and coastal discharge regulations; and
- The catch, consumption, and human use patterns of seafood species collected from coastal and offshore waters.

Strategy (Total DOE FY 1994: \$0.294 Million)

Cost-Sharing Target: None

This activity involves a three-year study of the environmental and health related impacts of produced water and sand discharges from gas operations. Data on NORM, heavy metals, and hydrocarbons in water, sediment, and biota will be collected and evaluated.

Human health related impacts will be studied through field collections and analyses of commercially and recreationally important fish and shellfish tissues. Additionally, information on seafood catch, consumption, and patterns for the Gulf of Mexico will be gathered and analyzed. These data will also be analyzed by Brookhaven National Laboratory for study of NORM Environmental and Human Population Risks.

The facilities to be studied will include both offshore and coastal facilities. Coastal sites also will be studied to determine ecological recovery of impacted wetland and open areas. The economic impact of existing and proposed Federal and State effluent regulations also will be evaluated.

The program elements are as follows:

- Environmental field sampling and analysis of NORM, organics, and heavy metals;
- Assessment of economic impacts of offshore and coastal discharge requirements;
- Analysis of the Gulf of Mexico region seafood consumption and use patterns; and
- Field collections and analyses of commercially and recreationally important fish and shellfish tissues.

Impact (Near-Term)

- Tests the hypothesis that radionuclides contained in produced water discharges and produced sand have minimal impacts on the marine and coastal environments. This information will in part be used to assist regulatory agencies in reviewing scientific data in order to develop technically sound and justifiable regulations.

Impact (Mid-Term)

- Increases scientific knowledge on: the environmental fate and effects of NORM, heavy metals, and organics in produced water discharges and produced sands; the recovery of impacted wetland and open bay produced water discharge sites in coastal Louisiana and Texas; and the economic impacts of offshore and coastal discharge requirements on present and future operations in the Gulf of Mexico region.

FY 1993 Accomplishments

A cooperative agreement between DOE and MMS relating to the study has been finalized. A Scientific Review Committee, composed of industry and governmental agency representatives, has been organized to provide review comments on the Sampling and Analysis Plan and other deliverables. Review comments from the Committee, BNL, and DOE have been used to finalize the Sampling and Analysis Plan. The offshore and coastal field sampling programs was delayed until mid-1993 because of a needed re-evaluation with BNL of specific data needs, difficulties in identifying study sites, and the passage of Hurricane Andrew. Tasks associated with economic impacts and synthesis of seafood consumption and use are generally on schedule.

Planned Products

- Assessment of the fate and environmental effects of organics, trace metals, and NORM in water, sediment, and biota near several offshore facilities.
- Characterization of produced water and produced sand discharges as they pertain to organics, trace metals, and NORM variably found in association with the discharges.
- Evaluation of the recovery of four terminated produced water discharge sites located in wetland and high energy open bay sites of coastal Louisiana and Texas.
- Assessment of economic impacts of offshore and coastal discharge requirements.
- Synthesis of Gulf of Mexico region seafood consumption and use patterns.

Program FundingDOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Environmental and Economic Assessment of Gulf of Mexico Discharges (FE)	-	0.300	0.294	0.294
Total DOE	-	0.300	0.294	0.294

Cost-Sharing

Not Anticipated

Flow Diagram

Project	1994	1995	1996
Gulf of Mexico Discharges	T		

Coding:

T = Transfer technology or information for application

ENVIRONMENTAL DATA ANALYSIS

Tactical Objective

To develop an environmental regulatory impact data analysis system component to be used with the GSAM to identify and evaluate the principal environmental concerns requiring DOE supported research.

Issues

Current and potential environmental regulatory impacts and compliance cost are constraints that limit economic producibility of hydrocarbon resources.

Major Goals

This activity analytically identifies and evaluates the principal environmental concerns requiring DOE research, and focuses on accomplishing near-term and mid-term objectives. It includes data analysis/monitoring, evaluation, and planning/analytical efforts related to gas. Activity elements include assessment of trends in industry operational methods, extraction and process technologies, location specific environmental sensitivities, gas characteristics, environmental compliance practices, new low cost compliance technologies, and current and proposed regulations. Major goals of this activity are as follows:

- Assessment of trends in industry operational methods, extraction and process technologies;
- Development of environmental data management for risk-based regulations;
- Assessment of environmental compliance practices, and current and proposed regulations;
- Assessment of potential incremental impact on gas resource supply by environmental regulation compliance cost;
- Identification and assessment of Federal and State environmental regulations and regulatory trends for gas exploration;
- Assessment of national, regional and State trends in public perspectives and attitudes on environmental issues and concerns; and
- Enhancement of the GSAM.

Strategy (Total DOE FY 1994: \$ 0.440 million)

Cost-Sharing Target: None

DOE's approach is to work with States and others to identify and address environmental challenges to sustain or increased gas production within States or regions. DOE will also work with State and Federal regulatory agencies to adopt improved criteria for environmental regulations based on such factors as risk assessment and cost/benefit analysis. DOE will seek greater recognition of efforts by industry, government, and others to address environmental problems in a balanced and cost-effective manner. Further, DOE will strive to increase awareness of how environmental compliance costs and access restrictions affect gas resource recovery.

DOE will support efforts by industry, government, and others to exchange technical information on the environmental aspects of natural gas exploration, production, processing, transportation, and storage operations, including new technologies or methods for cost-effective environmental compliance and mitigation. Existing forums and technology transfer mechanisms will be used to the extent possible.

DOE's approach will entail using technical information created in other gas program projects, e.g., environmental risk assessment and technology development, as well as information available from external sources.

DOE also will identify and assess gas industry trends in exploration and production operations, Federal and State environmental regulations, and regulatory trends for gas exploration and production operations.

Impact (Near-Term)

- Develops dynamic analysis for gas resource supply impacted by environmental issues and concerns.
- Maintains access to gas resources that may be prematurely abandoned due to environmental concerns.
- Resolves environmental issues that limit production and future development of gas.
- Identifies alternative, less costly technologies to address environmental concerns.

Impact (Mid-Term)

- Develops and transfer new technologies to reduce environmental risk associated with gas extraction and processing.
- Reduces costs associated with environmental compliance requirements.
- Assures prioritization of RD&D activities that have a significant impact on the availability of gas resources for future production.

FY 1993 Accomplishments

- Initiated the characterization of environmental constraints on gas production and continued the identification and assessment of gas industry trends in exploration and production operations.
- Evaluated regional industry practices for compliance with associated environmental requirements.
- Identified and assessed Federal and State environmental regulations and regulatory trends for gas exploration and production operations.
- Assessed national, regional and State trends in public perspectives and attitudes on environmental issues and concerns.

Planned Products

- Development of a production environmental database for current industry waste storage and disposal practices for gas exploration and production.
- Compilation of data by region, State, waste characteristics, treatment effectiveness, costs, and associated environmental impacts will enhance the Gas Systems Analysis Model, GSAM, in determining environmental regulatory impacts on gas supply.

Program FundingDOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Environmental Data Analysis (FE)	-	0.343	0.440	0.440
Total DOE	-	0.343	0.440	0.440

Cost-Sharing

Not anticipated.

Flow Diagram

Project	1993	1994	1995	1996	1997	1998
Environmental Data Analysis	P S					D/T

Coding:

P = Achieve proof-of-concept

S = Select most promising concept for further development

D = Initiate field demonstration

T = Transfer technology or information for application

RISK ASSESSMENT OF EXPLORATION AND PRODUCTION OPERATIONS

Tactical Objective

To develop and utilize sound risk assessment approaches to help maximize production/resource recovery, and to reduce the cost of effective environmental protection.

