

## **3.2 DELIVERY AND STORAGE**

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# DELIVERY AND STORAGE

## 3.2.1 TECHNOLOGY SUMMARY

### OVERVIEW

Natural gas, a clean-burning and domestically abundant fossil fuel, is an increasingly important component of the Nation's energy portfolio. Natural gas is now recognized by many as the fuel of choice in the long-term transition to a sustainable energy future. Adequate, responsive, and cost-efficient underground storage is a vital part of maintaining the confidence level of natural gas consumers. Stored gas can supplement pipeline capacity during periods of heavy demand and serve as backup supply during an interruption in wellhead production. Today there are more than 17,000 gas storage wells at 375 sites around the country.

Increased access to underground storage will allow more extensive use of the interstate pipeline system. Following deregulation and FERC Order 636, most interstate storage became open access, with up to 90% now available to natural gas transportation customers. New storage facilities have also been built, largely salt caverns where natural gas can be injected and withdrawn on a continuing basis throughout the year.

Natural Gas is distributed to virtually every region of the country through an extensive system made up of more than 1.3 million miles of pipeline, meters, compressor stations, and approximately 375 storage reservoirs. The gas industry currently has the capability to deliver approximately 3.5 Tcf of gas from these storage sites, which are heavily concentrated in and near major eastern and midcontinent markets. The Annual Energy Outlook 1998 forecasts that electric generation demand for natural gas will grow by 4.24 Tcf between 1996 and 2010. This is the consuming sector that places highest demands on deliverability. Four U.S. regions that have substantial growth rates for generation gas are New England, Mid Atlantic, South Atlantic, and East North Central. The total deliverability

growth needed for these four regions is 6,180 MMcfd, adding 12 percent to existing storage deliverability. Other regions have less need for storage than these four because of either their lower growth rate or their proximity to gas production. Much of this needed deliverability can be obtained by improvement of existing storage facilities and the balance by adding facilities.

### **DEPARTMENT-WIDE PROGRAM**

The Department of Energy is working with industry to help ensure a safe, reliable, and cost effective supply of natural gas.

Through the Natural Gas Delivery and Storage Program, DOE promotes the development of advanced technologies and methods to enhance and expand the delivery and storage system.

Once natural gas is produced, the gas delivery and storage system provides the link between wellhead and burner tip. DOE's Gas Storage Program focuses on the development of technologies and methods to enhance and expand this system. Many of the advances in other oil and gas program areas directly benefit the gas delivery and storage system, improving the development, deliverability, and maintenance of underground storage caverns.

Advanced technology will be a key factor in meeting the challenges facing the natural gas industry. These challenges require significant investment in R&D at a time when gas distribution companies are focusing their resources on operating profitably in a deregulated environment. Extensive restructuring, driven primarily by Federal regulatory change, has transformed the heavily regulated industry of the past into an intensely competitive, market driven one. Deregulation has placed significant demands on the gas delivery and storage system. Demands will intensify with impending electric utility sector restructuring. The gas industry also must address the need for system expansion in response to increased demand in the east and the westward shift in gas supply, and

plan for the increased maintenance required by the aging delivery and storage system infrastructure.

Development of advanced technologies that meet industry needs would result in a more efficient natural gas storage system and benefit both industry and consumers. The gas storage industry would benefit from improved storage efficiency through increased deliverability, decreased deliverability revitalization costs, and increased operating efficiency. Local distribution companies would gain from improved system reliability and flexibility. Industrial and power generation end users would benefit from advanced storage concepts, and residential customers would benefit from lower costs for service.

An enhanced gas storage system would also contribute to increased use of clean burning, abundant domestic natural gas resources, helping to meet our Nation's energy and environmental goals.

### **PROGRAM ACTIVITY SUMMARY**

Program efforts are primarily focus on the four cost-effective technologies and engineering practices described below.

- *Deliverability Enhancement:* The objective is to reduce the costs associated with storage well deliverability decline and to increase deliverability from storage to support the projected market growth to 28.84 Tcf by 2010. Deliverability losses averaging 5 percent annually are costing the industry in excess of \$100 million annually for remedial measures. Increasing deliverability is the key to providing customers with cost-effective storage service under Federal Energy Regulatory Commission (FERC) Order No. 636. Implementation of a variety of technologies and operating practices are needed to achieve deliverability targets and reduce potential field problems. The R&D efforts include development of preventative methods and technologies, improvements of current remedial

measures (e.g., acidizing and reperforating), development of novel hydraulic fracturing techniques, and the effective use of horizontal wells.

