PDHonline Course C239 (2 PDH)

Underground Natural Gas Storage Basics

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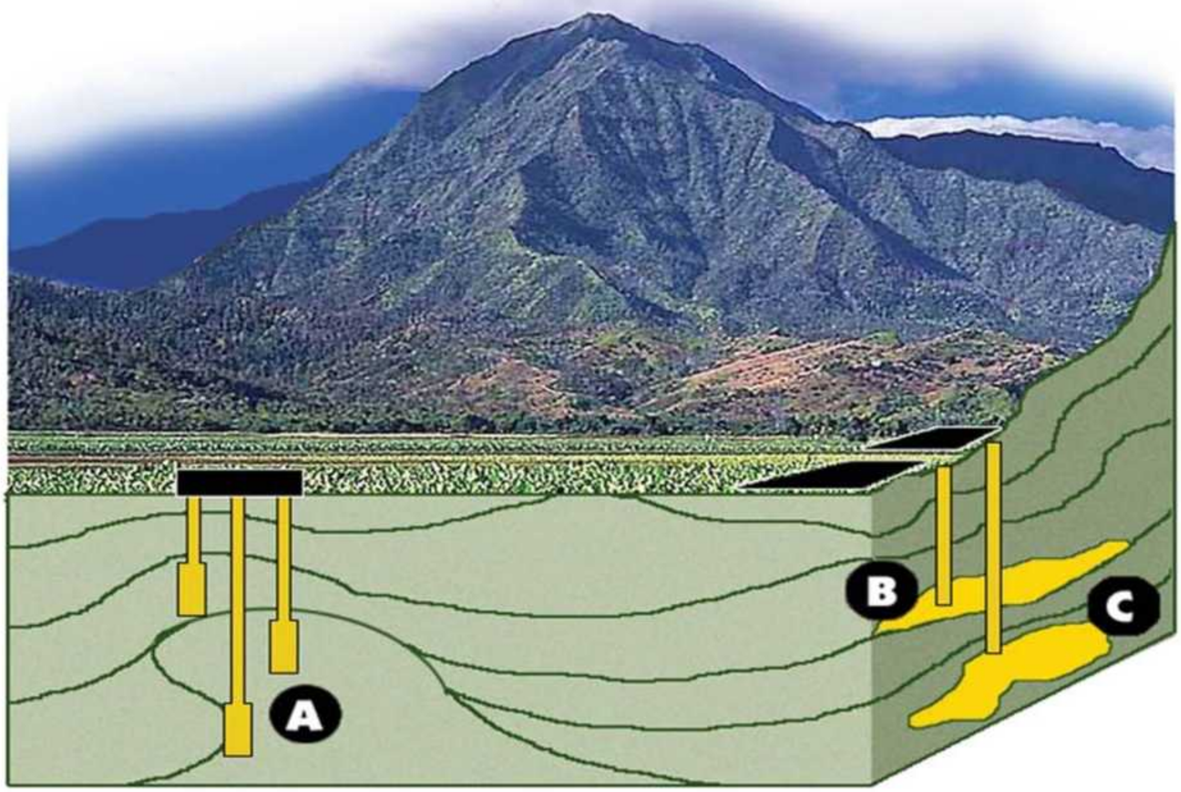
CURRENT STATE OF AND ISSUES CONCERNING

Underground Natural Gas Storage

Docket No. AD04-11-000



A – Salt Caverns B – Aquifers C – Depleted Reservoirs

Federal Energy Regulatory Commission

Staff Report • September 30, 2004

Current State of and Issues Concerning
Underground Natural Gas Storage

Table of Contents

Key Findings:

- Under average conditions and from a nationwide perspective, storage appears to be adequate to meet seasonal demand; however, continued commodity price volatility indicates that more storage may be appropriate.

- Storage may be the best way of managing gas commodity price, so the long-term adequacy of storage investment depends on how much price volatility customers consider "acceptable."

- A study performed by the National Petroleum Council indicates that there may be a need in North America for 700 Bcf of new storage between now and 2025. Another study, by The INGAA Foundation, concludes that 651 Bcf of new storage may be needed in the United States and Canada by 2020. In addition, there may be certain region-specific (e.g., Southwest, New England) needs for new storage.

- Geology, economics and environmental impacts may stall development and could jeopardize achieving forecasted capacity needs.

- Reengineering of existing storage fields is underway in order to improve working gas capability – application of new engineering techniques can help to ensure that development of new fields stays on track.

- Four key methods that market participants use to value storage (e.g., cost of service; least-cost planning; seasonal valuation, or intrinsic; and, option-based valuation, or extrinsic) do not always reach the same result because they are based on differing views of the need and reasons for storage.

- Storage projects in certain geographic areas (e.g., Southwest) often fail the Commission's market-based rates tests.

- Creative ratemaking approaches may encourage storage development.

- Creative certificate and policy choices may also encourage storage development by reducing costs and permitting additional opportunities to generate revenues.

This report addresses three aspects of the state of and issues concerning the underground storage of natural gas: the history of storage development and its physical characteristics and the need for storage; the economics of underground storage; and, ratemaking options for future storage development.

The underground storage of natural gas has historically been critical in assuring that overall demands and use-specific requirements of natural gas customers are met. The Natural Petroleum Council's (NPC) September 2003 report[1] noted that the demand for storage is expected to increase in the foreseeable future. Specifically, the NPC foresees the need for an additional 700 Bcf of new storage in the United States and Canada over the next 20 years, which translates to an average of 35 Bcf of new storage being added each year.

Presently, from a national perspective and assuming average weather, storage appears to be adequate. However, simply considering average demand and national balances does not tell the complete story. For some market areas, particularly those that are distant from supply sources, the development of new storage infrastructure could cost-effectively help customers maintain service reliability and manage commodity price volatility.

In addition, gas prices have increased with the decline in gas production. During the "gas bubble" of the 1980s-1990s, production increased in response to short-term spikes in demand. Production increases coupled with demand decreases in this same period allowed supply to meet demand, even during peak periods, without significant price spikes. As production declined or flattened over the past few years, production spikes can no longer be relied upon to meet demand spikes. As a result, commodity price swings manage demand fluctuations.[2]

Building new storage may be an effective way to reduce commodity price volatility. Demand for storage services to manage price volatility will depend on customer tolerance for price risk, how that price risk is valued, and the cost of service. Accordingly, there may be a public policy interest in encouraging storage development.

While the desire of project sponsors to build new storage in the Southwest and Northeast has been demonstrated by the various applications seeking to develop projects, the development has not occurred for economic, environmental, geological and political reasons.

Specifically, in the Southwest there have been three recent storage projects that, for various reasons, have not been developed. The Desert Crossing storage project, although initiated, has not been further pursued; while no formal reason for not pursing development was provided, market (contractual) support did not materialize and environmental concerns associated with certain aspects of the proposal were raised.[3] The Copper Eagle storage project, located on the outskirts of Luke Air Force Base, became the subject of security and safety concerns; plans for its development have been delayed following expressions of concern by the State of Arizona legislature.[4] The sponsor of the Red Lake storage project did not pursue development owing to Red Lake's unwillingness to go forward without authorization for market-based rates. Its inability to demonstrate a significant lack of market power resulted in the Commission's decision to deny market-

[1] *Balancing Natural Gas Policy – Fueling the Demands of a Growing Economy*, National Petroleum Council (2003).

[2] *See Report on the Natural Gas Price Spike of February 2003*, Staff Investigating Team, July 23, 2003.

[3] *Desert Crossing Gas Storage and Transportation System LLC*, 98 FERC ¶ 61, 277 (2002).