Issues

Offshore and coastal gas production may result in the discharge of produced water and sand. These discharges can contain significant amounts of NORM, as well as organics and heavy metals. The concern that the discharge of these materials to offshore and coastal environments may result in significant impacts to human health at the population level, as well as environmental impacts to individual organisms, populations, communities or ecosystems, has resulted in regulations and restrictions that are not supported by sound science. The processing of natural gas may result in the formation of NORM scale in pipe and equipment. Data are needed on the characteristics and formation of downstream NORM deposition and their associated transport and fate. The gas industry and Federal and State regulatory agencies are interested in potential methods and technologies, such as wetlands mitigation banking, for environmental impact mitigation.

Major Goals

- Identify and assess environmental and human health risk assessment approaches for gas exploration, production, and processing;
- Assess cause and effect on individual animals and communities of discharge of NORM to coastal and offshore waters;
- Identify significant impacts of gas platforms on benthic communities;
- Identify and develop environmental impact mitigation methods and technologies, such as wetlands mitigation banking, for gas operations in environmentally sensitive areas; and
- Analyze the transport and fate of downstream NORM in gas systems and deposition in equipment and vessels.

Strategy (Total DOE FY 1994: \$0.778 Million)

Cost-Sharing Target: 5%

The Environmental Risk Assessment activity will initiate the development of an approach to environmental risk assessment for NORM discharge in produced water, and identifying overall impacts to benthic communities near produced water outfalls. An approach appropriate to the discharge of NORM to coastal and offshore water will be developed for the assessment of cause and effect on individual organisms, and by extrapolation, to communities. Efforts will include the development of statistical methods to identify significant impacts of gas drilling and production platforms on benthic communities. The Human Population Risk Assessment activity will develop an approach to population risk assessment for NORM discharged to coastal and offshore environments in produced water. In addition, NORM in gas production equipment and vessels will be characterized with respect to volumes of gas flow, NORM constituents, radioactivity, deposition conditions, transport, and fate.

Impact (Near-Term)

- Identifies potentially significant risks associated with the discharge of NORM to coastal and offshore waters.

- Maintains access to gas resources that may be prematurely abandoned due to concerns over potential environmental and human health risks from downstream NORM.

Impact (Mid-Term)

- Provides realistic health and environmental risk estimates to support regulation.
- Provides analyses of the potential for wetlands mitigation banking as a tool for gas operations.
- Provides realistic data on the characteristics, transport, and fate of downstream NORM.

FY 1993 Accomplishments

- Developed an approach for assessing the human health risk at the population level for NORM discharge.
- Completed final report on the Wetlands Mitigation Banking - Phase I project, describing the results of a national survey of wetlands mitigation banks.
- Developed a strategy for continued research on alternative wetlands mitigation options, including Wetlands Mitigation Banking - Phase II project (wetlands mitigation banking as a potentially useful environmental impact mitigation approach for the gas industry). Phase II will focus on the assessment of gas industry needs related to the potential for the development of wetlands mitigation banks.

Planned Products

- Assessment of human health impacts at the population level, and environmental impacts at the individual organism, population, community, or ecosystem levels associated with the discharge of NORM and other contaminants in produced water and sand associated with natural gas production.
- Assessment of wetlands mitigation banking and other mitigation options as potentially useful environmental impact mitigation approaches for the gas industry, based on work by Louisiana State University, ANL, and others for DOE.
- Characterization of downstream NORM in gas production equipment and vessels with respect to volumes of gas flow, NORM constituents, radioactivity, deposition conditions, transport, and fate.

Program Funding**DOE Historical Spending (\$ in millions)**

Projects	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
NORM Environmental and Human Population Risks (FE)	-	0.100	0.227	0.200
Wetlands Mitigation Banking - Phase II (FE)	-	0.125	0.200	0.178
Transport and Fate of NORM in Gas Systems/Deposition in Equipment (FE)	-	-	0.400	0.400
Analysis of Wetlands Constraints in Expanding Reserves (FE)	-	0.210	-	-
Total DOE	-	0.435	0.827	0.778

Cost-Sharing (\$ in millions)

Performer	Projects	FY 1992 Actual	FY 1993 Planned	FY 1994 Estimate
ANL ¹	Wetlands Mitigation Banking - Phase II	-	0.250	0.356
Total		-	0.250	0.356

¹ ANL: Argonne National Laboratory**Flow Diagram**

Projects	1994	1995	1996
NORM Environmental and Human Population Risks			T
Wetlands Mitigation Banking - Phase II			T
Transport and Fate of NORM in Gas Systems/Deposition in Equipment			T

Coding:

T = Transfer technology or information for application

TECHNOLOGY DEVELOPMENT TO IMPROVE ENVIRONMENTAL PERFORMANCE

Tactical Objective

To increase incremental gas production by developing technologies to enable industry to improve environmental performance and reduce the cost of environmental compliance.

Issues

Compliance costs associated with environmental regulations continue to increase at an average rate of four percent/year. In addition, there are growing restrictions for both onshore and offshore access to exploration and production locations, and the enactment of new environmental laws.

Major Goals

- Provide small and independent operators with technology to prevent NORM scale through inhibition or some other means in gas production operations;
- Develop and transfer technology on decontamination/disposal alternatives for NORM resulting from gas producing operations;
- Develop and transfer technology to minimize wastes associated with natural gas drilling and development operations; and
- Develop and transfer technology to rapidly and inexpensively measure air emissions from gas production operations with remote sensors.

Strategy (Total DOE FY 1994: \$0.500)

Cost-Sharing Target: None

The approach is to identify alternative methods of increasing incremental gas production by developing technologies to meet desired levels of environmental protection, reduce environmental regulatory compliance costs, and minimize waste generation. Strategies include: field testing of technologies to demonstrate their cost-effectiveness, collecting technical data, facilitating subsequent technology transfer, and applying a synergistic approach to developing technologies by coordinating environmental RD&D and resource and extraction RD&D.

Impact (Near-Term)

- Maintains access to gas resources that may be prematurely abandoned due to environmental concerns such as NORM scale.
- Resolves environmental issues that limit production and future development of gas resources.
- Identifies alternative, less costly technologies to address environmental concerns.

Impact (Mid-Term)

- Reduces costs associated with environmental compliance requirements.
- Develops and transfer new technologies to reduce environmental risk associated with gas resource extraction and processing.

Planned Products

- Implementation of technology to prevent NORM scale associated with natural gas production operations.
- Implementation of technology to decontaminate/dispose of NORM in gas production operations.
- Implementation of technology to minimize wastes associated with natural gas drilling and development operations.
- Implementation of technology to detect methane emissions in gas production operations.

Program FundingDOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
NORM Scale Prevention (FE)	-	-	0.200	0.000
Waste Minimization (FE)	-	-	0.100	0.100
NORM Scale Decontamination/Disposal Alternatives (FE)	-	0.206	0.400	0.400
Air Emissions Detection (FE)	-	-	0.156	0.000
Total DOE	-	0.206	0.856	0.500

Cost-Sharing

Not anticipated.

Flow Diagram

Projects	1994	1995	1996
NORM Scale Prevention			T
Waste Minimization		T	
NORM Scale Decontamination/Disposal Alternatives			T
Air Emissions Detection		T	

Coding:

T = Transfer technology or information for application

ENVIRONMENTAL OUTREACH AND TECHNOLOGY TRANSFER

Tactical Objective

To obtain improved Federal and State regulations for protecting health and the environment that may affect U.S. natural gas supply. To increase the availability of information on the environmental aspects of natural gas exploration, production, processing, transportation, and storage to industry and government decisionmakers.

Issues

Increasingly more stringent environmental regulations could have a substantial impact on the U.S. gas industry and future domestic gas supply. Analyses recently conducted by the NPC showed that, compared to a more balanced regulatory approach, stringent environmental requirements could decrease U.S. gas production by 2.0 to 2.3 Tcf per year in the year 2010 depending on the level of future economic growth (10 to 12 percent of current annual supply), with a cumulative reduced production of up to 20 Tcf by the year 2010. The magnitude of these potential impacts highlights the need for government and industry to work together to develop more cost-effective solutions to environmental problems.