- **Advanced Storage:** The power generation sector accounts for nearly 2 Tcf of the projected growth in natural gas demand. Gas-fired power generation represents a major growth market for the natural gas industry. A recent study conducted for the Gas Research Institute, "Current Market Drivers and Probable Trends in the Utilization of Natural Gas Storage," concluded that peak day requirements for most industrial and regional segments will increase, flexibility in storage services will be critical, and a need for cost-effective peaking service is evident. Research efforts include investigation of alternative storage facilities, e.g., lined rock caverns, refrigerated mined caverns, and gas storage as hydrates, and improvements in salt formation storage. This research will ensure that gas demand can be met by a reliable and efficient gas storage and delivery system.
- **Improved Gas Measurement:** An important component of gas storage is the gas metering facility which is used to

monitor gas injection and flow rates. The difference in these rates are used to establish gas storage inventories. The industry is in need of advanced gas meters. Improved accuracy and reliability of gas measurement will lead to increased operational efficiency at storage facilities because of more accurate inventories. Cost savings will be realized through reduced installation and operation costs. Research efforts are directed at testing and evaluating ultrasonic meters to provide an industry standard for their use. Ultrasonic meters have many advantages over conventional orifice and turbine meters. Metering research will eventually lead to the development of a total energy flow or direct energy meter which will deliver real-time gas flow and energy content data.

- **Reservoir Management:** There are over 370 underground storage facilities in operation in the United States. Gas is stored in depleted oil and gas reservoirs and aquifers in the majority of these facilities. Working gas (gas that can be delivered to customers) and deliverability is not always optimized at every facility because of the complex geology of the reservoir and/or because

**Delivery Station  
in a Refinery**



of the way the field had been developed prior to being converted for storage. The major goal of the reservoir management project area is to increase the efficiency of storage operations. Research efforts are focused on reservoir characterization and engineering assessment of storage facilities through partnerships with industry. Activities include increasing capacity and deliverability using horizontal wells, qualifying storage fields for the use of delta pressuring (increasing maximum pressure) as a means of increasing capacity and deliverability, and developing new technologies to identify (e.g., advanced methane detection systems) and prevent gas loss.

**FY 1996 - 1998 CROSSCUT BUDGET SUMMARY  
(\$ IN MILLIONS)**

Projects	FY 1996	FY 1997	FY 1998
Deliverability Enhancement	0.577	0.322	0.350
Advanced Storage Concepts	0.157	0.512	0.252
Gas Measurement	0.144	0.001	0.245
Reservoir Management	0.100	0.100	0.100
Natural Gas Deliverability Model (DELIVER)	0.111	0.050	0.050
EIAGIS-NG Geographic Information System	0.150	0.100	0.100
<b>Total</b>	<b>1.239</b>	<b>1.085</b>	<b>1.097</b>

## **3.2.2 PROJECT DESCRIPTIONS**

### **3.2.2.1 DELIVERABILITY ENHANCEMENT**

#### **BACKGROUND**

There are over 17,000 existing gas storage wells in the United States. According to a 1993 study conducted for the Gas Research Institute (GRI) "State-of-Technology Assessment and Evaluation of Gas Storage Well Productivity Enhancement Techniques," these wells are losing, on average, 5.2 percent per year of their capability to inject and withdraw natural gas. The storage industry is offsetting this loss through various remediation treatments and by drilling new wells at a cost of over \$100 million per year. Roughly two-thirds of the cost to restore lost deliverability and one-third of the deliverability offset come from infill/replacement wells. Thus, there is great potential for restoring capability of existing wells that are not being treated, and to reduce the cost of deliverability enhancement by reducing the number of infill/replacement wells.

Excluding new wells or delta pressuring, the GRI report identified fracture stimulation technology as having the greatest potential for increasing well deliverability. However, fracturing represents less than 5 percent of the revitalization treatments performed by the storage industry. In FY 95, DOE initiated a Fracture Stimulation Field Demonstrations project to test new and novel fracture stimulation technologies to restore lost deliverability. Three technologies that are being tested under this project are liquid CO<sub>2</sub>/sand, tip screenout, and extreme overbalanced treatments (surging and perforating).

However, not all wells are suited for and/or require fracture stimulation to restore lost deliverability. Hence, a means to determine the causes of lost deliverability, i.e., damage mechanisms, and thus, define the best approach to remediate the damage, is

required. The GRI initiated a field study "Investigation of Storage Well Damage Mechanisms" to determine the root causes of lost deliverability. DOE funding in FY 1996 expanded the study from 8 fields to 12 fields to provide a better representation of the entire storage industry.