[4] *Copper Eagle Gas Storage L.L.C.*, 97 FERC ¶ 62,193 (2001); *Copper Eagle Gas Storage, L.L.C.*, 99 FERC ¶ 61,270 (2002).

based rate authority.[5] Evidence of the desire for storage in the Southwest was demonstrated in the *Southwestern Gas Storage Conference* held on August 23, 2003, in Phoenix, Arizona.[6] There, participants, including the Chairman of the Arizona Corporation Commission, expressed unanimous support for the proposition that development of new storage in the region was needed.

In the Northeast, two major projects, the NE Hub storage project and the Avoca storage project, similarly never came into service, and the Wyckoff/Greyhawk storage project has been delayed, although they all were certificated by the Commission, but encountered various technical and economic problems.[7] While these projects were located in New York state in areas where the geology is conducive to the development of underground storage, the geology in other parts of the Northeast is not practical for the development of underground storage.

As discussed in more detail in this report, there are other approaches to achieving the development of new storage using both new and existing fields. For example, reengineering of existing storage fields is an ongoing exercise to improve working gas capability. In addition, the application of new engineering techniques can prove useful in achieving greater deliverability from existing fields. These techniques also help to ensure the efficient development of new fields in areas geologically conducive to storage, stays on track.

Through new design approaches and the application of advanced engineering techniques, certain physical barriers to the development of new storage can potentially be overcome. However, as discussed later in this report, long-term market price signals appear to be weak for new storage development. Further, the four key methods that market participants use to value storage (cost of service; and, least-cost planning seasonal arbitrage, or intrinsic; and option-based or extrinsic) do not always reach the same result because they are based on differing views of the need and reasons for storage.

But regulatory requirements may prove to be a financial barrier inhibiting development in some regions. Storage developers have claimed a preference for market-based rates. And, in the markets where new storage developers cannot assert market power, market-based rates have been allowed.

Current Commission rate policy provides considerable flexibility to design cost-based rates, negotiated rates and market-based rates. Additional cost-based rates and market-based rate alternatives could be explored to encourage additional storage development. Further, revised storage project certification requirements and procedures could potentially reduce costs and offer the potential to generate additional revenues

This report sets out some of these approaches and also describes some non-cost-based approaches that may be useful in addressing financial obstacles to new storage development.

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[5] *Red Lake Gas Storage, L.P,* 103 FERC ¶ 61,277 (2003); *Red Lake Gas Storage, L.P.*, 102 FERC ¶ 61,077 (2003).

[6] *Southwestern Gas Storage Technical Conference,* Docket No. AD03-11-000, Notice of Technical Conference (2003).

[7] *NE Hub Partners, L.P.*, 105 FERC ¶ 61,334 (2003); *Avoca Natural Gas Storage*, 88 FERC ¶ 62,245 (1999); *Wyckoff Gas Storage Company, LLC*, 105 FERC ¶ 61,027 (2003).

Natural gas storage facilities are used to meet gas demand peaks which exceed production and long-haul pipeline throughput. Increasingly, storage also plays a variety of roles helping market participants manage pipeline imbalance charges and daily and seasonal price volatility. When cold weather or other market conditions create more demand for gas than domestic production or imports can satisfy, gas that has been put in storage can be withdrawn to make up the difference. While natural gas is also stored for peak daily and hourly uses mainly by distribution companies and liquefied natural gas (LNG) is stored briefly at import terminals, this report will focus on what is known as traditional underground gas storage, as well as, the new, nontraditional usage of storage developed by the unbundling of storage and the new market conditions.

Traditional Underground Storage

Geology is a key issue for determining the location of new traditional underground storage projects and the expansion of existing projects. There are areas that have the geological characteristics to construct storage fields; other areas do not. Selection of any new underground gas storage location depends on geological and engineering properties of the storage reservoir, its size and its cushion, or base, gas requirements. It also depends on the site's access to transportation pipeline infrastructure, gas production sources, and to markets.

The use of underground gas storage facilities in the natural gas industry is almost as old as the development of long distance transmission lines. The first high pressure transmission lines began operations in 1891 with successful construction of two parallel 120-mile, 8-inch diameter lines from fields in northern Indiana to Chicago. The first successful gas storage project was completed in 1915 in Welland County, Ontario. The following year, operations began in the Zoar field near Buffalo, New York.

Underground storage field operations include a host of component and interdependent facilities. There are injection/withdrawal wells, observation wells, water disposal wells, gathering lines, dehydration facilities, gas measuring facilities, compressors, etc. Underground storage fields come in three basic types: depleted gas/oil reservoirs, salt caverns, and aquifers. Access to at least one major transportation pipeline to receive gas or deliver gas is, of course, a complementary requirement.

The Nontraditional Usage of Underground Storage

In addition to meeting the traditional seasonal load variations, the hourly swings, and emergency situations, storage is now being used to meet services created by both the unbundling of storage and by the new market conditions. Specifically, storage is being used to:

1. Meet the regulatory obligation to ensure supply reliability at the lowest cost to the ratepayer by maintaining specific levels of storage inventory.
2. Avoid imbalance penalties and facilitate daily nomination changes, parking and lending services, and simultaneous injections and withdrawals.
3. Ensure liquidity at market centers to help contain price volatility and maintain orderly gas markets.
4. Offset the reduction in traditional supplies that were relied upon to meet winter demand.
5. Increase the comfort inventory level of working gas or top gas.
6. Offset, through the injection of more gas during the shoulder months, the growing summer peak impacts from electric generation.
7. Support other electric generation loads.

Three Types of Underground Gas Storage Facilities

Salt Cavern

Some storage facilities use caverns that are leached or mined out of underground salt deposits (salt domes or salt formations). Salt cavern capacity typically is 20 percent to 30 percent cushion gas and the remaining capacity is working gas. Working gas can generally be recycled 10-12 times a year in this type of storage facility. These facilities are characterized by high deliverability and injection capabilities and are mainly used for short peak-day deliverability purposes (i.e., for fueling electric power plants).

Depleted Oil/Gas Reservoir

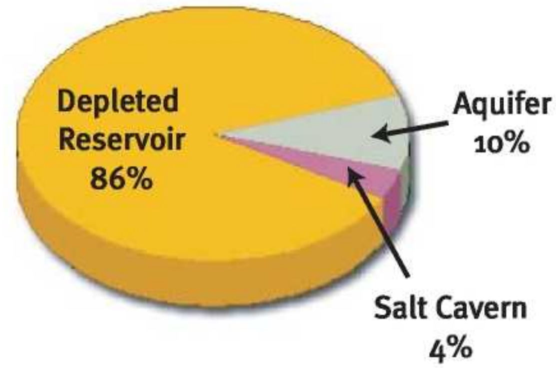
The most common underground gas storage facilities are those that use deep underground natural gas or oil reservoirs that have been depleted through earlier production. These reservoirs are naturally occurring, and their potential as secure containers has been proven over the millennia that the reservoirs held their original deposits of oil and gas. An underground gas storage field or reservoir is a permeable underground rock formation (average of 1,000 to 5,000 feet thick) that is confined by impermeable rock and/or water barriers and is identified by a single natural formation pressure. The working gas capacity is typically 50 percent, with the rest of the capacity maintained to ensure adequate deliverability. Gas is typically withdrawn in the winter season and injected during the summer season. This type of storage facility could be used for seasonal system supply or for peak-day demands.

Aquifer

A large number of reservoirs are bound partly or completely by water-bearing rocks called "aquifers." The nature of the water in the aquifer may vary from fresh to nearly saturated brines. Aquifer storage facilities typically have high cushion gas requirements, ranging between 50 percent to 80 percent. However, they achieve high deliverability rates, with gas injected in the summer season and withdrawn in the winter.

