3.0 Multi-Year Program Plan

CONTENTS

3.1 Natural Gas Supply

Contents

NATURAL GAS SUPPLY

3.1.1 TECHNOLOGY SUMMARY

OVERVIEW

High resource estimates have caused natural gas to be regarded as an abundant and economically competitive domestic energy resource. This perception, along with the increasing competitiveness of natural gas, has contributed to increased demand for natural gas throughout the United States. This interest is increasing internationally, particularly in the western hemisphere under the *Summit of the Americas* activities. This interest acknowledges the environmental benefits of natural gas, especially regarding issues related to global warming.

The total size of the "economically" recoverable Lower-48 natural gas resource base has been estimated by the Energy Information Administration (EIA) to be 1,046 Tcf with current technology, and 1,355 Tcf with advanced (2020) technology (EIA's Annual Energy Outlook 1998). This can be compared to the "technically" recoverable natural gas resource base estimated by the National Petroleum Council at 1,065 Tcf with current technology, and 1,295 with advanced technology.

Current proved domestic reserves of natural gas are 165 Tcf, including Alaska. Proved reserves are composed of natural gas primarily from conventional, less geologically complex reservoirs.

The restructuring of the U.S. oil and natural gas industry continues to have an effect on technology advancement. In addition, the amount of capital available for research and development continues to decline. Environmental compliance and other operating costs are increasing; therefore, these higher costs, combined with low wellhead prices, constrain operating profit margins, which result in premature abandonments of natural gas wells and leases.

Department-Wide Program

DOE's Natural Gas Supply program is administered through the Offices of Fossil Energy, Energy Efficiency and Renewable Energy, Energy Research, and Policy. For the Office of Fossil Energy, individual projects are implemented through the offices of the Federal Energy Technology Center in Morgantown, West Virginia and Pittsburgh, Pennsylvania. Projects are cost-shared with industry at varying levels of participation depending on the type of project and the associated risk, i.e., industry cost-sharing percentage is lower for basic research projects and is higher for technology demonstration projects.

The program includes exploration, production, and processing research, development, and demonstration (RD&D), as well as extraction and processing-related environmental research. To better serve the needs of DOE stakeholders, the Department-wide program now uses an integrated "systems approach" to address the issues related to technology, market, policy, and the environment, from the reservoir to ultimate consumption.

The Department is committed to improving and expanding the integration, coordination, and partnering of Federal and non-Federal efforts in these areas.

Furthermore, the Department's traditional natural gas supply program has been expanded to actively seek additional partnerships with stakeholders, such as the Gas Research Institute, Petroleum Technology Transfer Council (PTTC), National Advanced Drilling and Excavation Technology program, Interstate Oil and Gas Compact Commission, and the North American Coalbed Methane Forum. The objectives of these partnerships are to increase the effectiveness of the DOE program, and to increase the synergy between the Department and these efforts. The Department is equally committed to increasing the synergy in-house between fundamental geoscience and environmental research and applied aspects of RD&D and deployment. Integrating and optimizing Federal efforts with non-Federal efforts is at the core of this goal.

Key Trends

- Technological advances continue to enhance industry's ability to find and develop new natural gas reserves at competitive prices.
- Technological advances continue to minimize the impact of natural gas exploration, production, and processing operations on the environment.
- Industry interest in exploration technology has increased, and recent technological advances in deepwater drilling have opened up additional offshore areas as potential new discovery sites.
- Reducing the costs of exploration, production, and processing operations has been a key driver for research, development, and demonstration projects. However, future advances will likely be smaller due to declining investments.
- Significant technological advances for natural gas processing are resulting in cost-competitive technologies for production of high quality fuels and premium chemicals.
- Natural gas company RD&D spending has been, and will continue to be, constrained by low prices and industry restructuring trends.
- Low natural gas wellhead prices are reducing industry investment in new technology development, which may adversely affect long-term gas supplies.
- Natural gas demand continues to increase, while the level of drilling activities remains subject to price swings.
- The Administration continues to support natural gas as an increasingly

important fuel option in the U.S. energy supply portfolio.

- The Administration continues to promote and enter into partnerships with the natural gas industry to develop advanced natural gas technologies.
- Environmental regulations and ensuing compliance costs continue to increase.
- Industry interest in environmental compliance technology continues to increase.

Technology

- Advanced technology will be required to help natural gas continue as a cost-competitive energy source into the next century.
- Advanced natural gas technology is needed to offset the decline in production expected after technical limits of currently available technology have been reached.
- The applicability of a technology tested under one set of geologic/reservoir conditions to another set of conditions may require refinements based on localized geologic and engineering evaluations in order to maximize new applications of the technology.
- The diverse nature of natural gas reservoirs (onshore, offshore, low permeability formations, deep reservoirs, Devonian shale, coalbed methane) and associated exploration, production, and processing problems require addressing many divergent problems simultaneously.
- Decreasing investments in technology RD&D by the private and public sectors adversely affect the rate of technology development.
- Low natural gas prices could prevent industry from achieving projected technology advancement rates and incremental supply and reserves attributed to application of advanced technology.
- Supply will come from a variety of geologic settings, each possessing a unique set of technological barriers which must be overcome in order to ensure long-term supply.
- The cost of exploration, production, and processing technologies must be reduced in order to ensure an abundant supply.
- New technology may be beyond the financial capacity of undercapitalized producers. Cost-effective second generation advanced technologies are needed for their widespread deployment.