Government at all levels is gaining an awareness that costly or burdensome regulation can reduce industry productivity, jobs, and revenues. Recognition is also broadening that regulations based on inadequate technical information may hinder optimal environmental protection or gas resources recovery. Industry and government decisionmakers need reliable information on the environmental aspects of natural gas exploration, production, processing, transportation and storage. Small independent producers need information on technologies and practices that can reduce environmental compliance costs, liabilities, and the potential for environmental damage.

Major Goals

- Ensure that natural gas can make a greater contribution to the energy security and environmental enhancement of our Nation;
- Create a balance between costs and benefits in environmental legislative and regulatory processes;
- Eliminate costly or burdensome environmental regulation;
- Minimize or alleviate access restrictions on industry;
- Moderate the financial impact on industry associated with environmental compliance and mitigation; and
- Increase the availability of technical information to industry and government decisionmakers.

Strategy (Total DOE FY 1994: \$0.400 million)

Cost-Sharing Target: 25%

DOE's approach is to work with States and others to identify and address environmental challenges to sustained or increased gas production within States or regions. DOE will also work with State and Federal regulatory agencies to adopt improved criteria for environmental regulations based on such factors as risk assessment and cost/benefit analysis. DOE will seek greater recognition of efforts by industry, government and others to address environmental problems in a balanced and cost-effective manner. DOE will also strive to increase awareness of how environmental compliance costs and access restrictions affect gas resource recovery.

DOE will support efforts by industry, government and others to exchange technical information on the environmental aspects of natural gas exploration, production, processing, transportation, and storage operations, including new technologies or methods for cost-effective environmental compliance and mitigation. Existing forums and technology transfer mechanisms will be used to the extent possible.

DOE's approach will entail using technical information created in other gas program projects, e.g., environmental risk assessment and technology development, as well as information available from external sources.

Impact (Near-Term)

- Sustains gas production in marginally economic fields.
- Increases availability of technical information.
- Increases awareness of overlapping environmental and gas resource recovery and utilization objectives.

Impact (Mid-Term)

- Increases natural gas reserves.
- Improves environmental performance.
- Improves regulation.

FY 1993 Accomplishments

- Assisted NPC in assessing the potential cumulative impact of environmental regulations on U.S. gas supply.
- Transferred the results of research studies related to discharges from oil and gas operations in offshore and coastal areas of the Gulf of Mexico and wetlands mitigation banking to regulatory agencies and government decisionmakers.
- Supported various environmental outreach and technology transfer efforts under the DOE advanced oil recovery research program on issues common to oil and gas exploration and production: (1) cosponsored the first SPE/EPA Environmental Conference on oil and gas exploration and production; (2) sponsored environmental compliance workshops for producers and State regulatory officials in cooperation with the Interstate Oil and Gas Compact Commission; (3) cosponsored waste management seminars for oil and gas in cooperation with American Petroleum Institute and GRI; and (4) sponsored meetings of State officials from Appalachia to exchange information on regulatory program activities related to oil and gas exploration and production. Projects funded under the oil program do not duplicate projects funded under the gas program. However, many environmental issues, regulations, and industry practices are common to both oil and gas resources recovery.
- Assisted the State of California, Department of Conservation, in conducting a comprehensive assessment of the impact of Federal, State and local environmental regulations on oil and gas production in California.

Planned Products

- Assist at least two States annually to improve environmental regulations applicable to gas exploration, production, processing, transportation, and storage.
- Continue to work cooperatively with industry, States, and others on cost-effective, risk-based environmental regulation and information exchange. Continue to support dialogue among interested parties to identify and resolve environmental barriers to natural gas supply.
- Technical conferences, workshops and seminars.

Program FundingDOE Historical Spending (\$ in millions)

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Environmental Outreach and Technology Transfer (FE)	-	-	0.490	0.400
Total DOE	-	-	0.490	0.400

Cost-Sharing

Most individual projects will be cooperative, cofunded, or cost-shared, and will involve a mix of industry, State, Federal agency, professional organization and other partners.

Flow Diagram

Not applicable.

SOURCES OF ATMOSPHERIC METHANE

Tactical Objective

To quantify methane emissions to the atmosphere from rice paddy fields, boreal peat bogs, and ruminants.

Issues

Methane emissions from various sources require quantification to understand the increasing atmospheric concentration of methane and to predict its future concentration levels. Further, the physical, chemical, and biological processes that control the emissions must be understood.

Major Goals

- Quantify methane emissions from rice paddy fields in China and the southeastern U.S., and determine factors controlling the emission levels;
- Quantify the methane emissions from boreal peat bogs, and determine factors controlling the emission levels;
- Develop and verify models of methane emission from ruminants and methane production, diffusion, and oxidation in peat bog sediments; and
- Refine current regional, continental, and global estimates of methane emissions from ruminants.

Strategy (Total DOE FY 1994: \$ 0.500 Million)

Cost-Sharing Target: None

Field measurements at selected sites are taken to develop the requisite data. Rice paddy research is conducted in cooperation with the Chinese Academy of Sciences. Research is supported through grants to university based researchers.

Impact (Near-Term)

- Develops data on major biogenic sources of methane.

Impact (Mid-Term)

- Establishes foundation for future measurement programs.

FY 1992 Accomplishments

- Completed a seven-year data set for one Chinese rice paddy site.
- Completed a two-year experiment in a boreal peat bog.

Planned Products

- A time series of rice paddy methane emissions extending over a variety of geographic regions.
- Identification of key controlling processes for methane emissions from rice paddy fields and boreal peat bogs.

Program Funding**DOE Historical Spending (\$ in millions)**

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Sources of Atmospheric Methane (ER)	-	0.500	0.500	0.500
Total DOE	-	0.500	0.500	0.500

Cost-Sharing

Not anticipated.

Flow Diagram

Not applicable.

ATMOSPHERIC CHEMISTRY RESEARCH ASSOCIATED WITH NATURAL GAS

Tactical Objective

To assess the environmental impact from increased combustion of natural gas.

Issues

The principal pollutants from the burning of natural gas are nitrogen oxides. These oxides are contributors to secondary pollutants, specifically nitric acid which increases the acidity of rain, and ozone which is the main ingredient in photochemical smog. Although acid rain is primarily a regional environmental concern, observed changes in upper tropospheric/lower stratospheric ozone are also suspected to have global climate change implications. Furthermore, tropospheric/stratospheric exchanges of ozone and NO_x may affect the processes of lower stratospheric ozone depletion from CFCs.

Major Goals

- Conduct field studies of the chemical, physical, and dynamical processes associated with transformations of NO_x from the burning of natural gas;
- Complete laboratory studies that address the key photochemical processes involving NO_x ; and
- Develop global atmospheric chemistry models that will integrate key processes and perturbations of the atmospheric climate system.

Strategy (Total DOE FY 1994: \$ 4.0 Million)

Cost-Sharing Target: None

Field studies, laboratory studies, and atmospheric chemistry model development are the key elements of this research. Research is supported through the DOE National Laboratories.

Impact (Near-Term)

- Provides understanding in controlling processes.

Impact (Mid Term)

- Allows prediction of future concentrations and modeling of chemical interactions.

FY 1993 Accomplishments

- Initiated field studies.

Planned Products

- Predictive models for understanding the controlling process in free tropospheric chemistry relative to NO_x .

Program Funding**DOE Historical Spending (\$ in millions)**

Project	FY 1992 Actual	FY 1993 Approp.	FY 1994 Request	FY 1994 Approp.
Atmospheric Chemistry Research Associated with Natural Gas (ER)	-	2.000	4.000	4.000
Total DOE	-	2.000	4.000	4.000

Cost-Sharing

No formal cost-sharing is anticipated. However, field studies are conducted in cooperation with other national and international field research programs.