The following chart , based on the Department of Energy's Energy Information Administration (EIA) final 2001 data, shows that depleted reservoirs are the dominant type of underground storage based on total capacity. These percentages have slightly changed using 2002 EIA data, which are not yet final.[8]

Types of Underground Storage Capacity



Source: Energy Information Administration

Summary of Physical Characteristics of Traditional Natural Gas Storage

(The following descriptions are from the Natural Gas Supply Association)[9]

The most common form of underground storage consists of depleted gas/oil reservoirs. Depleted reservoirs are those formations that have already been tapped of all their recoverable hydrocarbons. This leaves an underground formation geologically capable of holding natural gas. In addition, using an already developed reservoir for storage purposes allows the use of the extraction and distribution equipment left over from when the field was productive. Having this network in place reduces the cost of converting a depleted reservoir into a storage facility. Depleted reservoirs are also attractive because their geological characteristics are already well known. Of the three types of underground storage, depleted reservoirs, on average, are the cheapest and easiest to develop, operate and maintain.

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[8] Form EIA-191, Monthly Underground Gas Storage Report.

[9] *See* NGSA's Web site at http://www.naturalgas.org/naturalgas/storage.asp

Aquifers are underground permeable rock formations that act as natural water reservoirs. However, in certain situations, these water-containing formations may be reconditioned and used as natural gas storage facilities. Because they are more expensive to develop than depleted reservoirs, these types of storage facilities are usually used only in areas where there are no nearby depleted reservoirs. Traditionally, these facilities are operated with a single winter withdrawal period, although they may be used to meet peak load requirements as well. Aquifers are the least desirable and most expensive type of natural gas storage facility for a number of reasons. First, the geological characteristics of aquifer formations are not as thoroughly known as are depleted reservoirs. A significant amount of time and money goes into discovering the geological characteristics of an aquifer and determining its suitability as a natural gas storage facility. Also, the cushion gas requirement for aquifers is higher than for depleted oil/gas reservoirs.

Underground salt formations offer another option for natural gas storage. These formations are well suited to natural gas storage because salt caverns, once formed, allow little injected natural gas to escape from the formation unless specifically extracted. The walls of a salt cavern also have the structural strength of steel, which makes it resilient to reservoir degradation over the life of the storage facility. Salt caverns are formed out of existing salt deposits. These underground salt deposits may exist in two possible forms: salt domes and salt beds. Salt domes are thick formations created from natural salt deposits that, over time, move up through overlying sedimentary layers to form large dome-like structures. Salt beds are shallower, thinner formations. Because salt beds are wide and thin, salt caverns in them are more prone to deterioration and may also be more expensive to develop than salt domes.

Operating Characteristics of the Types of Underground Storage

The pressure range in a depleted reservoir for the storage operating cycle depends upon (1) the safe upper limit of the reservoir pressure (bottom hole or surface pressure), (2) the flow capacity of the wells, and (3) compression requirements when injecting gas into the reservoir or delivering to market. Normally gas and oil fields have pressures at discovery in the range of 0.43 to 0.52 pounds per square inch per foot of depth. The highest pressure level possible normally will provide the maximum storage capacity and the wells will have the highest flow capacity.

Peak-day or seasonal deliverability is directly related to storage volume vs. storage pressure. Required storage deliverability services (daily or seasonal volumes) require maximum storage pressure and gas-in-place volumes prior to the withdrawal season.

Therefore, the main issues are how much gas can be carried over from year to year, how long the gas can remain in the reservoir prior to being turned over and how soon can the capacity be refilled. These problems are not based on some theoretical behavior, but instead are based on experience under a variety of turnover and injection conditions.

It is operationally improper to simply let the gas sit in any storage field. If working gas is not recycled properly, it will move from higher pressure areas of the storage field to lower pressure areas, move into tighter formations or migrate to a point that will result in an increase in cushion gas requirements or gas loss.

The following table summarizes our understanding of how the three types of storage fields are generally operated. Less cushion gas is needed for salt caverns and they can be filled and emptied much more frequently than aquifers or depleted reservoirs. For aquifers or depleted reservoirs, the injection period usually corresponds with the months of April through October (214 days), while the withdrawal period is usually the months of November through March (151 days). Storage operators must use their best geologic and engineering judgment to vary from this schedule. Early season cold weather can reduce storage gas in place and deliverability, while late season cold weather can reduce the next season's required injections in terms of volumes and days.

Gas Storage Facility Operations

Type	Cushion to Working Gas Ratio	Injection Period (Days)	Withdrawal Period (Days)
Aquifer	Cushion 50% to 80%	200 to 250	100 to 150
Depleted Oil/Gas Reservoirs	Cushion 50%	200 to 250	100 to 150
Salt Cavern	Cushion 20% to 30%	20 to 40	10 to 20