Market

- Continued low wellhead prices and uncertainty about future wellhead prices may lead to increased well abandonment.
- Lack of timely information on availability and performance of new technologies by operators, the service sector, equipment vendors, and consultants reduces the deployment rate of new and/or advanced technologies.
- Low prices and uncertainty about future prices inhibit new projects (e.g., new wells) and/or advanced technology.
- Unless gas producers, especially independents, deploy new and advanced exploration and production technologies, and explore new domestic frontiers, adequate projected supply levels may not be realized.
- Market deployment of DOE-sponsored technologies and products must be expanded in order to help achieve production levels required to meet long-term gas demand.

- Advanced technology must be adapted to current and foreseeable low-to-moderate wellhead prices and show tangible benefits in that price environment.

Key Planning Assumptions

Technology

- Deployment of advanced technology for natural gas E&P operations will reduce exploration and production costs, and result in stable long-term supply.
- Continued technology advances will be needed, as future natural gas supplies will come from both deeper and more geologically complex reservoirs requiring specialized technology.
- More "low quality" natural gas supplies will come from both deeper and more geologically complex reservoirs requiring specialized technology.
- DOE and its stakeholders will continue to enter into partnerships in the development of more environmentally benign exploration, production, and processing technologies.

Market

- U.S. natural gas demand will increase to 24.08 Tcf in 2000 and 28.84 Tcf in 2010, as projected by the Energy Information Administration's *Annual Energy Outlook 1998.*
- The supply of natural gas from reservoirs is sustainable over the long-term.
- Increased demand for natural gas will deplete the highest quality, most easily accessible resources more rapidly. This will cause greater interest in that part of the resource base which is: constrained and/or under moratoria, harder to produce or more difficult to explore (i.e., fractured reservoirs), of lower than acceptable quality, and/or more remote from the marketplace.
- DOE RD&D programs, in coordination with other Federal and non-Federal efforts, will result in advanced technology that will help natural gas remain competitive as a fuel option in the United States.
- As major producers shift their interests overseas, smaller domestic producers most likely will be the companies that develop low permeability tight gas reservoirs and fractured reservoirs, which currently have marginal economics or present exploration difficulties.
- Demand will increase for more environmentally acceptable transportation fuels that are economically competitive with petroleum-derived fuels.

Policy & Regulatory

- The Administration's policy to maximize cost-effective use of natural gas will continue, thereby increasing the need for greater long-term supply.
- Areas currently under federal E&P moratoria (including the Arctic National Wildlife Refuge and offshore areas) will not be developed.

Environment

- Environmental concerns will continue to limit exploration of ecologically sensitive exploration areas.

Program Activity Summary

The Natural Gas Supply program includes five main areas: (1) Exploration and Production; (2) Natural Gas Processing; (3) Natural Gas and Oil Technology Partnership; (4) Fundamental Geoscience; and (5) International Center for Gas Technology. This combination of programs represents the full spectrum of activities that comprise the natural gas supply system.

The **Exploration and Production** program includes three product lines: (1) Drilling,

Completion, and Stimulation; (2) Low Permeability Formations Development; and, (3) Resources and Reserves Assessment.

The Drilling, Completion & Stimulation product line focuses on reducing costs and improving process efficiencies in reaching and recovering natural gas from various types of geological formations in an environmentally benign manner. It also addresses the barriers associated with the cost-effective completion and stimulation of natural gas wells in various types of geologic settings. The current program includes projects related to increasing the penetration rate during drilling operations, improvements in measurement-while-drilling, and improving the design of hydraulic fractures.

The Low Permeability Formations Development product line will develop and demonstrate economical and efficient tools and techniques for recovering natural gas from geologically complex, low permeability reservoirs containing large volumes of natural gas. Included are projects involving the intersection of naturally occurring fracture systems, and the demonstration of cost-effective production technology in low permeability formations.

The Resources and Reserves Assessment product line focuses on identifying, characterizing, quantifying and modeling the most attractive targets upon which to focus the exploration and production research effort. This is a diverse effort involving projects related to databases and modeling, improving recovery from mature fields, basin analysis, and technology transfer.

The **Natural Gas Processing** program comprises three areas: (1) Coalmine Methane; (2) Low Quality Natural Gas Upgrading; and (3) Gas-to-Liquids.

The Coalmine Methane activities focus on the capture of methane associated with coal mining. This effort involves demonstration of current technology to improve the penetration rate of this technology into the coal mining industry.

The Low Quality Natural Gas Upgrading product line focuses on developing techniques for removing large quantities of impurities from raw, natural gas, thus upgrading the quality of the gas to a more pure stream of methane and without poisonous concentrations of hydrogen sulfide.

The Gas-to Liquids conversion product line focuses on developing economical techniques to convert natural gas streams into more easily transportable liquid forms of

Development Wells in Anshutz Ranch East Field, Utah-Wyoming Border

hydrocarbon fuel, either liquefied natural gas or chemically stable liquid hydrocarbons as alternatives to oil-based transportation fuels.