Flow Diagram

Not applicable.

5.0 APPENDICES

5.0 APPENDICES

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ABBREVIATIONS

AFV	Alternative Fuel Vehicle
AMFA	Alternative Motor Fuels Act of 1988
Defense	Department of Defense
DOI	Department of the Interior
DOE	Department of Energy
DOD	Department of Defense
E.O.	Executive Order
EPA	Environmental Protection Agency
EPACT	Energy Policy Act of 1992
FERC	Federal Energy Regulatory Commission
FY	Fiscal Year
GRI	Gas Research Institute
GSA	General Services Administration
LNG	Liquefied Natural Gas
MMS	Minerals Management Service (DOI)
NARUC	National Association of Regulatory Utility Commissioners
NGVs	Natural Gas Vehicles
NOAA	National Oceanic and Atmospheric Administration
O&M	Operating and Maintenance
OPS	Office of Pipeline Safety (DOT)
ORD	Office of Research and Development (EPA)
RD&D	Research, Development and Demonstration
RSPA	Research and Special Programs Administration (DOT/OPS)
SCADA	Supervisory Control and Data Acquisition
SFV	Straight-Fixed-Variable
U.S.	United States
USGS	U.S. Geological Survey
VA	Department of Veterans Affairs
VAMC	Department of Veterans Affairs Medical Center

APPENDIX A

NATURAL GAS RELATED DEVELOPMENTS

**NATIONAL PETROLEUM COUNCIL STUDY: POTENTIAL FOR NATURAL GAS
IN THE UNITED STATES**

The National Petroleum Council, at the request of the Secretary of Energy, issued its comprehensive natural gas study in December 1992. Major findings of this analysis are:

- Resource base is abundant and can be produced and delivered at competitive prices that allow both expansion of the market and continued development of the resource.
- The gas market is increasingly diverse, with new challenges and opportunities. Opportunities include potential growth in all market sectors and several new technologies. Challenges, however, include competition with other fuel sources, improved energy efficiencies, and conservation.
- Increased reliance on competitive market forces has improved the gas industry's ability to serve customer needs in a diverse and expanding marketplace.

Major recommendations are:

- Federal, State, and local officials should allow competitive market forces to continue to develop and work.
- The Federal government should conduct research, development and demonstration (RD&D) in technology areas where there are no direct benefits to industry-funded research, upfront commercialization costs are prohibitive, or long-range research is needed. Government should look at "new ways to sponsor cooperative, joint research projects with industry participants, particularly independent producers."
- Industry needs to make the market work and perform to the benefit of the consumer, the environment, and the nation by playing an active role in the following areas: (1) reliability of gas supply; (2) customer orientation and marketing; (3) technology development and commercialization; (4) environmental regulation; and (5) leadership.

FERC ORDERS NO. 636, 636-A, AND 636-B

Federal Energy Regulatory Commission (FERC) Order No. 636, as classified and modified by Orders No. 636-A and 636-B, requires significant changes to the services provided by interstate natural gas pipelines. The changes ensure that pipelines provide transportation service equal in quality for all gas supplies, whether customers purchase gas from the pipeline or from another supplier. Major requirements are:

- Interstate pipelines must unbundle their transportation and merchant functions. Pipelines must maintain one-part volumetric rates for transportation provided to small customers.
- Upon compliance, pipelines will receive blanket sale for resale certificates authorizing the sale of gas at market-based rates. Existing sales certificates will be converted into new blanket certificates.
- Pipelines will provide open access transportation services equal in quality for all gas supplies, whether purchased from the pipeline or another seller.

- Pipelines are prohibited from including tariff provisions that inhibit the development of market centers.
- Pipelines will provide all shippers with equal and timely access to capacity release information through the use of electronic bulletin boards.
- Pipelines must provide customers with open access to storage on a contract basis.
- Open-access pipelines must provide firm shippers on downstream pipelines with access to the capacity on upstream pipelines held by the downstream pipeline. Moreover, pipelines must provide a generic capacity reallocation mechanism so that firm shippers can release unwanted capacity, on a temporary or permanent basis, to those desiring capacity.
- Pipelines will use the straight-fixed-variable (SFV) cost classification method unless FERC permits the use of another method. However, pipelines must adopt measures to avoid significant cost shifts resulting from the implementation of SFV.
- Pipelines may abandon sales and interruptible transportation service, without seeking FERC approval, on a case-by-case basis to existing customers, upon expiration or termination.

FERC/DOE NATURAL GAS DELIVERABILITY TASK FORCE REPORT

FERC/Department of Energy (DOE) Natural Gas Deliverability Task Force Report, a cooperative effort of government and private sector representatives, was issued in September 1992. The study concludes that emerging, competitive markets need a major overhaul of information systems on gas deliverability in the United States (U.S.). The current collection and reporting system for gas deliverability is inaccurate, unreliable, and not timely for gas buyers. Enhanced deliverability information is critical to more informed decisionmaking by government leaders and industry participants. Most importantly, Federal and State regulatory agencies need to work with the private sector to overhaul the current, outmoded reporting system on gas deliverability.

STUDY OF STATE REGULATION AND ITS IMPACT ON GAS CONSUMPTION

The recent regulatory and legislative changes that have taken place at the Federal level represent a new regulatory framework requiring States to reevaluate the regulation of natural gas. The decisions that States make within this new framework have ramifications for the Nation's economy, environment, and energy security. To address these changes, DOE issued a notice of inquiry in the *Federal Register*, August 21, 1992. Detailed comments were filed by 97 parties.

A summary of these comments was provided in April 1993. However, there is a growing consensus that four areas of State regulation adversely impact natural gas consumption:

- State regulations implementing Federal environmental laws are too restrictive. The regulations are making it more difficult, more time consuming, and more expensive to explore and drill for natural gas. This is particularly hurting small, independent producers.
- State prorationing policies restrict natural gas production and undermine DOE's natural gas strategy. In other words, market forces, and not government regulatory agencies, will ensure adequate supply and efficient delivery of natural gas. Respondents from the northeast expressed their strong support of the Markey-Scheur amendment.
- Coal-producing States actively promote the use of coal, and discourage the use of gas, in electric generation. These States also discourage the development of new gas end use technologies by

mandating least-cost resource planning policies (through public utility commissions and/or by not allowing local distribution company to include RD&D or advertising costs in rates).

- A number of State laws discourage the use of natural gas vehicles (NGVs), for example: (1) natural gas used as a vehicle fuel is taxed as much as \$0.18 per gallon; (2) private companies selling natural gas at a refilling station are required to register as public utilities, and sales from refueling stations are subject to public utility regulation; (3) NGVs are not allowed "below grade", for example, in underground parking garages or tunnels; and (4) location of NGV refueling stations is severely restricted.

The comments also set the stage for additional discussion of State issues in the second DOE/NARUC Conference entitled "State Regulation and Market Dynamics in the Post-Order 636/Energy Policy Act Era," April 25-28, 1993, in New Orleans, Louisiana.

EXECUTIVE ORDERS (PASSED IN 1993)

- Executive Order (E.O.) 12862 - Setting Customer Service Standards: Sets standards to ensure that the Federal government provides customer-driven high quality services. The level of service to be provided is to equal that delivered by private organizations providing comparable or analogous services. E.O. 12862 impacts the Natural Gas Plan by mandating that it be customer oriented, and is effective in both design and implementation in meeting customer needs.
- Executive Order 12844 - Federal Use of Alternative Fueled Vehicles: Sets goals (50 percent over those set forth in the Energy Policy Act of 1992) for the use of alternatively-fueled motor vehicles to: (1) reduce air pollution; (2) create domestic economic activity; (3) stimulate jobs creation; and (4) utilize domestic fuel sources. E.O. 12844 impacts the Natural Gas Plan by supporting the development of infrastructure to promote natural gas as a transportation fuel, and potentially increasing the need for additional natural gas exploration and production. E.O. 12844 and the Federal Fleet Conversion Task Force both identify major NGV marketing initiatives of the President. DOE is implementing this initiative with the Clean Cities Program.