Source: Analysis of FERC filings

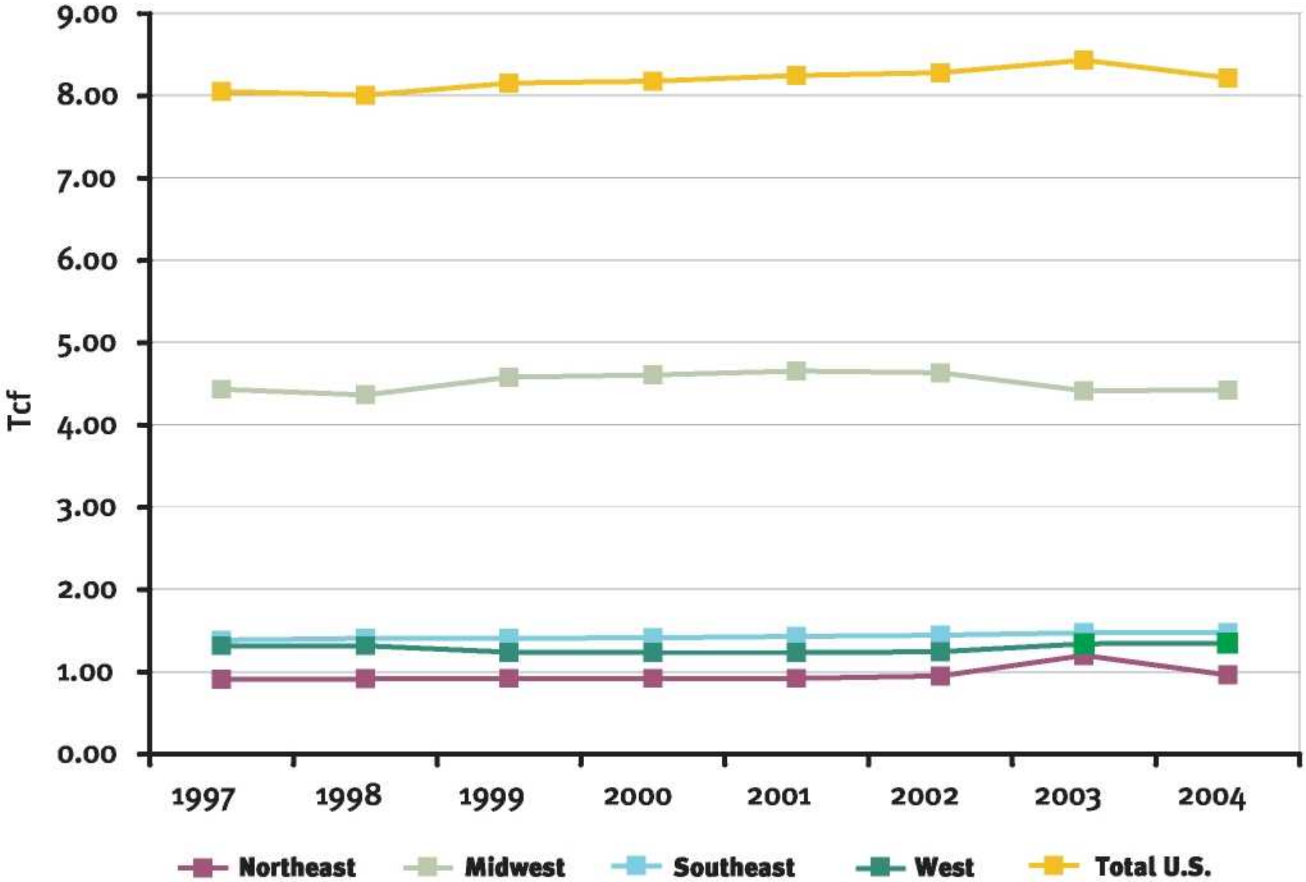
Nationwide Storage Capacity

Because not all storage is under the Commission's jurisdiction, we have to look to other sources of information to get nationwide totals of storage capacity. The EIA reports that as of 2002 (the latest data available), interstate pipelines operated nearly 55 percent of the nation's gas storage capacity[10] but had contractual rights to use only 8 percent of the working gas capacity for their own purposes. Local distribution companies (LDCs) and intrastate pipeline companies operated about 35 percent of working gas capacity and independent operators operated about 10 percent of working gas capacity. However, most of the pipeline's storage capacity, about 73 percent, is contractually committed to LDCs. Marketers also hold a significant share of storage capacity under contract, about 15 percent. The total maximum U.S. natural gas storage capacity (cushion, or base, gas plus working gas) *reported to* the EIA fluctuated slightly above the 8 Tcf level for the past eight years (8 to 8.4 Tcf), while for the same period, the EIA reports that working gas storage capacity has varied between 4.4 and 4.7 Tcf.

Using a different survey, the Office of Fossil Energy – which, like EIA, also is in the Department of Energy – reported that as of 2003 there were 110 underground gas storage operators that maintain and operate 415 underground gas storage facilities with a working gas capacity of 3.9 Tcf in this country. Of this total number of facilities, 201 are FERC-jurisdictional, controlled by 43 operators. The total FERC-jurisdictional working gas capacity is 2.5 Tcf. Close to half of all the storage capacity is located in the Midwest. The graph on the following page shows the relatively stable amount of storage capacity from 1997 to present, based on EIA's data.

[10] Form EIA-191, Monthly Underground Gas Storage Report.

Volumes of Underground Natural Gas Storage



Source: U.S. Department of Energy, Office of Fossil Energy

However, total reported storage capacity has never really been tested with operating experience. Thus, the value that defines "full" when determining the total working gas capacity is not known exactly. Even the EIA's "Basics of Underground Natural Gas Storage" discusses three different approaches to measuring "percent full" of U.S. natural gas storage. Based on our interpretation of historical data, staff believes there is a total practical storage operating capacity of 7.6 Tcf, of which 3.5 Tcf [11] is working gas capacity and the remaining 4.1 Tcf is cushion gas. The American Gas Association (AGA) reported that the largest working gas capacity held in storage during a given time period was 3,294 Bcf. Therefore, based on EIA data of total storage capacity being at least 8.2 Tcf for several recent years, the staff estimates that there is as much as 600 Bcf of potential working gas capacity available within existing storage fields for future use. Thus, staff estimates the total U.S. potential working gas capacity to be 3.6 to 3.8 Tcf. Based on these estimations, there is 200 Bcf to 500 Bcf of potential working gas capacity beyond the presently proven 3.5 Tcf of working gas that could be reengineered and used.

Another technical point is that storage working gas capacity is directly related to the availability of supply. If there is sufficient gas supply available during the early injection season when storage pressures are lowest, the storage operators could inject at the highest rates and re-

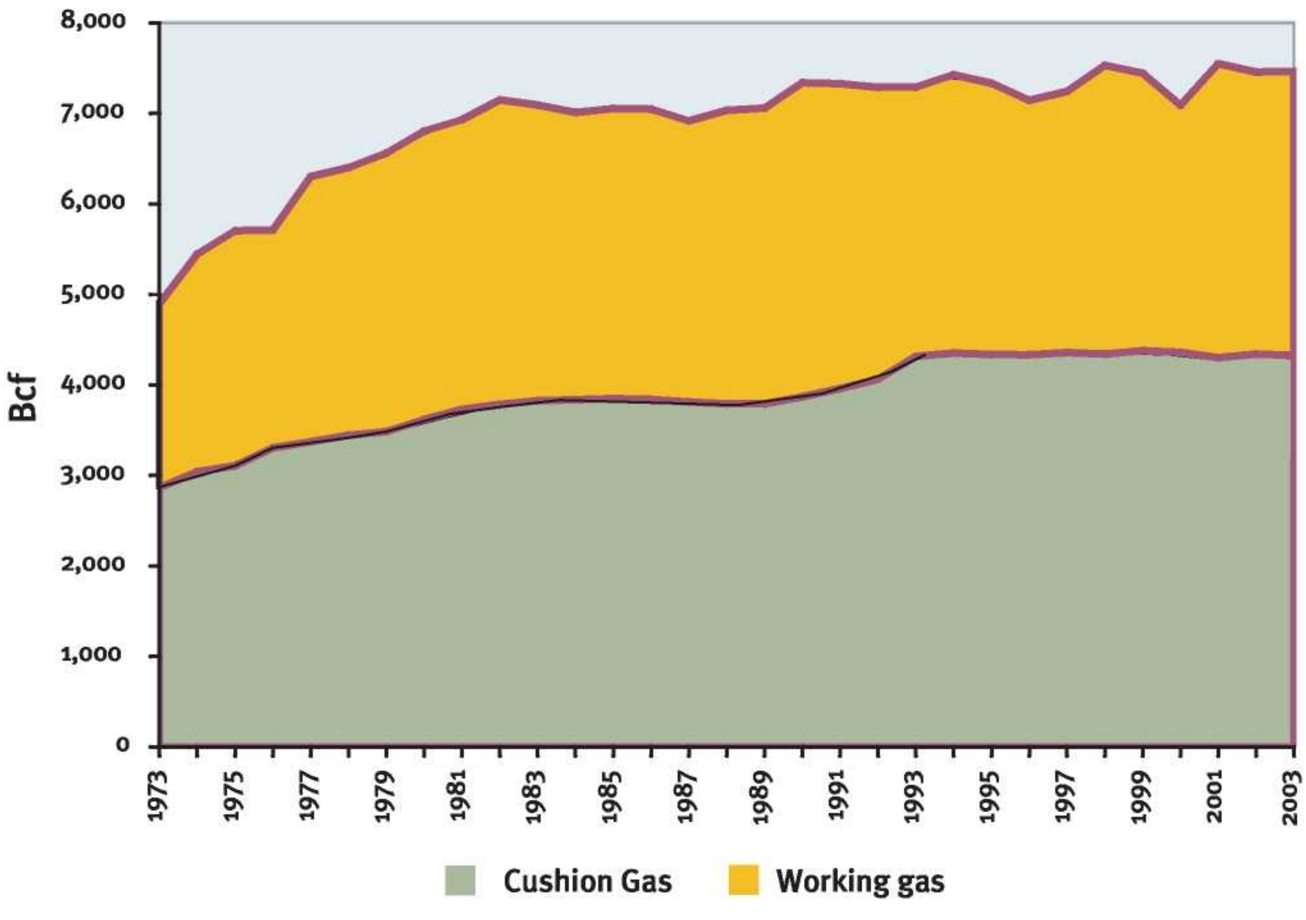
[11] Actual total operating capacity reported by EIA monthly (2001-02 withdrawal season). However, the total potential working gas capacity is estimated by EIA to be 3.9 Tcf, thus we would accept that working gas could be 3.5 Tcf to 3.9 Tcf.

pressurize their storage reservoirs to be ready for withdrawal season, which usually begins November 1 each year. As storage reservoir pressures increase, gas-in-place volume also increases and the injection rate declines gradually in late injection season. Therefore, the injection rate is higher at the beginning of injection season and lower at the end of injection season. The withdrawal rate is highest at the end of injection season, when storage reservoir pressure is highest. Storage operators estimate the volume of supply needed for each season and they try to refill their storage fields' working gas capacities based on historical performance levels and match their storage capacities with their customers' requirements. Many storage fields are designed to have some excess working gas capacities and operational flexibility to withdraw some cushion gas, as needed, within the late withdrawal season.