#### **MAJOR GOALS**

The major goal of the deliverability enhancement project area is to provide a cost-effective means to increase deliverability of the natural gas storage system. Goals specific to individual project areas include: advanced fracture stimulation technology to provide a better and longer lasting deliverability enhancement than other techniques; develop a methodology to deduce storage well damage mechanisms and determine the best remedial treatment; and develop improved remedial treatment technologies, e.g., acidizing, and coiled-tubing cleanout.

#### **PROJECT OBJECTIVES**

**Fracture Stimulation Field Demonstrations:** field test new or improved cost-effective fracture stimulation technologies and techniques that can restore lost injection and withdrawal capability in existing underground gas storage wells.

**Investigation of Storage Well Damage Mechanism:** determine the mechanisms responsible for loss of deliverability in gas storage wells in a number of geologic environments; define testing procedures to deduce damage mechanisms; and provide a basis for defining procedures to prevent or remediate damage.

#### **EXPECTED BENEFITS**

Improved stimulation treatments and better application of technology through an increased understanding of damage mechanisms will lead to cost effective deliverability enhancement. Deliverability of the gas storage system will increase due to better deliverability enhancement. Cost of storage service will be lower because of



better application of technology and reduced withdrawal and injection costs.

### PLANNED PRODUCTS

- New and better fracture stimulation technologies, e.g., CO<sub>2</sub>/sand fracturing and extreme overbalanced (EOB) perforation.
- A new computer model to design and analyze EOB treatments.
- A GRI report that identifies the damage mechanism found in storage wells. The major damage mechanisms that have been identified are bacteria and inorganic precipitates, e.g., sulfates and iron compounds.
- Improved remedial treatment technologies to treat damage mechanisms such as bacteria and inorganic compounds.
- Two videos highlighting the results of the damage mechanism study and the importance of deliverability.

### STRATEGY (FY 97 FUNDING: \$0.322 MILLION)

Increasing deliverability has become the highest priority for storage operators since FERC Order 636. Hence, deliverability enhancement has been and will continue to be a major research area for DOE. Past and present research will continue to focus on ways of improving technology or developing new cost-effective technology to improve deliverability.

### RECENT ACCOMPLISHMENTS

At the Galbraith field, located in Jefferson County, Pennsylvania, fracture stimulation with liquid CO<sub>2</sub> and proppant demonstrated immediate, dramatic improvements in deliverability. Two of the three wells had improvements of six- and seven-fold in absolute open flow (AOF) at maximum reservoir pressure. These were the first ever CO<sub>2</sub>/sand stimulations in a gas storage reservoir.

At Huntsman field, located in the Cheyenne County, Nebraska, the project introduced fracturing technology to an operator who had no prior fracturing experience.

Deliverability was improved by 16 MMscfd in the first well by rigorously applying pre-fracture diagnostics to improve job design and overcome the unfavorable conditions of a thin caprock and high reservoir permeability.

At the Donegal field, located in Washington County, Pennsylvania, high formation in-situ stresses and a thin-bedded lithology combined to prevent effective hydraulic fracturing. This brought the introduction of EOB fracturing to the gas storage industry for application in wells that are difficult to stimulate. Rigorous data analysis and job design demands precipitated a major advance in software specifically tailored for the simulation and design of EOB techniques. This unique software has the potential to develop into a commercial product benefiting the worldwide oil and gas industry.

Work under a GRI/DOE cofunded project on damage mechanisms has identified bacteria and inorganic precipitates, e.g., iron compounds, sulfates, and carbonates, as the leading cause of deliverability reduction. Other damage mechanisms discovered were oils (both compressor and naturally occurring), production chemicals, mechanical obstructions, stimulation fluids, and sanding.



**PROGRAM FUNDING**

**DOE HISTORICAL SPENDING  
(\$ IN MILLIONS)**

Projects	FY 1996	FY 1997	FY 1998
Fracture Stimulation Field Demonstrations	0.355	0.144	0.100
Damage Mechanism	0.222	0.178	0.000
Improved Remedial Technology Tests	0.000	0.000	0.250
<b>Total</b>	<b>0.577</b>	<b>0.322</b>	<b>0.350</b>

**COST SHARING (\$ IN MILLIONS)**

Projects	FY 1996	FY 1997	FY 1998 Estimate
Fracture Stimulation Field Demonstrations	0.255	0.766	0.693
Damage Mechanism	0.800	0.600	N/A
Improved Remedial Technology Tests	N/A	N/A	0.500
<b>Total</b>	<b>1.055</b>	<b>1.366</b>	<b>1.193</b>

**SCHEDULE**

Projects	1997	1998	1999	2000	2001	2002
Fracture Stimulation Field Demonstrations	_____					
Investigation of Storage Well Damage Mechanisms	_____					
Improved Remedial Technology Tests	_____					
Fracture Stimulation Optimization	_____					

### 3.2.2.2 ADVANCED STORAGE CONCEPTS

#### BACKGROUND

The Gas Research Institute's 1995 Annual Baseline Gas Projection predicted an increase in total U.S. gas demand of over 5 Tcf between 1994 and 2010. Traditional storage and pipeline capacity will be used to deliver most of this projected growth in gas demand to the end-use sectors. However, there are certain market areas where alternatives to conventional storage may be required.