The **Fundamental Geosciences Program** 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 the 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.

Program Funding

FY 1996-1998 Crosscut Budget Summary ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Drilling, Completion, and Stimulations	5.049	5.393	2.971
Low Permeability Formation Development	4.176	4.128	4.578
Resources and Reserves Assessment	3.922	3.927	4.293
Coalmine Methane	0.375	0.000	0.965
Low Quality Gas Upgrading	1.343	1.093	0.715
Gas-to-Liquids	2.885	5.066	3.150
Natural Gas and Oil Technology Partnership	1.000	1.000	1.000
International Center for Gas Technology	0.314	0.312	0.318
Fundamental Geosciences Research	5.500	3.800	3.800
Total	**24.564**	**24.719**	**21.790**

3.1.2 Project Descriptions

3.1.2.1 Drilling, Completion, and Stimulation

Background

This activity supports the DOE Strategic Plan by developing, testing, and fostering widespread deployment of advanced gas well *drilling, stimulation, and completion* products and technologies. New products and processes will benefit the domestic industry by reducing up-front capital requirements and/or improving cash flow profiles over producing well life. Advanced technologies also result in a smaller environmental "footprint" from drilling operations. These impacts are especially important in times of low wellhead natural gas prices and projected growth in natural gas demand. Progress towards the product line goal is considered essential by DOE, the Gas Research Institute, American Gas Association (AGA), and the industry in meeting the primary natural gas production requirements of the Nation. Economic growth will also be supported as new products and technologies are exported/deployed on a worldwide basis by U.S. companies.

Major Goals

The product line goal is to increase the net present value of oil and gas reserves over the life cycle of the producing wells by means of improvements in drilling, completion, and stimulation technologies and equipment as achieved by:

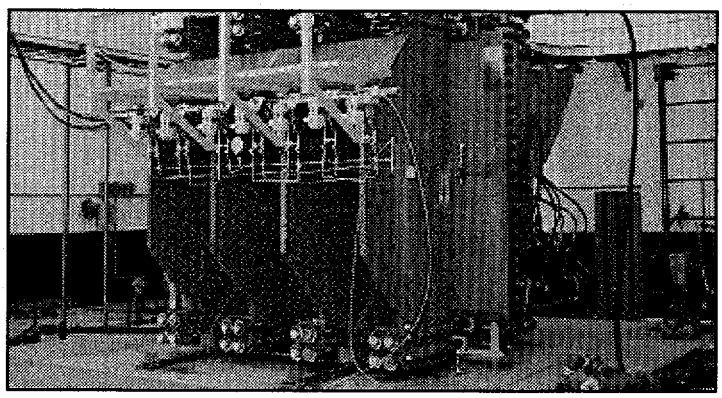
- Assisting petroleum industry in drilling research and development for near/mid-term product development;
- Encouraging demonstrations of new technologies and methods which enhance project profitability; and
- Co-participating with industry in development of completion and stimulation technologies and methodologies that look promising for improving reservoir development economics.

Project Objectives

Key project objectives are as follows:

- Underbalanced drilling fluid, model, and systems to facilitate wider technology application through a state-of-the-art drilling foam model, a low-weight solid additive (LWSA) system, a closed loop circulation system, and an electromagnetic based measurement-while-drilling (MWD) system.

Fracturing Fluid Characterization Facility



- High rate-of-penetration (ROP) drilling systems using conventional drilling fluids to introduce alternative drilling systems (e.g., directional air hammer and mud hammer) to reach target intervals in less time and at a lower cost.
- Advanced stimulation processes to improve process understanding and optimize applications. Complement large-scale laboratory experiments with field-based research and development (R&D). Fluid rheology, propellant transport, and fracture geometry are evaluated and minimum formation damage fracturing is being field tested with gas well operators.
- Advanced revolutionary drilling systems to introduce and investigate revolutionary drilling concepts that have the potential for reducing drilling time by 50 percent.
- Drilling rig equipment to enhance an aging rig inventory with capabilities adequate for present-day demands.
- Advanced well completion technology to ensure wellbore integrity in all wellbore geometries and maximize access to producing zones.

Expected Benefits

The primary expected benefits are:

- An economic gas supply to meet the 25-30 Tcf/year demand projected for the 21st century.
- Safe, efficient, and environmentally sound recovery technologies.
- Increase confidence in gas supply by continued success in reserve replacements and improved extraction and supply efficiencies.