Actual Storage Operating Capacities

As shown below, based on historic EIA data, cushion gas averaged about 54 percent of the total operating capacity from 1975 through 1991. In 1992, cushion gas began to increase, reaching 61 percent of the total operating capacity in 2000. While cushion gas has been increasing, working gas capacity has been decreasing. This increase/decrease of cushion and working gas capacity could represent the reclassification of working gas to cushion gas as a result of open access, as well as maintaining higher storage pressures to support higher withdrawal rates. Also, this supports the need for realignment or re-engineering of existing storage fields to improve the cycling capability of the storage fields and reduce cushion gas requirements if and when higher storage services are needed.

Relative Volumes of Working and Cushion Gas



Source: Graph generated by FERC staff from EIA data

Storage Capacity Summary

Total U.S., storage operating capacity (EIA data) =
7.6 Tcf (actual)
Total U.S., working gas capacity (potential) =
3.9 Tcf (estimated by EIA)[12]
Total U.S., actual operating working gas =
3.5 (1990-1991 withdrawal season)

Total Jurisdictional operating capacities
(staff estimation) = 5.2 Tcf
Total Jurisdictional working gas capacities
(staff estimation) = 2.5 Tcf

Regional Distribution of Underground Storage

The maps below illustrate the regional distribution of underground storage, which is concentrated in upper Ohio Valley, Michigan, Illinois, Gulf Coast and south central locations. This regional distribution is based on convenient geology, historic natural gas usage patterns and location of depleted oil/gas reservoirs. There are locations in the northeastern United States where there are no depleted oil/gas field, salt domes/formations or natural geological confinements for the development of underground storage fields. While an alternative is the importation and storage of LNG (surface or subsurface), this alternative faces land use and local siting barriers.[13]

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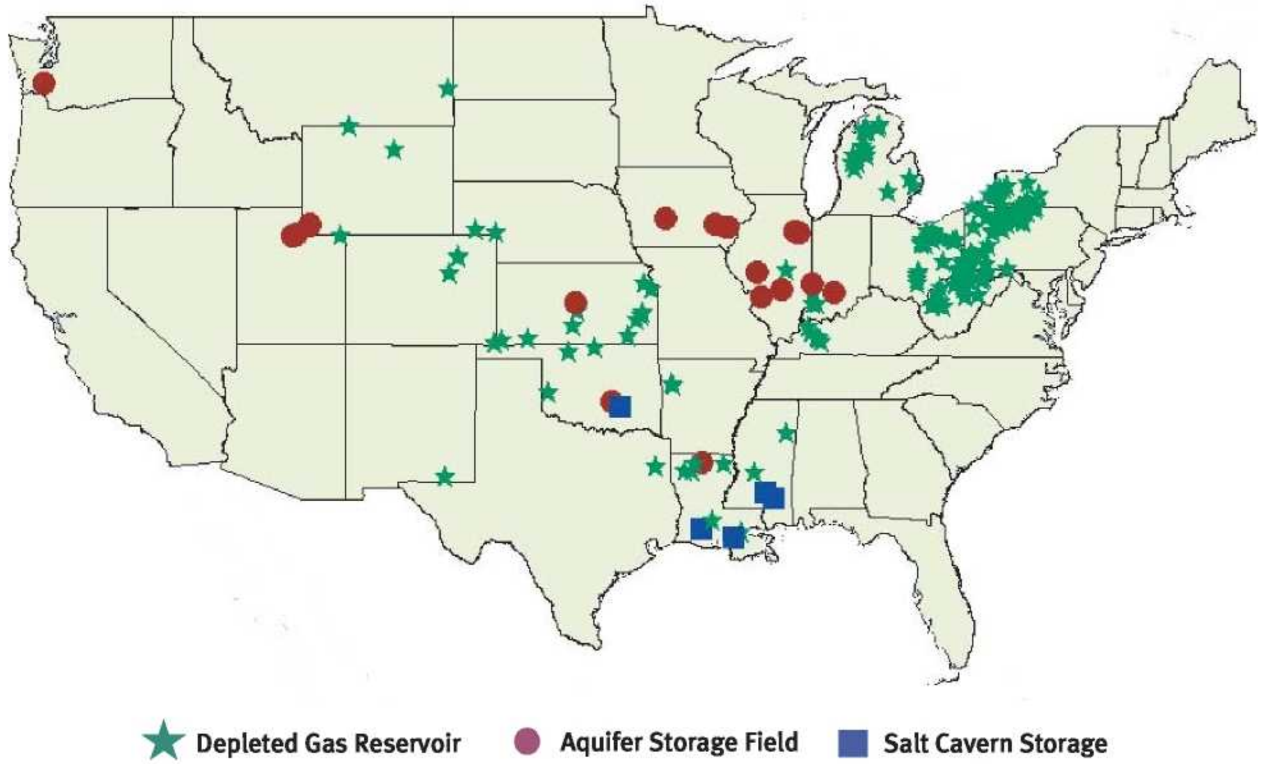
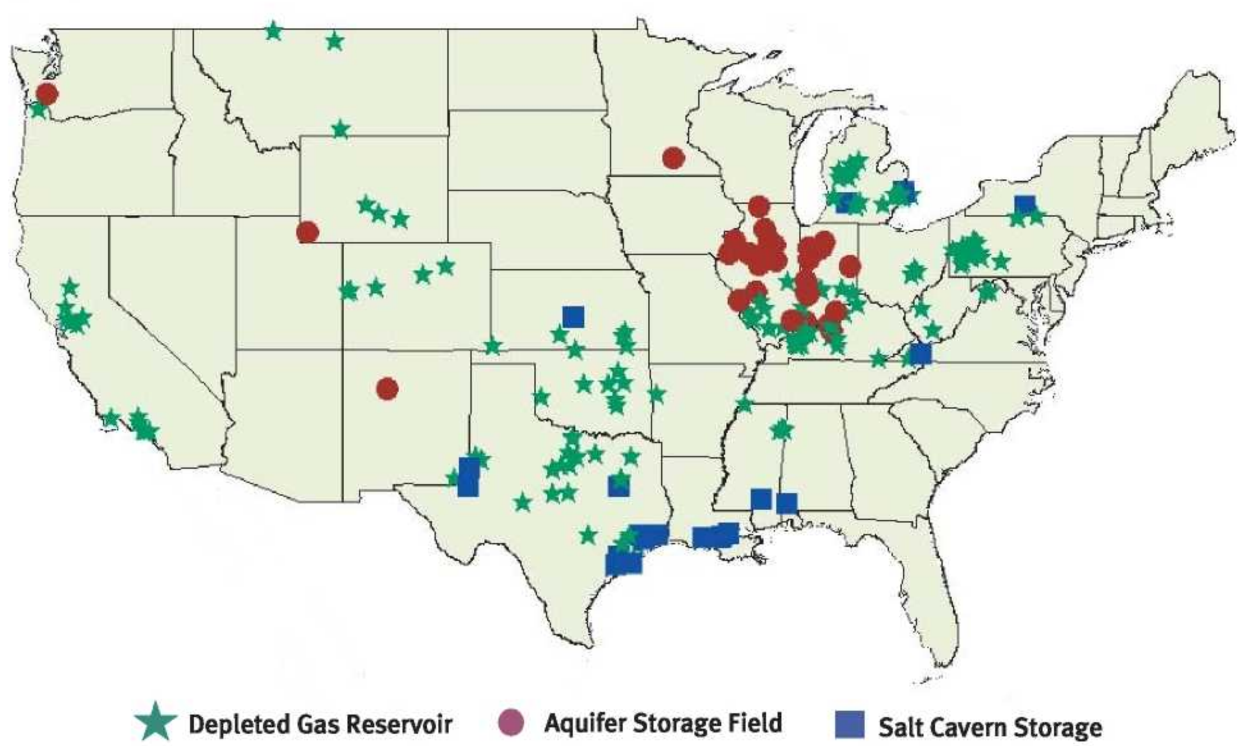
[12] EIA, Natural Gas Monthly, 1973-2003, shows estimated working gas capacity of 3.2 to 3.5 Tcf.