The power generation sector accounts for nearly 2 Tcf of the projected growth in natural gas demand. Gas-fired power generation represents a major growth market for the natural gas industry. However, the large, high-pressure, highly variable loads required for individual power generators can be difficult to serve, particularly for natural gas pipelines. The presence of local gas storage may reduce the need for additional pipeline facilities to meet these requirements.

The New England region and the South Atlantic region have a combined projected growth of over 1.5 Tcf of natural gas. With the exception of the State of West Virginia, conventional underground gas storage is almost nonexistent in these two regions. Hence the need for alternatives to conventional storage facilities may be

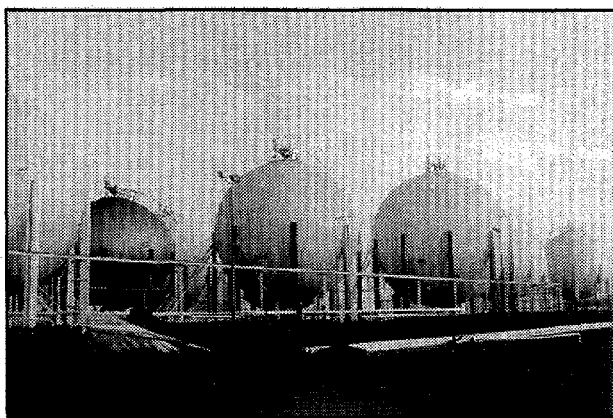
warranted, especially to serve the peaking needs of these two areas.

Lastly, a recent study conducted for the Gas Research Institute, "Current Market Drivers and Probable Trends in the Utilization of Natural Gas Storage", consisted of a survey of natural gas storage users and providers to determine current needs for various types of storage services and probable trends for the next five years. The study concluded that peak day requirements for most industrial and regional segments will increase, flexibility in storage services will be critical, and a need for cost-effective peaking service is evident.

In FY 95, DOE initiated a study, "Natural Gas Storage-End Use Interaction," to determine future need for storage, and identify areas of the U.S., where alternatives to conventional storage would be required. A major part of the project was to improve modeling capabilities of the Gas Systems Analysis Model (GSAM), being developed under another DOE contract (see Section 3.1.2.3), to better model the storage sector, including peaking services.

In FY 96, DOE initiated a Program Research Development Announcement for advanced storage concepts. Feasibility studies, conceptual designs and cost analyses will be conducted for four different alternative storage applications. The areas of research include: (1) lined rock cavern storage; (2) refrigerated mined cavern storage; (3) improved salt cavern storage; and (4) gas storage as hydrates.

#### Storage Tanks in a Refinery



#### MAJOR GOALS

The overall goal of this project area is to ensure that gas demand throughout the year 2010 can be met by a reliable gas storage and delivery system. Goals specific to individual project areas include:

(1) develop an analytical tool to evaluate natural gas storage requirements under various technological, economical, and market conditions; and (2) increase market penetration of advanced or alternative gas storage facilities that will meet the growing

needs of the natural gas industry and end-use customers and can demonstrate reduced cost of natural gas to end-users at or below the cost of natural gas currently available.

### **PROJECT OBJECTIVES**

**Natural Gas Storage-End Use Interaction:** Identify market needs for natural gas storage in new and growing natural gas market areas through the year 2010. This research will: (1) identify market areas and end-use sectors where new natural gas underground storage capacity and deliverability is required and can be economically employed; and (2) analyze technical and economic impact of advances to conventional underground gas storage.

**Advanced Storage Concepts:** Demonstrate technical feasibility, develop conceptual designs, and conduct cost analyses for innovative natural gas storage concepts that fully demonstrate commercialization potential to meet the projected needs of the natural gas industry and the end-use markets of the U.S. through the year 2010.

### **EXPECTED BENEFITS**

Natural gas usage will increase in market areas where gas demand has been very low or non-existent. Gas prices in these areas will be lower.