Planned Products

Planned products are:

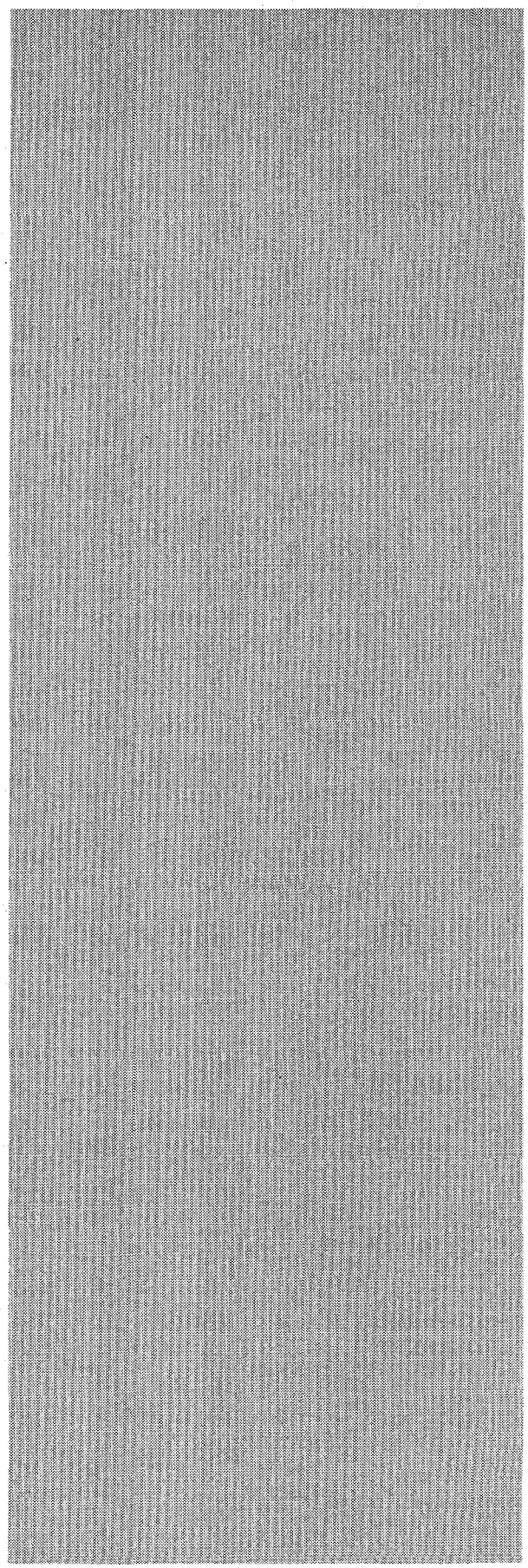
- Evaluation of the accomplishments at M-Sites and further field testing of selected technologies.
- Field testing of a fracture geometry imaging tool using geophone arrays in the Cotton Valley formation with an industry consortium.
- Field testing of the downhole pump for high pressure jet-assist drilling and evaluation of the likelihood of achieving an acceptable mean time between failure for commercialization.
- Field testing of slimhole high power motors/thermally stable diamond (TSD) bits.
- Field testing of light weight solid additives for underbalanced drilling applications using mud.
- RD&D focused at fracturing fluid and process barrier issues important to industry at the Fracturing Fluid Characterization Facility.
- Development and field testing of a prototype slimhole, coil tubing, steerable air-percussion drilling system.
- Design, development, and field testing of an integrated underbalanced directional drilling system using positive displacement motors and electromagnetic measurement while drilling.
- 15 additional CO_2/sand fracturing technology demonstrations in target basins.
- Field testing of a conventional size steerable air percussion drilling system.
- Initial development of promising industry-proposed revolutionary drilling systems.

Strategy (FY 97 Funding: $5.393 Million)

Program strategy emphasizes new thrusts into the underbalanced drilling technology , measurements while drilling, and advanced drilling, which have been in the planning process for some time.

Recent Accomplishments

- Directional drilling with a percussion air hammer was developed and successfully tested in cooperation with Smith Tool Company. Results show this new technology has the potential for doubling the penetration rates in air-drilled directional and horizontal boreholes.
- An electromagnetic MWD system was licensed to Sperry Sun Drilling Service after DOE's development support to Geoscience Electronics.
- Introduced a "dry stimulation" process to domestic producers to avoid formation damage in water-sensitive strata. Results showed that post-fracturing production is multi-fold and capable of flowing within two days.
- Completed design, fabrication, and testing of a high-power slimhole motor that should increase drilling rates and reduce costs.
- Completed fabrication of first generation near-bit directional module prototypes for measuring real-time position of the bit. This tool should reduce the risks of drilling horizontal wells out of zone.



Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Drilling	**3.438**	**2.463**	**0.900**
Steerable Air Percussion (Smith)	0.648	0.000	0.300
Slim Hole Drilling (Maurer)	0.349	0.000	0.000
Underbalanced Directional Drilling (Sperry-Sun)	0.975	0.042	0.500
Underbalanced Drilling Product (Maurer)	0.262	0.000	0.100
High Power Down-Hole Pump (Flow Drill)	0.980	0.000	0.000
Advanced Drilling System (TBD)	0.200	1.467	TBD
MWD/LWD Development (TBD)	0.000	0.928	TBD
Underbalanced Drilling Development (TBD)	0.000	0.000	TBD
Conventional Mud Hammer (TBD)	0.000	0.000	TBD
Steerable Mud Hammer (TBD)	0.000	0.000	TBD
DEA-101/44 Participation (Maurer)	0.024	0.026	0.000
Completion	**0.043**	**0.700**	**TBD**
Multistrata Study (College of West Virginia)	0.043	0.000	0.000
Advanced Completion System (TBD)	0.000	0.700	TBD
Stimulation	**1.367**	**1.219**	**1.800**
Fracture Fluid Characterization (University of Oklahoma)	0.800	0.719	0.300
Multiwell Site (CER)	0.067	0.400	0.000
CO_2/Sand Fracturing (PCS)	0.300	0.000	1.000
Advanced Stimulation (Union Pacific)	0.200	0.000	0.500
Stimulation Optimization (Stim-Lab)	0.000	0.100	0.000
Support	**0.201**	**1.011**	**0.271**
GSAM Modeling (ICF)	0.000	0.082	0.100
Technology Modeling (in-house)	0.201	0.194	0.000
Drilling, Completion, and Stimulation (Exhibits)	0.000	0.005	0.171
National Laboratory Partnership (LANL/LLNL)	0.000	0.730	TBD
Total	**5.049**	**5.393**	**2.971**