[13] In addition to the LNG import terminal at Everett, Mass., which has a storage capacity of 3.4 Bcf, there are 46 liquefaction and satellite storage tanks located in Connecticut, Maine, Massachusetts, New Hampshire and Rhode Island owned and operated by LDCs. The total combined storage of peak shaving and satellite storage is 15 Bcf. Cumulative vaporization capacity of these storage tanks, plus that from the Everett facility, is approximately 2.3 Bcfd, which can supply as much as 50 percent of the region's peak day needs. In addition to the LNG storage, LDCs have 260 propane tanks in New England with a total storage capacity of 1 Bcf of liquefied petroleum gas (LPG). Vaporization from LPG can meet 5 percent of New England's peak day needs. *See also* New England Natural Gas Infrastructure, Docket No. PL04-1-000, December 2003.

FERC Jurisdictional U.S. Storage by Type and Location



Non-jurisdictional U.S. Storage by Type and Location



Source: Developed using Platts PowerMap and GasData

The Commission's Role in Underground Storage

Commission Certificates

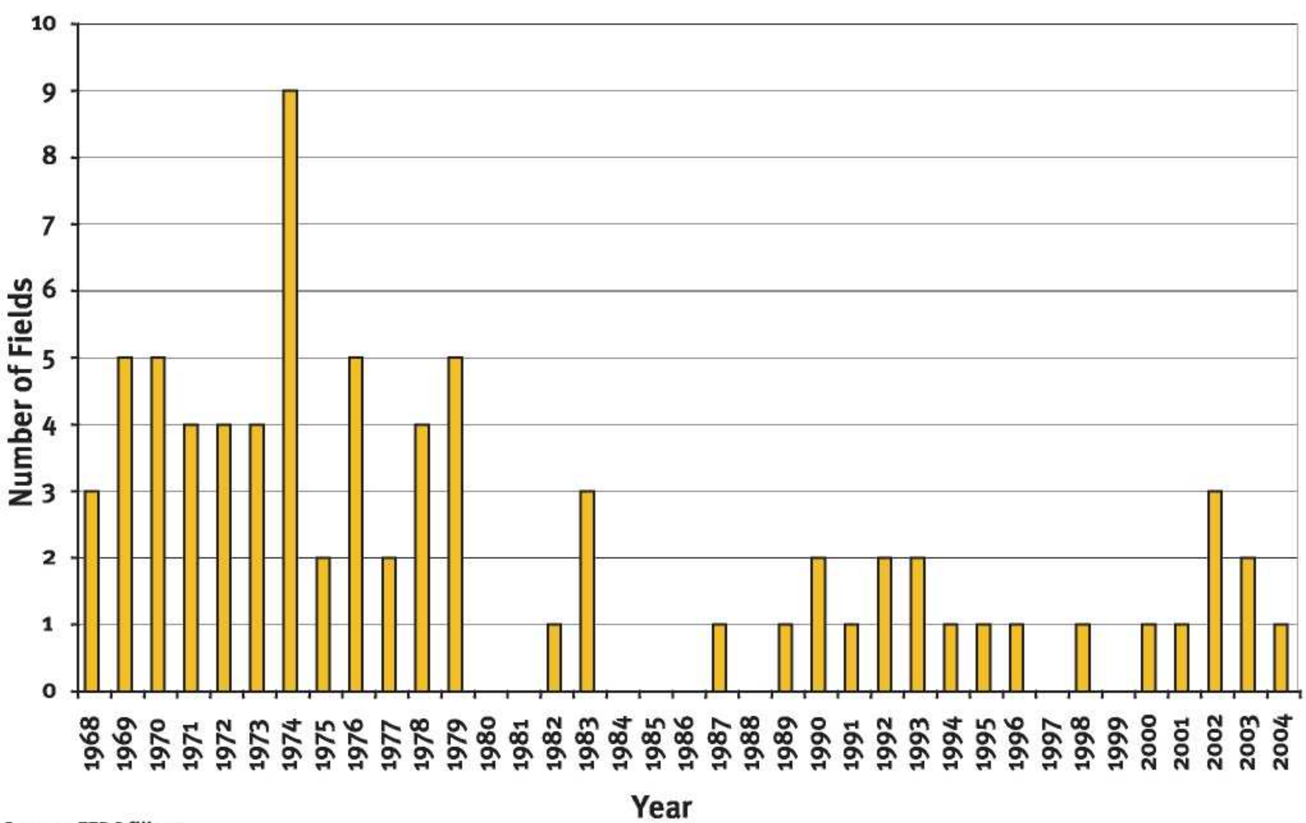
The Commission has jurisdiction over any underground storage project that is owned by an interstate pipeline and integrated into its system. Also, independently operated storage projects that offer storage services in interstate commerce are under the Commission's jurisdiction. The chart below is based on staff's compilation of Commission orders and it shows that the annual number of new storage fields certificated by the Commission has decreased since the 1970s and early 1980s. Beginning in 2002, the new certificated storage fields mostly involved the development of small depleted gas fields and salt cavern storage fields.

Likewise, based on our compilation of applications at the Commission, the number of applications to construct and modify storage facilities has fluctuated from the 1970s through 2004. We attribute the large number of applications during the late 1970s and early 1980s to the industry's reaction to colder-than-normal winters. The current increase in the number of storage applications reflects modifications of existing storage fields (increasing capacity and efficiency) as well as applications by independent storage operators entering the natural gas market as a result of Order No. 636.