SECRETARIAL INITIATIVES FOR 1993

- Domestic Natural Gas and Oil Initiative: Establishes new initiatives to: (1) enhance gas and oil production from existing and new fields through advanced technologies and dissemination of information concerning natural gas technologies; (2) increase gas utilization by stimulating markets for natural gas; (3) protect the environment by improving environmental technologies and practices; and (4) expand employment opportunities in the domestic gas and oil industries.
- Federal Fleet Conversion Task Force: Created by E.O. 12844, the Task Force is charged with developing recommendations for carrying out the E.O. 12844 with special emphasis on setting a course that will lead to widespread use of alternatively-fueled vehicles by private and Federal, State, and local government fleets, and ultimately by the public. A chief recommendation of the Task Force was the establishment of the Clean Cities Program (discussed below). Because this Task Force was created to carry out directions mandated in E.O. 12844, it will have the same impacts on the Natural Gas Plan as E.O. 12844.
- Implementation of the Energy Policy Act of 1992 (EPACT): Provides tax incentives to independent oil and gas producers, authorizes substantial funding for energy-related research and development, promotes renewable energy and vehicles that run on non-gasoline fuels, encourages energy conservation and efficiency, and restructures the electric utility industry to promote more competition.

Provisions of EPACT will impact the Natural Gas Plan by allowing funding for gas and oil RD&D, as well as potentially increasing the demand for natural gas (e.g., compressed natural gas vehicles).

- **Advanced Computational Technology Initiative:** Develops a collaborative RD&D program between DOE, National Laboratories, and the gas and oil industry to enhance, apply, and transfer advanced computational technologies so that industry can more effectively find and recover hydrocarbons. This initiative will support the mission of the Natural Gas Plan for increased and more efficient use of natural gas in commercial, residential, industrial, and transportation sectors.
- **Science and Technology Policy:** Ensures that the National Laboratories continue their key role in basic research, and encourages more cooperative research between the Laboratories, industry, and universities. This policy will impact the Natural Gas Plan by providing industry with access to the additional RD&D capabilities of the National Laboratories to develop advanced extraction and utilization technologies.
- **Climate Change Action Policy:** Sets goals to reduce United States greenhouse emissions to 1990 levels by the year 2000 while enhancing prospects for economic growth and job creation, and repositioning the U.S. to compete and win in the global market. Among others, this policy includes provisions to raise efficiency standards for home appliances, reduces depletion of non-industrial private forests and increases tree planting, and stimulates investment in efficient electrical motor systems. In all, the proposed measures (mostly voluntary, only a few mandate industry participation) would reduce emissions by 100 million metric tons per year. The effect of this policy on the Natural Gas Plan would be increased demand for natural gas, especially in the utility sector. Coal-fired power plants are a major source of CO₂ emissions that are claimed to be the key contributor to global warming.
- **Clean Cities Program:** Set up by the Federal Fleet Conversion Task Force, this Program has two components: First, it sets up a locally-directed program to accelerate alternative fuel use by coordinating public/private efforts to acquire both alternatively-fueled vehicles and the necessary refueling infrastructures. Second, it supports locally directed programs through coordination at the national level to aggregate purchases, ease or remove regulatory barriers, provide incentives to use AFVs, and optimize the use of Federal funds. Because this program has its origin in E.O. 12844, it will impact the Natural Gas Plan as described in the E.O 12844 discussion.

APPENDIX B

NATURAL GAS STRATEGIC PLAN STRENGTHS/WEAKNESSES

EXTERNAL

Opportunities:

- Administration's technology policy supports an expanded gas program in partnership with National Laboratories, industry, and the States.
- Regulatory reform for electricity and natural gas, and industry restructuring are increasing the competitiveness of gas.
- Advanced production and end use technologies, that are environmentally sound, reduce costs and are competitive in traditional and new markets, are needed.
- Concern about environmental protection by both the public and administration is placing more attention on the contribution of natural gas to national goals.
- Stage is set for expanded use of natural gas utilization opportunities in the transportation and electric power sectors.

Threats:

- Diverse regional and State interests; bias against natural gas which is based on indigenous State resources and tax/regulatory policies.
- Perceived deliverability problems coupled with volatile gas prices could adversely affect willingness to rely on gas for base load electric generation, industrial and other uses.
- Incomplete industry restructuring and regulatory reform impede industry maturation process.
- Slow market commercialization and/or infrastructure development for end use technologies impede the growth of gas markets.

INTERNAL

Strengths:

- Administration is not only removing regulatory barriers to increased use of gas, but also is exploring regulatory options.
- Proactive administration emphasizing gas use resulted in increased RD&D funding for natural gas programs.
- Administration emphasis on gas use resulted in increased RD&D funding for natural gas programs.

Weaknesses:

- Past dominance of coal and nuclear culture in DOE contributed to insufficient attention to natural gas programs.
- Past insufficient funding for natural gas RD&D programs.

APPENDIX C

NATURAL GAS RELATED RESEARCH BY OTHER FEDERAL DEPARTMENTS AND AGENCIES

1. DEPARTMENT OF DEFENSE

The Department of Defense (Defense or DOD) has been actively involved in the development and application of natural gas technologies. In contrast to DOE's strategy which emphasizes RD&D, Defense's natural gas program strategy focuses on procurement and demonstration of gas technologies. Specific fiscal year (FY) 1993 and FY 1994 Defense activities are summarized in the following table.

Defense Natural Gas Research Activities and Funding for FY 1993 and FY 1994 (\$ in millions)

Activity/Program	FY 1993	FY 1994 Request Goal	FY 1994 Conference
Fuel Cells and Cooling			
Procurement			
Fuel Cells	18.000	30.000	18.750
Cooling (Heat Pump)	6.000	18.000	11.250
Subtotal, Procurement	24.000	48.000	30.000
Operating & Maintenance (O&M) (Installation)	-	6.000	6.000
Fuel Cells	-	1.800	1.800
Cooling	-	-	-
Subtotal, O&M	-	7.800	7.800
R&D			
Cooling: Desiccant	-	0.750	0.200
Fuel Cells:			
200 Kw Phosphoric Acid	-	5.000	1.250
Molten Carbonate	11.800	-	8.625
Proton Exchange Membrane	-	-	1.250
Solid Oxide	-	-	0.250
Subtotal, R&D	11.800	5.750	11.575
Subtotal, Fuel Cells and Cooling	35.800	61.550	49.375
NGVs			
R&D			
Research	3.000	10.000	6.000
Demonstration	7.000	15.000	9.000
O&M			
Infrastructure Plan	-	1.500	1.500
Subtotal, NGVs	10.000	26.500	16.500
DOD Plan for Natural Gas Utilization Equipment	0.570	-	-
Total	46.370	88.050	65.875

2. DEPARTMENT OF TRANSPORTATION

The Office of Pipeline Safety (OPS) of the Department of Transportation conducts natural gas research primarily in the areas of pipeline safety and leak detection, and conducts studies related to seismic evaluation, informational systems development, and environmental protection. Funding levels and highlights of these activities, as provided in the FY 1993 Budget Submission of the *Research and Special Programs Administration* (RSPA), are as follows:

Office of Pipeline Safety RD&D Program Funding

Activity	Funding Level (\$ in millions)			
	FY 1991 Enacted	FY 1992 Enacted	FY 1993 Enacted	FY 1994 Request
Identify Environmentally Sensitive Areas and Protective Measures	0.000	0.100	0.100	n/a ¹
Evaluate New Pipeline Component Technology	0.070	0.070	0.075	n/a
Study of Supervisory Control and Data Acquisition (SCADA) Methods	0.000	0.050	0.050	n/a
Seismic Activity	0.000	0.000	0.100	n/a
Information Systems Development	0.195	0.225	0.325	n/a
Survey Onshore Liquid Gathering Lines	0.000	0.000	0.050	n/a
Total	0.265	0.445	0.700	0.850

¹ Not available.