Cost Sharing ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Drilling	**1.480**	**0.743**	**0.350**
Steerable Air Percussion (Smith)	0.252	0.117	0.117
Slim Hole Drilling (Maurer)	0.174	0.000	0.000
Underbalanced Directional Drilling (Sperry-Sun)	0.419	0.018	0.215
Underbalanced Drilling Product (Maurer)	0.047	0.047	0.018
High Power Down-Hole Pump (Flow Drill)	0.588	0.000	0.000
Advanced Drilling System (TBD)	--	0.329	TBD
MWD/LWD Development (TBD)	--	0.232	TBD
Underbalanced Drilling Development (TBD)	--	--	TBD
Conventional Mud Hammer (TBD)	--	--	TBD
Steerable Mud Hammer (TBD)	--	--	TBD
DEA-101/44 Participation (Maurer)	--	--	--
Completion	--	--	--
Multistrata Study (College of West Virginia)	--	--	--
Advanced Completion System (TBD)	--	--	--
Stimulation	**0.583**	**0.359**	**TBD**
Fracture Fluid Characterization (University of Oklahoma)	0.400	0.359	0.000
Multiwell Site (CER)		--	--
CO_2/Sand Fracturing (PCS)	0.117	0.000	TBD
Advanced Stimulation (Union Pacific)	0.066	--	--
Stimulation Optimization (Stim-Lab)	--	--	--
Support	--	--	--
GSAM Modeling (ICF)	--	--	--
Technology Modeling (in-house)	--	--	--
Drilling, Completion, and Stimulation	--	--	--
National Laboratory Partnership (LANL/LLNL)	--	--	--
Total	**2.063**	**1.102**	**0.350**

TBD: To be Determined

Schedule

Projects	1997	1998	1999	2000	2001	2002
Drilling						
Steerable Air Percussion (Smith)						
Slim Hole Drilling (Maurer)						
Underbalanced Directional Drilling (Sperry-Sun)						
Underbalanced Drilling Product (Maurer)						
High Power Down-Hole Pump (Flow Drill)						
Advanced Drilling System (TBD)						
MWD/LWD Development (TBD)						
Underbalanced Drilling Development (TBD)						
Conventional Mud Hammer (TBD)						
Steerable Mud Hammer (TBD)						
DEA-101 Participation (Maurer)						
Completion						
Multistrata Study (College of WV)						
Advanced Completion System (TBD)						
Stimulation						
Fracture Fluid Characterization (University of Oklahoma)						
Multiwell Site (CER)						
CO_2/Sand Fracturing (PCS)						
Advanced Stimulation (Union Pacific)						
Stimulation Laboratory (TBD)						
Support						
GSAM Modeling (ICF)						
Technology Modeling (In house)						
DCS (TBD)						
National Laboratory Partnership (TBD)						

3.1.2.2 Low Permeability Formation Development

Background

As new discoveries from conventional supplies decline, future supplies of natural gas will increasingly have to come from low permeability (tight) reservoirs. The National Petroleum Council's (NPC) 1992 natural gas study estimated 349 Tcf of gas resource in tight sand formations in major basins throughout the United States. Areas containing significant resources/reserves include the Greater Green River Basin (GGRB), Piceance, Wind River, Uinta, and Anadarko Basins. Under current limitations in exploration and production technology, only a small portion of this vast resource is economic to develop at current gas prices. According to the 1992 NPC study, technology must continue to evolve for natural gas to fulfill its role in the United States' energy picture.

Gas production from low permeability formations is hindered by the formations' capability to allow gas to flow to the wellbore. Hence, economic production of natural gas can only occur where the flow path to the wellbore is enhanced. Geologic processes have created natural fractures in most formations that provide channels for gas to flow. In formations where the natural fracture network is extensive and dense, economic production can be achieved without wellbore enhancements. However, most low permeability formations require hydraulic fracturing to connect the wellbore to the majority of the formation to allow commercial production.

DOE and GRI have been conducting collaborative research to build industry confidence in the gas production potential of major tight gas sand basins. The effective application of production technology to the complex fractured geology of tight gas sand formations is governed by new knowledge on the subject which was not state of the art. Accordingly, DOE's multiwell experiment (MWX), a comprehensive production technology field laboratory in the Piceance Basin, produced extensive knowledge on tight sandstone production and transferred this technology to the producing community. In addition, GRI's Staged Field Experiments and Advanced Stimulation Technology Deployment Program have developed stimulation technology and transferred that technology to industry as well. Together, DOE and GRI worked at the MultiSites (former MWX location) to validate the microseismic mapping technique to image hydraulic fractures.