### **PLANNED PRODUCTS**

- New facilities using advanced gas storage technologies.
- An analytical tool, the Gas Systems Analysis Model, for evaluation of the gas storage and delivery system.

### **STRATEGY (FY 97 FUNDING: \$0.512 MILLION)**

Gas demand forecasts have projected a 2 Tcf growth in gas-fired power generation, a 1.5 Tcf growth in the New England and South Atlantic areas where conventional underground storage is nonexistent, and the increasing need to provide cost effective peaking services. New research was

initiated in FY 97 to maintain a reliable and efficient delivery and storage system. Innovative storage systems will provide cost-effective gas service to areas where conventional storage does not exist or cannot meet the needs of the end user.

### **RECENT ACCOMPLISHMENTS**

The Gas Systems Analysis Model was enhanced to include a gas storage module. This allows technology and economic forecasts to be conducted to determine future technology requirements of gas storage. Recommendations for improvements to GSAM were made to better model the storage and delivery system.

Four contracts will be awarded to investigate advanced storage concepts. The areas of research include: (1) lined rock cavern storage; (2) refrigerated mined cavern storage; (3) improved salt cavern storage; and (4) gas storage as hydrates.

**PROGRAM FUNDING****DOE HISTORICAL SPENDING  
(\$ IN MILLIONS)**

Projects	FY 1996	FY 1997	FY 1998
Natural Gas Storage— End-Use Interaction	0.157	0.042	0.000
Advanced Storage Concepts	0.000	0.470	0.252
<b>Total</b>	<b>0.157</b>	<b>0.512</b>	<b>0.252</b>

**COST SHARING (\$ IN MILLIONS)**

Projects	FY 1996	FY 1997	FY 1998 Estimate
Natural Gas Storage— End-Use Interaction	0	0	N/A
Advanced Storage Concepts	N/A	0	0.200
<b>Total</b>	<b>0</b>	<b>0</b>	<b>0.200</b>

**SCHEDULE**

Projects	1997	1998	1999	2000	2001	2002
Natural Gas Storage— End Use Interaction	—————					
Advanced Storage Concepts	—————					
Advanced Storage Pilot Tests	—————					

### **3.2.2.3 GAS MEASUREMENT**

Natural gas storage is vital to the delivery of gas throughout the United States. Gas is injected into storage fields during periods of low demand (Summer) and withdrawn from storage during periods of high demand (Winter). During periods of peak demand, gas storage provides as much as 30 percent of total gas demand.

Approximately 2 Tcf of gas is injected into and withdrawn from storage each year.

Therefore, it is extremely important to accurately measure the amount of gas at each storage facility, considering that at \$2/Mcf, the value of this gas is \$8 billion annually.

Storage operators use biannual pressure measurements in conjunction with metered gas volumes to maintain inventory at each storage facility. Measurement errors cause deliverability problems, especially near the end of the storage withdrawal season.

Orifice meters are typically used to measure gas flow at storage facilities. The rate of gas flow is measured by placing a constriction (orifice plate) in the pipeline and measuring the pressure drop across the plate. These meters can only measure gas flow in one direction, therefore, two meter runs are required, one for injection and one for withdrawal. Orifice meters must be calibrated in the field and require frequent maintenance. There are many variables that can cause measurement errors.

Ultrasonic meters have many advantages over orifice meters including: no moving parts, no pressure drop, bi-directional metering capability, proven accuracy, very low maintenance, self calibrating, and high repeatability. Therefore, ultrasonic meters can provide significant capital and operating cost savings through: (1) eliminating the need for two meter runs (bidirectional), (2) savings in compression (no pressure drop), (3) reducing maintenance and calibration, and (4) increasing the efficiency of storage operations by providing more accurate measurement.

The Gas Research Institute is conducting ultrasonic meter evaluation testing for natural gas flow applications at GRI's Meter Research Facility (MRF) at Southwest Research Institute (SWRI). The tests will provide guidance on performance, installation, and operation of ultrasonic meters and support an ongoing industry standards development effort. However, meter testing being conducted by GRI will not address many of the issues involving gas storage field applications.

In FY 97, DOE began research to address specific storage application issues that will complement and build upon the testing by GRI. Under DOE supported research, SWRI will test bidirectional flow, the effect of an upstream thermowell, and meter accuracy at very low flow rates. In addition, industry will be providing data from field installations, which will be evaluated and documented.

#### **MAJOR GOALS**

The overall goal is to provide accurate, real-time measurement of gas at gas storage facilities. Goals of individual projects include providing data for development of an industry standard and, if necessary, improve ultrasonic meter performance.