Activity 1: Identify Environmentally Sensitive Areas and Protective Measures

The proposed reauthorization of the Pipeline Safety Act of 1991 would direct RSPA to identify all hazardous liquid pipelines that are located in environmentally sensitive areas, and issue regulations for identifying those areas where leaks can severely damage the environment.

This activity, initiated in FY 1992 (\$0.100 million), provides the necessary basis for determining whether existing safety regulations need to be amended to increase the degree and scope of protection that must be provided in environmentally sensitive areas. In addition, this effort would recommend appropriate rules to require operators to provide increased controls and protection.

Earlier work examined whether the class location concept on which the gas pipeline safety regulations are based should be extended to hazardous liquid pipelines as well. Class locations are used in gas pipeline safety regulations to require more stringent requirements for pipelines in close proximity to high density population areas. This study will determine whether this concept should be applied also to liquid pipelines in close proximity to environmentally sensitive areas.

Work performed to date has been useful in identifying key attributes that make certain areas environmentally more sensitive to hazardous liquids transported by pipelines. The present information will

be used to develop a definition for the term "environmentally sensitive area" that can be adopted in hazardous liquid pipeline safety regulations.

During FY 1993 (\$0.100 million), emphasis is placed on identifying and investigating various types of environmentally sensitive areas traversed by hazardous liquid pipelines, such as wetlands, navigable waters, and aquifers, and on ranking the areas in order of potential harm from pollution by the liquids transported. In addition, it will examine existing pipeline environmental controls, such as remotely controlled valves and other measures available to protect areas from the harmful effects of spills, and recommend additional protective measures, as appropriate, including any ranking of the areas that the study may develop. Finally, it would develop a methodology for identifying pipelines which are located in environmentally sensitive areas.

Activity 2: Evaluate New Pipeline Component Technology

This activity pertains to pipeline safety and involves analysis to study and test components using existing technology and proposed new components or materials recently developed. Initiated in FY 1991 (\$0.070 million level of effort), this effort has continued through 1992 (\$0.070 million) and emphasizes the safety of pipelines including performance of materials, components, and manufacturing processes used by pipeline operators and manufacturers to keep product in the pipe and detect weaknesses that could result in accidental releases. RSPA must evaluate pipe and pipeline materials, components, and processes to identify new applications or raise safety concerns.

The pipeline safety program ensures the continuous evaluation of expanding pipeline technology development in order to ensure that pipeline safety regulations are up-to-date and will assist in further advancement of a new technology. Earlier work performed under this activity successfully gathered information on Remote Operated Vehicles for underwater inspections of offshore pipelines in shallow waters, and evaluated various fracture mechanics models, technical methodology of different leak detection systems, and operation and maintenance methodology for hazardous liquid pipeline systems.

The present activity (FY 1993, \$0.075 million) evaluates vapor dispersion and thermal radiation models for liquefied natural gas (LNG) facilities for possible use in a proposed LNG facility in Alaska. Timely analyses of failed pipe and pipe components will be needed in addition to gathering technical information and conducting technical tests.

Activity 3: Study of Supervisory Control and Data Acquisition (SCADA) Methods

This activity was initiated in FY 1992 (\$0.050 million) and makes improvements in detection techniques for leaks in gas and hazardous liquid pipelines to prevent accidents or mitigate their consequences. Current regulations require pipeline operators to check for leaks periodically. However, only by continuous monitoring can operators ensure that pipeline leaks are detected as early as possible. Unfortunately, this task is not feasible with ordinary techniques, and operators with or without instrumentation must survey the entire length of the pipeline.

Improvements in leak detection capability using computer-based SCADA systems are highly effective in shortening the time between a leak and its detection. However, the state-of-the-art in computer-based leak detection is not capable of detecting a leak instantaneously. Because of the intrinsic features of pipelines, even with a SCADA system, it can take up to 30 minutes to confirm a leak. This is more than enough time for a leak to find an ignition source, and result in an accident or exacerbate a spill. SCADA systems are installed on many pipelines utilizing computer technology to analyze data, such as pressure, temperature, and delivery flow rates continuously gathered from remote locations on the pipeline. Computer analysis of this data is used to assist in day-to-day operating decisions on the pipeline and to provide input for real time models of the pipeline operation which identify, size, and locate leaks. Several prototype computer-based SCADA systems with effective leak detection subsystems, are being developed by different groups, and a few are in place on major pipeline systems.

During FY 1992, a state-of-the-art study of SCADA was conducted. This study investigated and analyzed various SCADA systems and SCADA-based leak detection systems available for use to detect leaks in gas and hazardous liquid pipelines. At that time, both the manufacturers and pipeline operators using the systems were contacted and requested to provide input and data for the study.

The FY 1993 work (\$0.050 million) is focused on determining what features of SCADA systems or SCADA-based leak detection systems are suitable for general application in the gas and hazardous liquid pipeline industry. The present work will assist in identifying areas where further research is needed to minimize leak detection time.

Activity 4: Seismic Activity

The objectives of this FY 1993 activity (\$0.100 million) are to: (1) assemble, evaluate, and summarize available technical studies and field research on the affects of earthquakes on gas and oil pipelines, including aboveground pump and compressor stations, and petroleum storage tanks, and; (2) develop appropriate criteria that would be the basis for rulemaking in pipeline design, construction, and emergency response to minimize the effects of disruptive seismic activity and the potential for loss of life, injuries, and environmental damage.

Recent predictions about the likelihood of earthquakes necessitate investigation of the extent of potential damage to natural gas and hazardous liquid pipeline systems, and to develop criteria for protection of pipeline systems to minimize the potentially catastrophic consequences. At present, there are no pipeline safety regulations to determine the impact of seismic activity on pipeline systems. There are many natural gas and hazardous liquid pipelines built across active seismic zones such as in California, the lower Midwest, and Alaska. In recent years, some pipelines crossing or located near these faults have been damaged by seismic activity. Seismologists estimate that the New Madrid area (seismic zone) located in adjoining sections of Kentucky, Missouri, Arkansas, Tennessee, and Illinois may be subject to strong and destructive earthquakes within the next 25 years. Many other areas with pipelines near fault zones are at risk of seismic activity as well.

Activity 5: Information Systems Development

This activity was initiated in FY 1991 (\$0.195 million) and has continued through FY 1992 (\$0.225 million). It involves design and development of high quality data collection systems and analysis of data collected to support regulatory initiatives, safety policy, and safety and environmental problems identification. The basis of this work rests on the premise that sound pipeline safety policy must be based on analyses and evaluation of accurate, timely, and detailed data. This requires designing, developing, and operating a data collection system and conducting analyses of data obtained. To date, analyses of data has provided a basis for OPS' regulatory initiatives and safety policies.

The FY 1993 work (\$0.325 million) includes a survey of the unregulated (i.e., rural) onshore hazardous liquid gathering lines to identify the extent of their potential for environmentally damaging releases. This survey will determine the age and location of pipelines, and what specific standards, if any, are followed in operating and maintaining these lines. More specifically, the work involves analyzing the effects changing pipeline safety trends may have on public and environmental safety. Analyses and evaluation of data will result in identification and establishment of criteria and measurements that can determine the effectiveness of the pipeline safety program; support the targeted enforcement; and support contingency planning for emergencies at the Federal, State, and local level.