Current DOE research under the Low Permeability Formation Development product line is focused on advanced imaging and diagnostics technologies to detect and characterize natural fracture networks and verification tests of production technologies to prove undeveloped and underdeveloped gas resources locked within low permeability reservoirs.

Major Goals

The goal of the Low Permeability Formation Development product line is to develop technologies that will help industry increase production and reserves from low permeability formations to assure an adequate supply of natural gas well into the future. Specific goals include:

- Improve remote and in-situ techniques to detect and characterize natural fracture systems as well as various reservoir characteristics.
- Verify production technologies in basins with large tight gas sand resources/ reserves.

Project Objectives

A key objective is to develop and demonstrate, in partnership with industry, efficient development strategies for low permeability gas formations. Research efforts will be concentrated on natural fracture detection to increase the success rate of drilling economic wells and on production verification tests to improve the efficiency of

tight gas sand recovery. Work will be developed and demonstrated in priority basins and extrapolated to other basins throughout the United States.

Expected Benefits

- Ultimate recovery of gas in existing low permeability fields will increase through a better understanding of the natural fracture-production relationship.
- Dry holes (or uneconomic producers) will be reduced because of better methods to detect "sweet spots" of enhanced fracture systems.
- Tight gas sands production and reserves will increase from the demonstration and application of efficient development strategies.

Planned Products

- Methodologies to locate and define favorable production areas within tight gas sand basins nationwide.
- Techniques for the detection and mapping of fractured zones based on engineering, geological, and geophysical principles utilizing an integrated approach.
- Case studies of efficient and economic production technology from high angle and horizontal wells.
- Case studies of innovative stimulation techniques for improved recovery of gas.
- A hydraulic fracture imaging system that accurately maps fracture properties to help optimize treatments and gas recovery.

Strategy (FY 1997 Funding: $4.128 Million)

Natural Fracture Detection and Mapping

Natural fracture detection and mapping continues to be a major area of research. The main thrust has been in validating different approaches to detect natural fracture systems in areas that are well characterized by prior drilling and production. These research projects will culminate with verification tests in areas of little or no production. The final strategy is to provide a commercial service to use these technologies. Also, research will begin to advance to the next generation of fracture detection, moving from a more qualitative assessment of fracture systems to a more quantitative assessment to identify fracture properties (e.g., spacing, aperture), and fracture/pore space fluid properties.

Production Technology

Another major area of research will be to develop and demonstrate new production technologies for the efficient development of low permeability gas formations. DOE will verify technologies by conducting cost-shared tests in cooperation with industry and GRI. Industry involvement will facilitate transfer of technology. There are currently two major projects: the GGRB Production Test with Union Pacific Resources, and the Wind River Exploration and Stimulation Test with the Institute for Energy Research (IER) in cooperation with Synder Oil. The GGRB project will focus on horizontal well technology while the Wind River project will focus on detecting sweet spots (areas of over pressurization with enhanced porosity and permeability) and improved stimulation technologies. Successful applications of these technologies will lead to further testing in other basins while DOE continues to pursue opportunities for testing other promising technologies.

Recent Accomplishments

Coleman Research Corporation and Blackhawk/Geometrics Inc., completed analysis of a three-dimensional (3-D), P-wave seismic survey using azimuthal analysis of amplitude versus offset methods to determine areas of high natural fracture density and fracture orientation. An 80 percent success rate was obtained in distinguishing commercial production from non-commercial production from existing wells in the Maddin Gas Field, Wind River Basin, Wyoming.

Advanced Resources International has mapped subtle reverse faults that are responsible for natural fracture-based, high productivity trends within the tight gas sand formations at the Rulison Field, Piceance Basin, Colorado. Estimated ultimate recoveries (EURs) of gas for wells within the high productivity trends are over 2 Bcf whereas EURs are below 1 Bcf outside the trend. The methodology integrated analyses of remote sensing, aeromagnetic and seismic surveys, and basin analysis. Additional work using the same methodology at the adjoining Mamm Creek Field/Hunter Mesa Unit has contributed significantly to Synder Oil's rationale for locating new wells.

Lawrence Berkeley Laboratory completed well-to-well shear wave seismic surveys and well testing at the Conoco Test Site in Oklahoma, at a joint research site with Massachusetts Institute of Technology (MIT) in the Antrim Shale in Michigan, and at the Royal Center gas storage field in Indiana. Results have indicated that near wellbore changes in natural fracture apertures during pressure fluctuations and different fluid types within the fracture system can be detected. This methodology shows promise of commercialization within a few years.