#### **PROJECT OBJECTIVES**

**Ultrasonic Meter Testing and Evaluation:** Test and evaluate ultrasonic meters with respect to specific issues encountered in gas storage field applications. This research will provide data necessary to develop an industry standard for ultrasonic meter use and will identify additional testing and improvements to the meters that may be necessary.

#### **EXPECTED BENEFITS**

Improved accuracy and reliability of gas measurement will lead to increased operational efficiency at storage facilities because of more accurate inventories. Cost savings will be realized through reduction in installation and operation costs.

### PLANNED PRODUCTS

- Industry standard for using ultrasonic meters
- Reports on performance of ultrasonic meters under laboratory conditions (MRF) and field conditions
- Real-time, direct energy meter.

### STRATEGY (FY 97 FUNDING: \$0.001 MILLION)

Gas measurement is important not only financially but also from an operational point of view, since more accurate inventories will help storage operators to more efficiently manage their asset. DOE initiated research on ultrasonic meters in FY 97 because of the tremendous potential these meters have to offer to the storage industry. Research will continue on ultrasonic meters while new research on advanced gas measurement technologies, e.g., a direct energy meter, will be initiated.

### RECENT ACCOMPLISHMENTS

Ultrasonic meters have been received from two major manufacturers for testing at the MRF. Testing of the effect of a thermowell has been completed. Testing for bidirectional flow and low-flow rates has been initiated.

### SCHEDULE

Projects	1997	1998	1999	2000	2001	2002
<b>Gas Measurement</b>						
Ultrasonic Meter Testing and Evaluation	—————					
Advanced Gas Measurement		—————				
Direct Energy Meter			—————			

CNG Transmission Corporation and Columbia Gas Transmission have agreed to provide field performance data on ultrasonic meters for evaluation by Southwest Research Institute. CNG is planning to install two 12-inch ultrasonic meters at its Bridgeport, WV storage facility and expects them to be operational for the upcoming injection season. Columbia is installing a 20-inch multipath ultrasonic meter at its Victory storage facility in Marshall Co., WV. Both companies are running the meters in series with existing orifice meters for comparison.

### PROGRAM FUNDING

### DOE HISTORICAL SPENDING (\$ IN MILLIONS)

Projects	FY 1996	FY 1997	FY 1998
Ultrasonic Meter Testing and Evaluation	0.144	0.001	0.145
Advanced Gas Measurement	0.000	0.000	0.100
<b>Total</b>	<b>0.144</b>	<b>0.001</b>	<b>0.245</b>

### COST SHARING (\$ IN MILLIONS)

Projects	FY 1996	FY 1997	FY 1998 Estimate
Ultrasonic Meter Testing and Evaluation	0.225	0.245	0.600
Advanced Gas Measurement	N/A	N/A	0.000
<b>Total</b>	<b>0.225</b>	<b>0.245</b>	<b>0.600</b>

### **3.2.2.4 RESERVOIR MANAGEMENT**

#### **BACKGROUND**

There are over 370 underground storage facilities in operation in the United States. Gas is stored in depleted oil and gas reservoirs and aquifers in the majority of these facilities. Working gas (gas that can be delivered to customers) and deliverability (rate) is not always optimized at every storage facility because of complex reservoir geology or because of field development prior to it being converted for storage.

Since FERC Order 636, operational efficiency and deliverability are becoming increasingly important. The storage industry is beginning to use horizontal wells to increase deliverability of storage fields and to investigate re-engineering of storage operations to provide peaking services in addition to baseload services.

The storage industry must be able to optimize both individual well treatments and overall field performance, including the possibility of expanding the field's current capabilities. This means being able to identify which and how many wells require deliverability restoration, comparing the economic benefits of a well treatment program versus new infill or replacement wells (including horizontal wells), or a combination of both. Geologic modeling and reservoir simulation is a cost effective means of conducting a full field evaluation and determining optimum field performance. Once a reservoir has been characterized and a geologic model of the field developed, reservoir simulation provides a cost efficient means to analyze many operating scenarios.

In FY 94, 95 and 96, DOE/FETC initiated three Cooperative Research and Development Agreements (CRADAs) with industry (National Fuel Gas Supply Corporation, Equitrans, Inc., and Northern Indiana Public Service Company) to conduct reservoir characterization and engineering assessment studies.

#### **MAJOR GOALS**

The major goal of the reservoir management project area is to increase efficiency of storage operations. Specific goals include: increase use of geologic modeling and reservoir simulation studies for optimizing field performance; and demonstrate importance of horizontal wells to increase deliverability.

#### **PROJECT OBJECTIVES**

Reservoir Characterization and Engineering Assessment: Through industry and FETC partnerships, demonstrate importance of geologic modeling and reservoir simulation for optimizing development and operation of gas storage fields.