Current Commission Cases

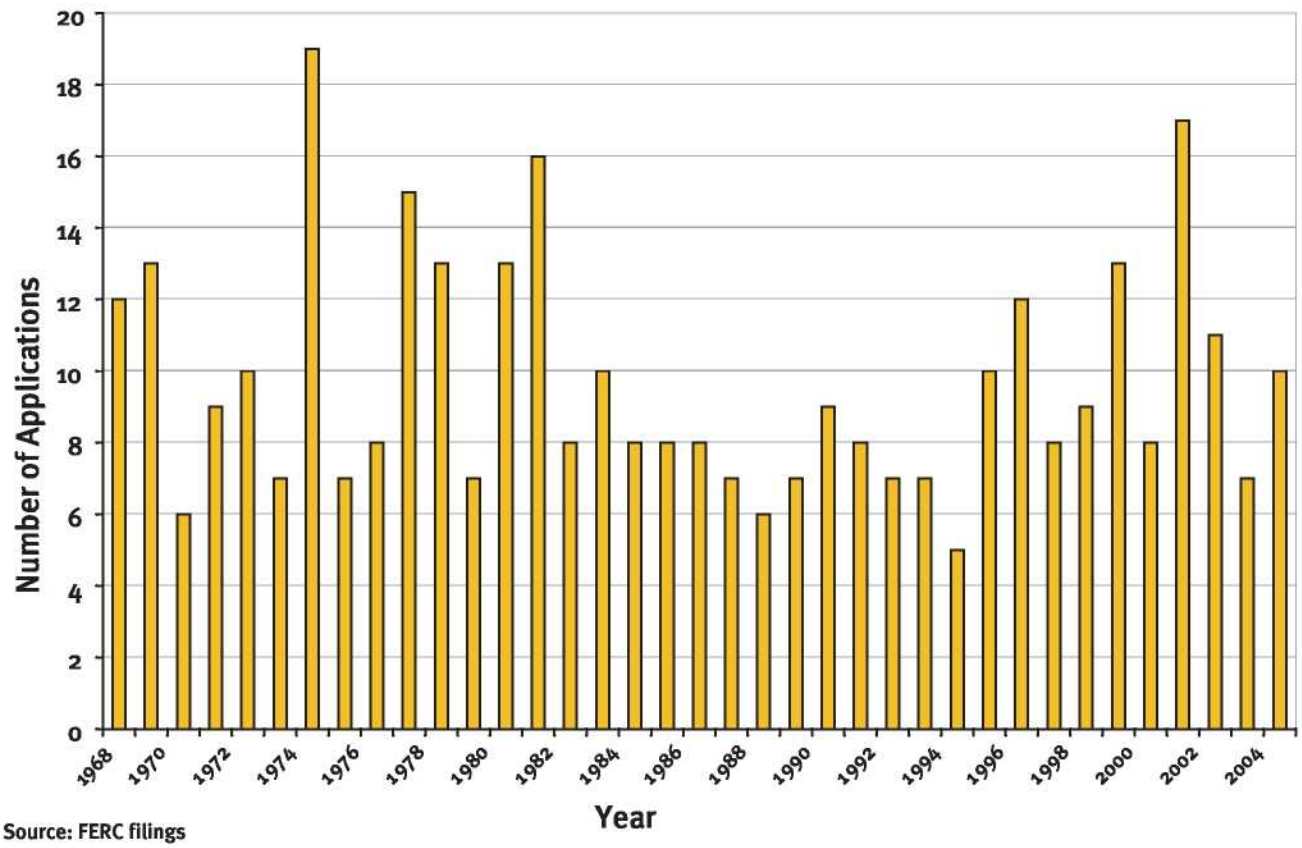
Eleven major interstate storage projects (adding six new storage fields) were certificated since 2002, authorizing

FERC Certification of New Storage Fields by Year



Source: FERC filings

Certificate Applications for Realignment of Storage



Source: FERC filings

the development of 74.7 Bcf of new interstate working storage capacity for the U.S. Of the 74.7 Bcf of new storage capacity, 17.9 Bcf has been delayed or put on hold when compared to the applicant's originally projected in-service date. Of the 11 storage projects, four projects would add 12.2 Bcf of new storage capacity into the Northeast region, but it is these projects that have been delayed. Two projects have added 12.1 Bcf of new storage capacity in the Midwest and five projects added 50.4 Bcf of new storage capacity in the Gulf Coast/Southeast.

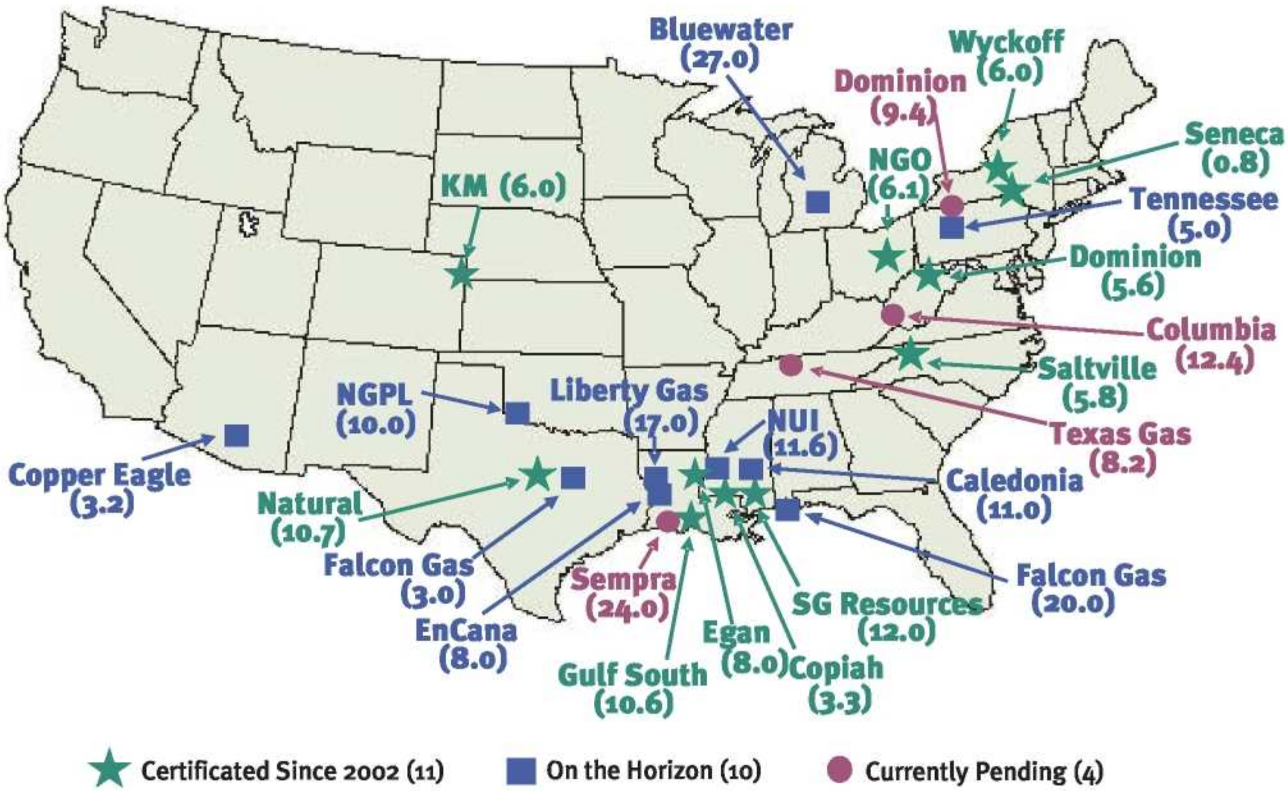
Four storage projects are pending before the Commission; they have a projected capacity of 54 Bcf for the Northeast, Midwest and Gulf Coast/Southeast regions. The present pending and anticipated storage projects will be required to meet the increasing seasonal peak-day requirements.

Ten publicly announced storage projects are on the horizon with potential storage capacity totaling 115.8 Bcf. Of this amount, 5 Bcf would be in the Northeast, 27 Bcf would be in the Midwest, 53.6 Bcf would be in the Gulf Coast/Southeast and 3.2 would be in the West.

The regional distribution of these approved, pending and on-the-horizon projects is shown on the map below.

Recent Gas Storage Projects

Capacity in Bcf; August 2004



Source: FERC filings and price industry reports

Current Developments Regarding Underground Storage

New Technologies

Current methods of improving storage field efficiency, such as mechanically removing debris, washing, injecting acids and creating new perforations in the well pipe often provide only limited and temporary improvements. New technologies are now being used to improve storage field efficiency:

- To unclog storage wells, a low-frequency/high frequency sound wave device is being used that vibrates the scale off the well pipe.
- There are innovative fracturing technologies, such as injecting high pressure liquid carbon dioxide instead of water or other liquids, to keep clays from sticking and sealing off parts of the reservoir.
- In salt cavern development, operators can chill the natural gas and condense its volume to reduce the size of the storage field and the amount of brine that needs disposing.
- Operators can use "lined rock caverns" in storage facilities, in which a steel tank has been installed in a cavern that has been blasted into the rock of a hill.
- Freezing natural gas in the presence of water creates hydrates, thus allowing for large quantities to be stored in same volumes.
- Operators can use the Bishop Process (TM by Conversion Gas Imports) in which LNG is unloaded offshore, warmed to 40 degrees Fahrenheit and then stored as natural gas vapor in underground salt caverns either onshore or offshore.