Work at the DOE/GRI Multi-Site in the Piceance Basin, Colorado, validated the microseismic technology for determining properties of hydraulic fractures. Heights were confirmed by the use of a downhole array of inclonometers; lengths were confirmed by fracturing into a deviated lateral well located 300 feet ahead of the fracture; and azimuth was validated by comparing the azimuth in the intersecting lateral with the microseismic azimuth. It is anticipated that a commercial service using the microseismic technology to determine hydraulic fracture properties will be available by the year 2000.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Production Technology	**1.430**	**1.577**	**1.950**
Greater Green River Basin Production Test (UPR)	1.370	0.379	1.950
Wind River Basin Exploration & Stimulation Tests (IER)	0.000	1.198	0.000
Microseismic Hydraulic Fracture Diagnostic Tests (B&A)	0.000	0.000	TBD
Multi-Strata Tests (College of West Virginia)	0.060	0.000	0.000
Natural Fracture Detection	**2.497**	**1.658**	**1.575**
Fractured Reservoirs Detection (Coleman)	1.095	0.378	0.530
Fractures Detection Optimization (ARI)	1.100	0.662	0.470
High Resolution Verticle Seismic Profile for Fracture Characterization (LBL)	0.150	0.238	0.200
Evaluation of Fracture Diagnostic Methods (LBL)	0.040	0.190	0.150
Geotechnical Research (SNL)	0.112	0.190	0.225
Support	**0.249**	**0.893**	**1.053**
GSAM Modeling (ICF)	0.040	0.091	0.000
Gas Hydrates Research (USGS/Naval Research Lab.)	0.000	0.340	0.300
Geotechnical Support (EG&G)	0.209	0.192	0.310
National Laboratory Partnership (INEL/LLL)	0.000	0.270	0.270
Special Projects (DOE)	0.000	0.000	0.173
Total	**4.176**	**4.128**	**4.578**

Cost Sharing / In-Kind Contributions ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998 Estimate
Production Technology	**2.289**	**0.000**	**3.255**
Greater Green River Basin Production Test (UPR)	2.289	0.000	1.595
Wind River Basin Exploration & Stimulation Tests (IER)	N/A	N/A	1.660
Microseismic Hydraulic Fracture Diagnostic Tests (B&A)	N/A	N/A	TBD
Natural Fracture Detection	**0.870**	**0.600**	**0.780**
Fractured Reservoirs Detection (Coleman)*	0.100	0.100	TBD
Fractures Detection Optimization (ARI)	0.770 0.780**	0.500	
Total	**3.159**	**0.600**	**4.035**

* Contributions in prior fiscal years totaled $1.950 million.

** $780,000 for a potential 3-D seismic survey

SCHEDULE

Projects	1997	1998	1999	2000	2001	2002
Production Technology						
Greater Green River Basin Production Test (UPR)						
Wind River Basin Exploration & Stimulation Tests (IER)						
Microseismic Hydraulic Fracture Diagnostic Tests (B&A)						
Advanced Technology for Efficient Low Permeability Development Tests (TBD)						
Natural Fracture Detection						
Fractured Reservoirs Detection (Coleman)						
Fractures Detection Optimization (ARI)						
High Resolution VSP for Fracture Characterization (LBL)						
Evaluation of Fracture Diagnostic Methods (LBL)						
Geotechnical Research (SNL)						
Advanced Diagnostic Field Tests (TBD)						
Next Generation Fracture Detection (TBD)						
Support						
GSAM Modeling (ICF)						
Gas Hydrates Research (USGS/Naval Research Lab)						
National Laboratory Partnership (INEL/LLL)						
Geotechnical Support (EG&G)						

VSP: Verticle Seismic Profile

3.1.2.3 Resources and Reserves Assessment

Background

The vast and abundant resource base has barriers to exploration and production that must be assessed in order to systematically apply the advanced technology that can convert the resource base to proved reserves. According to the National Petroleum Council's 1992 study, almost one-third of the technically recoverable resource base is contained in low permeability formations (approximately 400 Tcf). The quality of data available for characterizing the resource base and for prioritizing exploration and production barriers varies from marginal to good.

Different groups have need for similar information, but for different uses. Coordination between these groups such as DOE and Interior, the States, and industry must be improved. Data collection and data quality control is expensive. Therefore, issues with the data are discovered and addressed as models, and databases are developed. The two principal targets for increasing recovery from known fields are: (1) untapped reservoir compartments of gas within established fields; and (2) bypassed gas and partially drained zones in existing wells.

Originally this program was designed to characterize and quantify natural gas in low permeability formations; in promising but geologically poorly-defined occurrences (i.e., deep gas, convergent margins, and gas hydrates); and in secondary recovery of natural gas from heterogeneous formations in producing field areas.

The program is currently focused on three aspects of natural gas resource and reserves. These are: resource characterization and reserves analysis of tight gas formations; secondary natural gas resource and recovery; and natural gas information and analysis products and systems.

Major Goals

- Complete development of natural gas atlases.
- Stimulate recovery of secondary natural gas.
- Characterize the domestic natural gas resource base, thereby stimulating exploration, development, and production.
- Prioritize barriers to exploration and production associated with this resource base.
- Develop a methodology for assessing the risk associated with developing the natural gas resource base.
- Coordinate efforts in basin analysis with the U.S. Geological Survey.

Project Objectives

Objectives of this project are to: characterize both low permeability formations and in-field secondary gas targets in support of the development of a portfolio of technologies and methodologies for increasing their recovery; develop database information to reduce cost in natural gas exploration and development; and analyze the resource base and develop a system to quantify, characterize, and prioritize the most promising natural gas targets.