#### **EXPECTED BENEFITS**

Capacity and deliverability of storage fields will increase through more efficient storage operations.

#### **PLANNED PRODUCTS**

Technical papers, reports, and workshops providing case studies.

#### **STRATEGY (FY 97 FUNDING: \$0.1 MILLION)**

Since DOE began research in storage in FY 1994, three CRADAs have been initiated to show importance of geologic modeling and reservoir simulation to improve storage efficiency and to demonstrate the potential of horizontal wells. Work will continue on these CRADAs while DOE pursues other research to help improve the operational efficiency of storage reservoirs.

#### **RECENT ACCOMPLISHMENTS**

A horizontal well drilled by Northern Indiana Public Service Company (NIPSCO) as part of a Cooperative Research and Development Agreement with DOE was a big success and will greatly enhance the economics of their storage operation. Initial flow tests indicate that the horizontal well will significantly enhance gas deliverability



from the Royal Centers field, located in Cass County, Indiana, and will allow gas use from an area of the storage field that was not accessible from present vertical wells. The project success can be attributed to a coordinated effort between NIPSCO, DOE, and GRI contractors and an integration of geologic modeling and seismic surveying.

### PROGRAM FUNDING

#### DOE HISTORICAL SPENDING (\$ IN MILLIONS)

Project	FY 1996	FY 1997	FY 1998
Reservoir Characterization / Engineering Assessment	0.100	0.100	0.100
<b>Total</b>	<b>0.100</b>	<b>0.100</b>	<b>0.100</b>

#### COST SHARING (\$ IN MILLIONS)

Project	FY 1996	FY 1997	FY 1998 Estimate
Reservoir Characterization / Engineering Assessment	0.350	0.612	0.150
<b>Total</b>	<b>0.350</b>	<b>0.612</b>	<b>0.150</b>

### SCHEDULE

Projects	1997	1998	1999	2000	2001	2002
Reservoir Characterization/ Engineering Assessment	—————					
Improved Operational Efficiency	—————					

### 3.2.2.5 NATURAL GAS DELIVERABILITY MODEL (DELIVER)

#### BACKGROUND

Key policy issues and emergency planning require estimates of regional or State deliverability capability within the national network of interconnected delivery systems. Analytical procedures for estimating wellhead productive and pipeline capacities exist elsewhere, but the Natural Gas Deliverability Model (DELIVER) comprises a comprehensive framework to analyze gas deliverability issues within a coordinated network.

#### MAJOR GOALS

Development of a PC-based system for analysis of the U.S. gas delivery network capability to handle changes in supply or demand patterns, planned pipeline or storage expansion, or disruptions to gas supply or the delivery system.

#### PROJECT OBJECTIVES

- Develop a user-friendly system that can readily analyze gas deliverability with quick turnaround.
- Provide useful tabular and map displays of deliverability solutions to support further analysis or for inclusion in analysis reports.

#### EXPECTED BENEFITS

- Enhances ability of DOE to address questions relating to the gas industry's ability to deliver natural gas on a regional or State basis.
- Complements the Gas System Analysis Model (GSAM) to provide the capability to evaluate seasonal and peak day supply and consumption and other issues at a more disaggregated level than is considered in the GSAM model.

#### PLANNED PRODUCTS

- A PC-based analysis tool with updated data to address issues of national, regional, or State-level deliverability issues.
- An analysis report on the capability of the natural gas delivery system to supply gas to consumers under normal conditions and conditions of selected scenarios. The deliverability analysis will proceed for both the current network and the domestic network with planned capacity expansion.

#### STRATEGY (FY 97 FUNDING \$0.05 MILLION)

The project strategy is to: (1) develop a deliverability model with an updated database to include major capacity expansion projects, and (2) use the model to assess the capability of the natural gas delivery system to supply natural gas to consumers under a wide range of conditions.

#### RECENT ACCOMPLISHMENTS

Completion of an operational model in 1996 incorporating the responses from Beta-testing of the model. This version of DELIVER is based on 1994 data.

#### PROGRAM FUNDING

#### DOE HISTORICAL SPENDING (\$ IN MILLIONS)

Project	FY 1996	FY 1997	FY 1998
DELIVER	0.111	0.050	0.050
<b>Total</b>	<b>0.111</b>	<b>0.050</b>	<b>0.050</b>

### **3.2.2.6 EIAGIS-NG GEOGRAPHIC INFORMATION SYSTEM**

#### **BACKGROUND**

**E**IAGIS-NG is a PC-based geographic information system that allows natural gas analysts and others to select natural gas pipeline systems and associated databases through a menu driven operation and have the selected data mapped and displayed on a monitor. The system allows the user to rapidly modify and manipulate a pipeline/site map display and perform various geographic search operations as well as generate data summary and execute statistical routines.