More on LNG and Underground Storage

Quantities of LNG imports into the United States have increased almost six-fold from 85 Bcf in 1998 to 507 Bcf in 2003. Should LNG imports grow in the future as projected, more storage facilities (LNG tanks, salt cavern storage and depleted offshore oil/gas reservoirs) will be needed. The DOE is studying a novel method of unloading and regassifying LNG directly from ocean tankers for storage in underground salt caverns. Under the Bishop Process, LNG would be received directly from an offshore tanker, regasified, pressurized and warmed to 40 degrees F, then injected into underground salt caverns. A DOE study identified more than two dozen potential sites that had suitable salt formations, sufficiently close proximity to existing pipelines and navigable water.[14] This process would eliminate the need to build expensive aboveground cryogenic storage tanks. A combination of the Bishop Process with the construction or conversion of existing offshore depleted gas fields, platforms and lines could also be a means to import, store and transport LNG. There are many offshore depleted gas fields that could be used for this purpose.

Problems with Underground Storage Projects

A few storage projects have been canceled, delayed or placed on hold due to market concerns, environmental issues and rate issues. Specifically, storage projects have been placed on hold until the market improves or have been cancelled due to a lack of market interests. Environmental concerns such as brine disposal used in the development of salt caverns and land use have been raised. Storage projects have incurred funding problems and cost concerns, and some projects have been cancelled or delayed due to pipeline infrastructure problems. With the denial of market based rates for storage projects by the Commission, certain storage proponents believe cost-based rates may not provide adequate incentives to attract the investment necessary to develop the proposed storage facilities.

Need for More Storage

Estimations of the need for more storage first require projections of national and regional natural gas supply and demand. Then one must estimate the future expansion of natural gas transmission and distribution to gauge how much more storage might be needed to meet seasonal and peak deliverability demands. The price of natural gas and the price volatility also affect the need for storage and such factors also need to be estimated. The NPC gas study and other sources have estimated a need for additional storage in the United States and Canada of up to 700 Bcf by 2025. This has been projected on a regional basis by work sponsored by The INGAA Foundation, as follows below:

New North American Gas Storage Requirements

Incremental Working Gas Capacity in EEA Base Case	2004-2008	2009-2020	Total
Western Canada	30 Bcf	40 Bcf	70 Bcf
Eastern Canada/Michigan	36 Bcf	74 Bcf	110 Bcf
Midwest	–	60 Bcf	60 Bcf
New York	10 Bcf	56 Bcf	66 Bcf
Pennsylvania / West Virginia	33 Bcf	90 Bcf	123 Bcf
Gulf Coast	72 Bcf	5 Bcf	77 Bcf
West Coast	21 Bcf	78 Bcf	99 Bcf
Other	10 Bcf	37 Bcf	47 Bcf
Total	212 Bcf	439 Bcf	651 Bcf

Source: Energy and Environmental Analysis Inc, *At the Crossroads: Crisis or Opportunity for Natural Gas*

[14] *See* http://www.fe.doe.gov/programs/oilgas/storage/index.html.

Staff Observations on the Current State of Underground Storage

Natural gas storage is in better shape this year than last. From a national perspective, we have adequate storage volumes in place in the United States at this time to cover normal conditions. The EIA's "Weekly Natural Gas Storage Report" divides U.S. underground gas storage into three regions: East, West and Producing. As of September 9, the United States had 257 Bcf more in storage than at this time last year and 183 Bcf more than the five-year average for this time of year. If storage injection continues at its current pace, there should not be any problem in refilling working gas storage to the previous year's level (3,155 Bcf on October 31, 2003) and the storage fields should be full and pressurized to their designed levels.

In recent years, however, relatively few new storage fields have been built. Also, there has been an abandonment of a number of old, inefficient, and uneconomically operated underground gas storage fields. Traditionally, underground storage fields were designed to meet peak seasonal demands. Today, especially with the proliferation of gas-fired electric plants, storage facilities are increasingly expected to meet rather dramatic daily or even hourly swings. Thus, storage operations are changing with changing market characteristics. The load profile has changed for natural gas customers over the past few years, and gas supply now is required – sometimes quickly – throughout the year rather than merely meeting peak seasonal demands. Therefore, storage fields with high injection and withdrawal capabilities are becoming the main choice for many storage operators. The traditional marketplace now values highly diversified types of storage services and has increasingly sought storage that rewards flexibility, safety and reliability. This is the main reason why storage operators are re-engineering and conducting detailed studies of their storage fields to see how they can improve the performance of existing storage facilities. Storage field re-alignments are being implemented to increase working gas capacity within existing fields and to reduce cushion gas requirements, which results in increases in deliverability.

Since 1968, there have been many applications for the realignment of old storage fields. Storage operators have modified old storage designs, incorporated new design procedures and constructed surface and subsurface facilities. These modifications include drilling large-diameter wells, relocating wells within reservoirs, incorporating coil tubing drilling (CTD)[15] and horizontal well drilling and completing larger diameter wells. Additionally, storage operators are adding compression, dehydration facilities, and new gathering lines. Operators are also using new technical procedures to better understand reservoir geology, confinement and reservoir flow behaviors, abandoning uneconomical facilities and incorporating new storage operational procedures.

Storage field modifications have generally provided new operational capability for storage operators to recycle more working gas efficiently. By cycling working gas during both injection and withdrawal seasons, the storage operator is able to confine the storage gas, better define geological parameters, reduce gas migration/loss, increase efficiency and reduce operational cost. Finally, a few storage fields' working gas volume has increased and cushion gas volume of those same fields were reduced.

On balance, through realignments or re-engineering procedures, injection/withdrawal capability has increased without any significant increase in total storage operating capacity. In fact, data indicate that the total U.S. storage operating capacity (jurisdictional and nonjurisdictional) has remained about the same over the past few years. Thus, the recent trend in storage field construction activity has predominantly been the modification and realignment of existing storage fields to meet changing market demands rather than a dramatic increase in

[15] CTD is used in existing storage reservoir when the conventional well enhancing techniques (hydraulic fracturing, acidizing and/or reperforating) for enhancing well performance have not proved to be effective.

construction of new storage fields. During the past 10 years, there has been a significant increase in the ability to move gas in and out of storage.

It is the staff's technical opinion that prudent operational procedures and realignment of storage facilities within the past few years by storage operators have resulted in better use of storage capacity. Storage operators have modified their storage facilities and improved storage capabilities with different types of storage operations and services than offered in previous years. In staff's view, in the future, storage operators will construct a limited number of storage facilities on an as-needed basis. However, these projects will tend to be highly selective, taking advantage of particularly advantageous locations or highly favorable geological characteristics.

Historical storage engineering and operational data indicate that not all working gas has been recycled in many storage fields. There are many old storage fields that could and should be redesigned and realigned by incorporating new technology, reducing cushion gas volume, increasing working gas volume and increasing efficiency of storage operation by recycling more working gas. All these new designs and modifications will improve operational capability and reduce operational costs without necessarily increasing the total certificated storage capacity. It is advantageous environmentally and also more cost effective to improve the cyclic capability of existing underground field than to construct a new depleted oil/gas field. It is important to recognize that steadily increasing storage demands will not necessarily be met with large investment in new storage fields in the United States.

The level of total gas storage capacity has been relatively flat for a number of years. During the past few years we have seen an average of only one or two new underground gas storage certificated per year. However, the National Petroleum Council's projected need of up to 700 Bcf of new working storage capacity by 2025 discussed above can be met by the construction of only 35 Bcf of working capacity per year over the next 20 years. The industry appears to be close to meeting or surpassing this goal based on the storage projects that we have approved, have pending before us or are expecting to be filed in the near future. While several old storage fields have been abandoned, others have been sold for less-active local uses. However, over the past 10 years the Commission has authorized many storage realignment applications to improve injection/withdrawal and operational capability of existing storage fields.