Activity 6: Survey Onshore Liquid Gathering Lines

This activity was initiated in FY 1993 and involves surveying the onshore liquid and hazardous liquid gathering lines and determining their current conditions. There is a reason to believe that the size and the locations of these lines merits reconsideration of the need for them to be regulated under Part 195. In

1986, RSPA revised the definition of a hazardous liquid pipeline to mean a pipeline eight inches or less in nominal diameter that transports petroleum from a production facility. The number of pipeline miles that were redefined as gathering lines, and consequently unregulated, appears to be larger than originally foreseen.

To date, significant enhancement has been made in the existing data systems and development of new data systems to support pipeline safety activities, including development of:

- annual reports for hazardous liquid pipeline operators;
- enforcement tracking system and historical enforcement database;
- development of a program that allows direct computer access to accident data, annual reports, and safety related condition reports;
- a risk-based program for pipeline operator inspection;
- a program to generate and track user fee assessments and collections; and
- a program which streamlines the grant allocation process.

In FY 1993, RSPA intends to develop a regulatory history system, including database development and hypertext integration, at a funding level of \$0.275 million. Development of computer modeling programs to provide management tools for assigning inspection priorities and improvement of auditing techniques for monitoring annual and accident reports will require \$0.025 million in funds. Development of a hazardous liquid pipeline database and analyses of hazardous liquid data will cost approximately \$0.025 million.

Hazardous liquid pipeline operators will be surveyed by a questionnaire to determine the number of miles of hazardous liquid pipelines. The questionnaire will solicit information to determine if gathering lines are being operated and maintained in accordance with Part 195. In addition, information will be solicited to assess the condition of those pipelines in order to determine if those gathering lines are in poor condition which might necessitate regulatory action. The survey is necessary before any regulation can be considered and it would address pipeline length, diameter, and the environmental sensitivity of a location (proximity to bodies of water). The expected benefit would be a determination of the number and condition of hazardous liquid gathering lines in the United States.

3. U.S. GEOLOGICAL SURVEY

The U.S. Geological Survey (USGS) conducts natural gas investigations primarily in the areas of resource assessment and characterization of conventional and unconventional gas resources. The following table shows current and proposed research activities for FY 1993 and FY 1994.

Natural Gas Research Activities at the U.S. Geological Survey

Research Activity	Funding Source	Funding Level (\$ in millions)
Current FY 1993¹		0.728
• Controls and Resource Potential of Coalbed Gas	Oil and Gas Program	0.072
• Origin, Distribution, and Hazards of Natural Gas	Oil and Gas Program	0.046
• Gas Hydrate Resource Potential and the Relations Between Global Climate Change and Gas Hydrate Destabilization	Global Change Program	0.100
• Evaluation of Deep Gas Potential: Louisiana, Mississippi Salt Basin, and Gulf Coast	Oil and Gas Program	0.060
• Western Tight Gas Sandstones ²	Oil and Gas Program	0.350
• Coalbed Gas in Forest City Basin	Coal, Oil and Gas Programs	0.100
Proposed FY 1994³		4.000
• Natural Gas Investigations (interdisciplinary program; multiple projects)	Proposed for new USGS base funding	4.000

¹ Does not include the Environmental Protection Agency-funded activity (\$0.020 million) titled "Methane Flux Between Fossil Fuels and the Atmosphere: Environmental Consequences and Implications for Petroleum Resources;" and assessment activities that total approximately \$3 million for oil and gas combined.

² Matching funds by DOE at \$0.350 million for FY 1993.

³ Does not include the proposed DOE-funded activities: (1) Green River Basin Tight Gas Study (\$0.750 million); and (2) Gas Hydrates (\$0.100 million).

Natural Gas Investigations Program Elements (FY 1994)

The main elements of a Natural Gas Investigations program include: (1) Origin of Natural Gas; (2) Migration and Accumulation of Natural Gas; (3) Geologic Habitats of Natural Gas; and (4) Characterization of Natural Gas Reservoirs. All these elements include both conventional and unconventional natural gas resources, and interface with and provide information to an ongoing assessment of domestic natural gas resources.

Activity 1: Origin of Natural Gas

Natural gas originates either by direct generation from humic (woody) organic material, or by high temperature degradation of oil which is generated at lower temperatures from sapropelic organic material (e.g., algae). The following two projects are designed to enhance the understanding of the origin of natural gas so that more effective exploration strategies can be developed:

Geologic Controls on Distribution of Gas-Prone Kerogen: Empirical and experimental research will determine the influence of such factors as geologic age, tectonic setting, climate, depositional environment, sea level, and oxidation/reduction potential on the accumulation of humic kerogen dispersed in fine grained sedimentary rocks. A portion of this effort also would document the effectiveness of coal as a natural gas source rock.

Generation of Natural Gas from Oil and Nonmigrated Bitumen: Experimental and empirical research will document the temperature-time-chemical conditions under which reservoir oil and nonmigrated bitumen (still in source rock) are cracked to natural gas. Volumetric ratios for conversion of oil to natural gas during thermal cracking also will be determined.

Activity 2: Migration and Accumulation of Natural Gas

Accumulations of nonassociated natural gas commonly occur in geologic settings that are opposite of settings where oil accumulations occur (e.g., deep basin gas accumulations are concentrated in the structurally lowest parts of basins). This project will examine the physical mechanisms by which such natural gas resources accumulate.

Modeling of Natural Gas Migration: Natural gas migration by buoyancy and by fluid flow will be studied by computer modeling of sedimentary basins where major natural gas accumulations occur. Documentation of migration pathways and their evolution through time will be emphasized. The results of this research will serve as analogues for determining optimum exploration strategies in unexplored and underexplored basins.

Activity 3: Geologic Habitats of Natural Gas

Geologic settings most suitable for generation and preservation of significant natural gas resources are deep basins (>20,000 feet) and thrust belts which have not been thoroughly explored in the United States.

Deep Basins and Thrust Belts: Empirical research will be conducted in a number of deep basins and adjacent thrust belts throughout the U.S. to determine the burial, thermal, and structural histories that influenced generation and accumulation of natural gas. Emphasis will be placed on areas where abundant data is available (e.g., Arkoma Basin and Ouachita thrust belt in Arkansas and Oklahoma) and in unexplored areas with large natural gas potential (e.g., Brooks Range and foothills of Alaska). This research will determine the depth or thermal maturity limits on occurrence of gas resources and the geologic mechanisms by which natural gas is either preserved or destroyed (preservation of reservoirs and seals and stability of gas at high temperature).

Activity 4: Characterization of Natural Gas Reservoirs

Unconventional natural gas resources, which may represent as much as 40 percent of domestic natural gas resources, are commonly difficult to produce economically because of reservoir heterogeneity, low permeability, or a variety of other problems related to the petrophysical characteristics of reservoirs.

Fractured Reservoirs: Empirical three-dimensional mapping and fractural modeling of fractures (cleat) in coal will be conducted to develop a mathematical understanding of how natural gas flows through complex fracture systems. The results will serve as an analogue for similar studies of other rock types that are more common as natural gas reservoirs (e.g., low permeability sandstones), but are more difficult to study in-situ. This research will serve as a basis for developing strategies and techniques for better recovery of unconventional natural gas resources.

4. MINERALS MANAGEMENT SERVICE

The Minerals Management Service (MMS) natural gas research activities include mapping, assessment, and management of gas resources; Outer Continental Shelf research; and pipeline research. The table below shows appropriations and request for FY 1992-1994.