Expected Benefits

- Research results could accelerate conversion of the resource base currently undiscovered to economic reserves.
- Improved understanding of gas resources distribution in some of the most prolific basins in the U.S. will help reduce the economic risk associated with industry investments.
- Increased exploration and production success due to more efficient development of reservoirs, extension of field limits, and better assessment of opportunities for intrafield exploration

and development of mature gas provinces.

- Improved understanding of ultra-deep water areas of the Gulf of Mexico.
- Increased recovery from complex, mature sandstone reservoirs.
- Expanded portfolio of recovery methodologies will increase ultimate gas recovery from complex reservoirs.

Planned Products

- Completion of the Atlas of Major Appalachian Gas Plays and the Northern Gulf of Mexico Gas and Oil Atlas (Volumes 1 and 2), and associated data discs and CD-ROMs.
- Development of a gas database system, Gas Information 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, as part of GASIS, for 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, Gas Systems Analysis Model (GSAM), to exploit the upgraded data sets to determine the impact of changes in policy, regulatory environment, and advanced technology on the resource base and proven reserves.
- Development of a market analysis to improve the development of the atlases, GASIS, GSAM, and the basin analyses.
- Completion of preliminary geological studies by the USGS in the Big Horn Basin of Wyoming.
- Topical reports.
- Technology transfer workshops.

Strategy (FY 1997 Funding: $3.927 Million)

- Improve access to and quality of available geologic and engineering data for identifying investment opportunities and assessing risk associated with economic investments in the natural gas resource base.
- Develop modeling capability for use in assessing the impact of regulatory, environmental, and tax policies; and technological advances on the long-term supply of natural gas.
- Conduct analyses to determine resource and reserve potential of natural gas reservoirs, and develop methodologies for extraction of the resource.
- Increase access to information and technology development.
- Conduct additional secondary gas recovery studies in a basin outside the Gulf Coast of Texas by transferring results learned in the Gulf Coast Basin studies, and validate this approach.

Recent Accomplishments

- Completed preliminary version of the Atlas of Major Appalachian Gas Plays.
- Continued development of the Gas Systems Analysis Model.
- Completed preliminary work on the Atlas of Northern Gulf of Mexico Gas and Oil Reservoirs.
- Continued development of the Gas Information System.
- Initiated assessment of secondary gas recovery/reserve growth potential in the Permian Basin for carbonate reservoirs.
- Completed USGS geological studies in the Wind River Basin of Wyoming.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Geologic Data Integration	**1.650**	**1.269**	**1.445**
Natural Gas Markets (K&M)	0.150	0.068	0.050
Gas System Analysis Model - GSAM (ICF)	0.550	0.391	0.400
Gas Information System - GASIS (EEA)	0.600	0.508	0.400
Wind River Basin Analysis (USGS)	0.350	0.302	0.300
Basin Center Gas (USGS)	0.000	0.000	0.195
Deep Reservoir Studies (USGS)	0.000	0.000	0.100
Reserve Growth	**1.222**	**1.176**	**0.923**
Secondary Gas Recovery - TX (BEG)	0.800	0.831	0.0
Secondary Gas Recovery - Appalachia (WV Consortium)	0.000	0.232	0.268
Reserve Growth (University of Texas)	0.050	0.108	0.155
Reserve Assessment (Scioto)	0.372	0.005	0.000
Secondary Gas Recovery-Offshore (BEG)	0.000	0.000	0.500
Technology Support	**1.050**	**1.482**	**1.925**
Offshore Assessment (Marine Board)	0.025	0.025	0.025
Technology Transfer (PTTC)	0.700	0.742	0.742
Advanced Technology (INEEL)	0.000	0.000	0.480
Program Planning (HQ)	0.000	0.019	0.000
In-House (FETC/Systems)	0.325	0.267	0.259
Systems Analysis (HQ)	0.000	0.079	0.129
Technology Support (EG&G)	0.000	0.100	0.100
Coalmine Methane Studies	0.000	0.250	0.000
Special Projects	0.000	0.000	0.190
Total	**3.922**	**3.927**	**4.293**

Cost Sharing

Secondary Gas Recovery (BEG): 60 percent.

Schedule

Projects	1997	1998	1999	2000	2001	2002
Geologic Data Integration						
Natural Gas Markets (K&M)	▬	▬				
Gas System Analysis Model (ICF)	▬					
Gas Information System (EEA)	▬	▬	▬			
Basis Analysis (USGS) MT, WY, ND, and NM	▬	▬	▬	▬	▬	▬
Reserve Growth						
Secondary Gas Recovery - TX (BEG)	▬					
Secondary Gas Recovery - Appalachia (WV Consortium)	▬	▬	▬			
Reserve Growth (University of Texas)	▬	▬	▬			
Reserve Assessment (Scioto)	▬					
Technology Support						
Offshore Assessment (Marine Board)	▬	▬	▬	▬	▬	▬
Technology Transfer (FETC/Pittsburgh)	▬	▬	▬	▬	▬	▬
Advanced Technology (INEEL)	▬	▬	▬			
Program (FETC)						
In-House (FETC/Systems)	▬	▬	▬	▬	▬	▬
Systems Analysis (HQ)	▬	▬	▬	▬	▬	▬