The EIAGIS-NG grew as a response to radical changes that have occurred in the natural gas industry since the late 1980s and those that are anticipated through the end of this decade. These changes make the need for a system that can visually reflect and focus upon the relative locations of major pipeline interconnections and market center/hubs imperative. It is important for interested parties to be able to evaluate and track the potential impact of pipeline development as it affects the transmission of supplies to market areas. Additionally, the ability to simply locate and display geographic information concerning one or more pipelines systems is often key to providing an accurate picture and complete analysis of specific query. The EIAGIS-NG system provides these capabilities to the analyst.

#### **MAJOR GOALS**

- Develop a PC-based mapping and database system focusing upon the natural gas pipeline network within North America. The system provides industry analysts with the capability to graphically examine interrelationships among the pipelines and associated energy facilities. It allows the users to quantify and qualify the capabilities of natural gas pipelines to deliver gas from

supply sources, including storage, to consuming areas.

- Develop a user-oriented geographic information system to provide almost instantaneous retrieval and display of natural gas pipeline location and infrastructure data.
- Build a series of relational databases and map files which would provide analysts (and others) with access to information on how gas is received, transported, stored, and consumed.
- Build a system which would allow users to quickly locate pipeline disruptions and other situations and to analyze the impact of these on consuming areas.

#### **PROJECT OBJECTIVES**

- Provides rapid access to pipeline network information and facility locations not previously available.
- EIAGIS-NG will provide the ability to track new pipeline projects and access their impact upon the future of the natural gas transmission and distribution network.

#### **EXPECTED BENEFITS**

- EIA and DOE will have immediate access to: (1) maps for over 150 inter and intrastate natural gas pipeline systems; (2) the locations of interstate pipeline compressor stations, interconnections, receipt and delivery points, (3) the locations of existing, proposed, or abandoned underground storage sites, and (4) many other energy related facilities.
- Analysts will be able quickly to extract, format, and display geographically requested natural gas data and perform statistical manipulations not previously available. Map displays and other graphical presentations of analytical results may be saved as a system option.

- Analysts will have the capability to develop new ways to display and present data on a geographical or relational basis for further analysis or incorporation into reports.
- Tracking of events and situations within the natural gas industry will be facilitated.

**PLANNED PRODUCTS**

Products and analyses developed from the EIAGIS-NG system will be used extensively in the EIA "National Gas Deliverability on the Interstate Natural Gas Pipeline System" report scheduled for completion in the latter part of 1997.

In conjunction with the execution of several (1997) natural gas projects, EIAGIS-NG's capabilities are being broadened to include pipeline load-factor analysis as a key feature of the system.

**STRATEGY (FY 97 FUNDING: \$0.1 MILLION)**

The basic EIAGIS-NG system has been operational since April 1997. Its major components—programs, map files, databases, and documentation—have been completed. Currently, the system is undergoing some enhancements and upgrades to adapt to changing technological needs (e.g., Internet integration). A significant effort also is directed at maintenance of system maps and databases. The EIAGIS-NG has been designed to expand into other natural gas-related areas, such as oil product pipelines and electrical transmission lines.

**RECENT (FY 1996) ACCOMPLISHMENTS**

- Completed an enhancement to the EIAGIS-SD (storage deliverability) subsystem of EIAGIS-NG that permitted output from the Gas System Analysis Model (GSAM) to be processed into a regional map display and bar graph. The work was performed for DOE/Fossil Energy's Federal Energy Technology Center (Morgantown, WV).

- Completed upgrades to the mapping process that included an interactive SQL query routine. Also developed interface programs for several new databases included in the system, for instance, the Nehring Field/Reservoir database and annual gas/oil/electrical databases.
- Completed the revision of several system administration program processes that improved capabilities of the EIAGIS-NG database administrator to maintain the overall system and to audit the integrity of the system components (i.e., data dictionary and database control files).

**PROGRAM FUNDING**

**DOE HISTORICAL SPENDING (\$ IN MILLIONS)**

Project	FY 1996	FY 1997	FY 1998
EIAGIS-NG	0.150	0.100	0.100
<b>Total</b>	<b>0.150</b>	<b>0.100</b>	<b>0.100</b>

DOE/Fossil Energy provided \$100,000 in FY 95 and \$50,000 in FY 96 for EIAGIS-SD (Storage Deliverability) development.