Natural Gas Research Activities of the Minerals Management Service

Projects	Annual Budget (\$ in millions)		
	FY 1992	FY 1993	FY 1994
<ul style="list-style-type: none"> Gulf of Mexico Atlas¹ <ul style="list-style-type: none"> Trends of Major Oil and Gas Reservoirs 	-	0.100	0.100
<ul style="list-style-type: none"> OCS Nitrogen Oxide (NO_x-smog) Reduction <ul style="list-style-type: none"> Gas Turbine NO_x Reduction Technology 	0.150	0.150	0.150
<ul style="list-style-type: none"> Development of a Management and Assessment Program for Offshore Oil and Gas Pipelines <ul style="list-style-type: none"> Storing/Analysis of Pipeline Inspection Data 	0.048	-	-
<ul style="list-style-type: none"> Pipeline Inspection Methods and Technology 	-	-	0.100
<ul style="list-style-type: none"> Pipeline Leak Detection <ul style="list-style-type: none"> Erosional/Corrosional Velocity Criterion for Sizing Multiphase Flow Lines 	0.025	-	0.100
Total	0.223	0.250	0.450

¹ Cost-shared by DOE and Gas Research Institute (GRI). DOE cofunding levels are \$0.500 million each for FY 1993 and FY 1994. GRI cofunding levels are \$0.400 million each for FY 1993 and FY 1994.

5. DEPARTMENT OF VETERANS AFFAIRS

The Department of Veterans Affairs (VA) involvement in natural gas research includes operating cost-effective and efficient utility program management tools for power generation. Currently, VA is planning for the following natural gas-related undertakings for FY 1994:

Use of DOE Storage Capacity

VA intends to purchase natural gas directly from DOE and inject it into DOE's Naval Petroleum Reserves in California during times of low prices and withdraw daily as needed. The VA could save an estimated \$0.500 to \$1 million per year by using DOE fields for the purpose of storage facilities. Further, opening the fields to commercial use as storage facilities could enhance the value of this Federal resource by at least \$5 million per year.

Price variations in the natural gas market from low demand times to high demand times are traditionally 20-100 percent. By purchasing at low demand times, and storing and withdrawing daily as needed, VA would enjoy the lowest prices throughout the year. This could result in additional savings of an estimated \$0.597 to \$0.715 million in 1993 alone.

Administrative actions for this activity include negotiation of interagency agreements with DOE; contracting for a one year supply of gas to be delivered to DOE fields in March or April of 1993; and contracting for transporting gas to VA facilities throughout the year as needed. Operational activities include coordinating the schedule of delivery and injection into DOE fields; ensuring capacity on interstate pipelines from field to facility; monthly cost allocation to each facility according to usage; and coordination daily nominations to DOE, interstate pipelines, and local gas companies.

Bypassing the Local Utility Company

Several VA Medical Centers (VAMCs) are located near the interstate pipeline for natural gas distribution. The FERC rules allow consumers to bypass the local gas company and connect directly to the interstate where it is economical to do so.

In most cases, when an engineering study shows it is economical, the local gas company will petition the consumer to enter into negotiations for a rate low enough to make it uneconomical to bypass them. The Western Region has three facilities that are candidates for bypass: Tucson and Phoenix, Arizona and Roseburg, Oregon.

This activity involves conducting an engineering study of the cost for bypass at the Tucson and Phoenix VAMCs. If the study shows a significant savings, the next step would be to negotiate for lower rates or install the bypass.

6. GENERAL SERVICES ADMINISTRATION

The General Services Administration (GSA) purchases alternative fuel vehicles, including natural gas vehicles. Alternative fuel vehicle acquisition costs for FY 1991-1994 are shown below:

**General Services Administration
Alternative Fuel Vehicles – Acquisition Costs¹**

Fiscal Year	Number of Vehicles	Base Price Total (\$ in millions)	Incremental Acquisition (\$ in millions)	Total (\$ in millions)
1991	140	1.264	0.784	2.048 ³
1992	3,125	25.155	6.699	31.855 ⁴
1993	2,920	23.727	2.626	26.353 ⁵
1994 ²	150	1.693	0.879	2.572 ⁶

¹ The numbers shown do not include control vehicle costs.

² Estimate - Not awarded.

³ \$1.264 - GSA funded.

\$0.784 - DOE funded through the Alternative Motor Fuels Act of 1988 (AMFA).

⁴ \$27.730 - GSA funded.

\$4.125 - DOE funded through AMFA.

⁵ \$24.256 - GSA funded.

\$2.097 - DOE funded through AMFA and Executive Order 12759.

⁶ \$1.693 - GSA funded.

\$0.879 - DOE funded through AMFA and Executive Order 12759.

7. ENVIRONMENTAL PROTECTION AGENCY

The Office of Research and Development (ORD) of the Environmental Protection Agency (EPA) conducts research on methane as related to the global climate change. Details of this and other natural gas related specific activities by EPA are shown in the following tables.

EPA's Global Climate Change and Other Natural Gas Related RD&D Projects

Project	Funding (\$ In millions)	
	FY 1993	FY 1994
Global Climate Change Research (see Table below)	5.500	n/a
Application of methane reburn concepts to develop more efficient, reliable, and pollution free gas combustion systems (a project with Ohio Edison)	0.300	-
Assistance to Ukraine in removing NO _x from coal-burning power plants using natural gas reburn technology	0.020	-
Characterization of methane emissions (the study will calculate and test the global warming effect of these emissions)	0.200	0.200
Cleanup waste methane from landfills for use in a commercially practical phosphoric acid fuel cell	1.700	1.400
Total	7.720	1.600

EPA/ORD's Global Change Research for Methane Related Projects¹ (FY 1993)

Research Activity	Project Total (\$ In millions)	Estimated Portion for Methane (\$ In millions)
• Anthropogenic Methane/RITG Emissions Research	3.900	1.000
• Tropospheric Chemistry	3.100	1.500
• Greenhouse Gas Pools and Fluxes in Terrestrial Ecosystems	1.800	1.500
• Assessment of Biospheric Carbon Pools and Fluxes	1.400	1.000
• Effects of Global Changes on Rice System Yields	1.500	0.500
Total	11.700	5.500

¹ The projects listed are components of the National Research Program on Global Change, which is managed by the Subcommittee for Global Change Research, Committee of Earth and Environmental Sciences, and the Federal Coordinating Committee for Science, Engineering, and Technology. This interagency coordination flows from the White House's Office of Science and Technology Policy, and is managed by the President's Science Advisor.

8. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce is responsible for measuring the concentrations of methane in the atmosphere. Currently, the Agency deploys three ships to monitor methane concentrations nationwide from 35 air sampling sites. The budget for FY 1991-1993 for methane monitoring has been approximately \$0.060 million per year. Similar level of effort is anticipated for FY 1994.

9. DEPARTMENT OF AGRICULTURE

The Department of Agriculture conducts research on natural gas indirectly in the areas of crop drying, irrigation (using pumps), heating facilities for animals, and biomass research.

RESEARCH FUNDING SUMMARY

**Natural Gas Related Research Funding by
Other Federal Departments and Agencies (\$ in millions) ¹**

Department/Agency	FY 1991	FY 1992	FY 1993	FY 1994
Department of Defense (DOD)	n/a ²	n/a	46.400	65.875 ³
Department of Transportation Office of Pipeline Safety (DOT)	0.265	0.445	0.700	0.850
Department of the Interior U.S. Geological Survey (USGS)	n/a	n/a	0.728	4.000
Department of the Interior Minerals Management Service (MMS)	n/a	0.223	0.250	0.450
Environmental Protection Agency (EPA)	n/a	n/a	7.720	1.600
General Services Administration (GSA)	1.263 ⁴	27.730 ⁴	24.256 ⁴	1.693 ⁴
National Oceanic and Atmospheric Administration (NOAA)	0.060	0.060	0.060	0.060
Total	1.588	28.458	80.114	74.528

¹ Refer to each Department/Agency description for detailed breakdown.

² Not available.

³ Conference budget.

⁴ Alternative fuel vehicle acquisition funding excludes DOE funding.

END

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