Storage: A game changer that transformed the gas industry

By: Bill White, *Researcher/Writer, Office of the Federal Coordinator*

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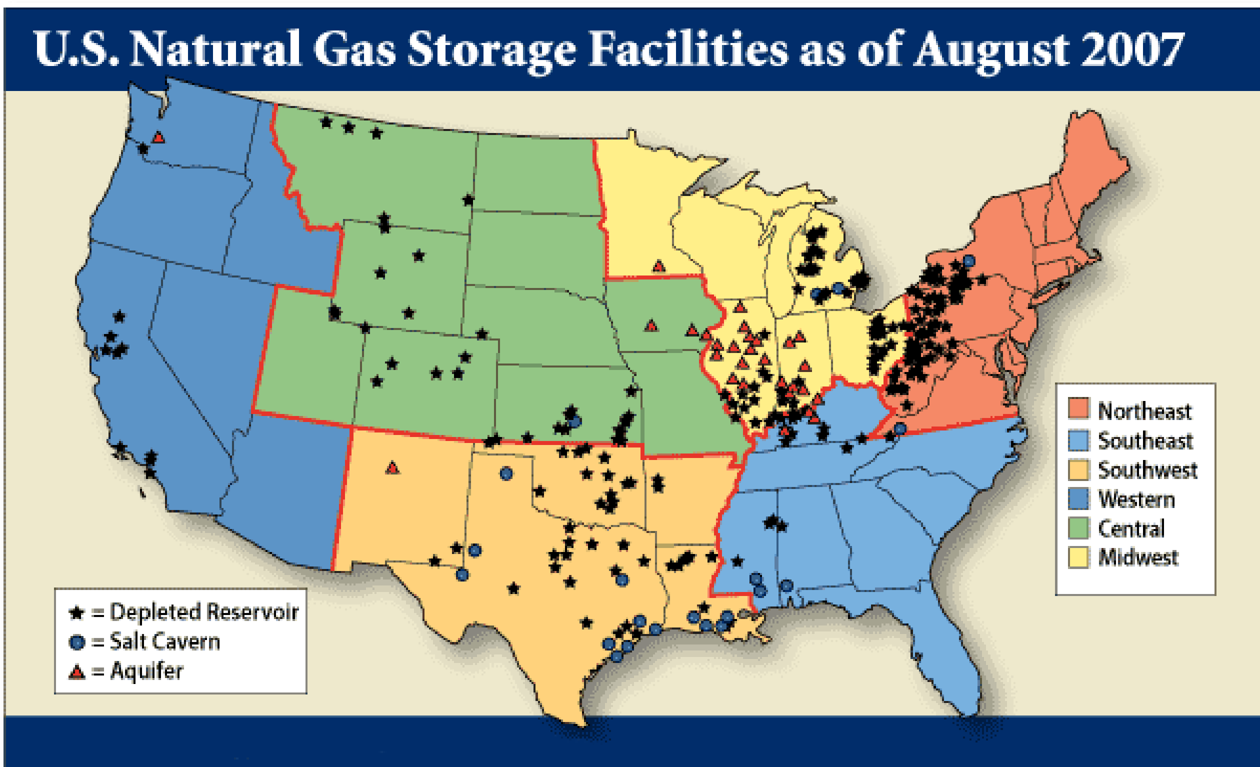
The invisible link that keeps North America's natural gas industry running efficiently lies buried in more than 450 sites across the Lower 48 and Canada.

This unseen - and unheralded - agent is underground natural gas storage, and it underpins the gas industry from production to pipelines to consumers.



Source: U.S. Energy Information Administration. Graphic courtesy of the Texas Comptroller of Public Accounts from "The Energy Report" http://www.window.state.tx.us/specialrpt/energy/

Because so much natural gas is stored after production, gas utilities can reliably flow fuel to homeowners' furnaces when frosty winters boost demand for heat. Thanks to gas storage, electricity plants have additional fuel to power their spare generators when sweaty summers cause consumers to crank up air conditioners.

Underground natural gas storage solves the imbalance between relatively constant natural gas production during the year and gas consumption that swings wildly with the seasons.

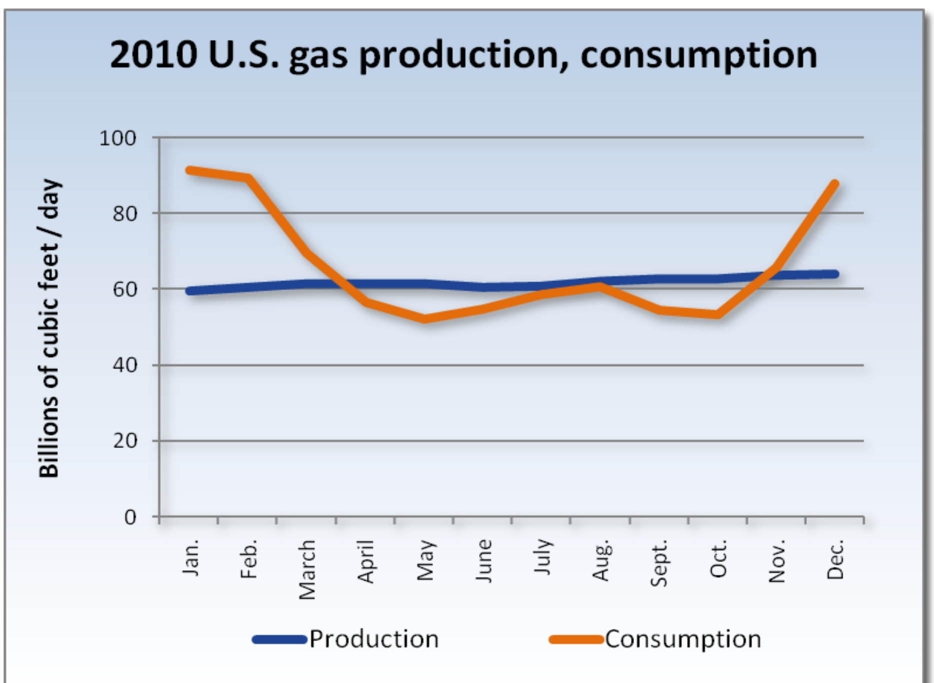
In the same way that stockpiling water behind dams allowed farming to flourish in parts of the arid West, underground gas storage was a catalyst for impressive growth within the natural gas industry. After innovators learned in the 1950s how to store gas and retrieve it from hollowed-out salt beds and old abandoned oil or gas reservoirs, the gas industry started finding new markets and new ways to use the nuisance hydrocarbon that flowed up from oil wells. As a result, flaring or venting much of the produced methane largely became a practice of the past.

One chronicle of the gas industry labels the development of modern storage as among "the most important advances in the industry's history."

A wild imbalance

The chasm between steady gas production and erratic gas consumption can be seen in these numbers:

Last year, U.S. gas production ranged from 60 billion cubic feet a day in January to 64 bcf a day in December, a 4 bcf range from low to high. But consumption varied from 52 bcf a day in April to 92 bcf a day in January, a 40 bcf range. When needed, storage and imports filled the gap between production and consumption.



Source: U.S. Energy Information Administration

Because the proposed multibillion-dollar Alaska North Slope pipeline through Canada would carry so much gas - 4.5 bcf a day - some of it likely would need to go into storage at times during the year.

U.S. underground gas storage sites hold a three- to 10-week supply of natural gas, depending on the time of year.

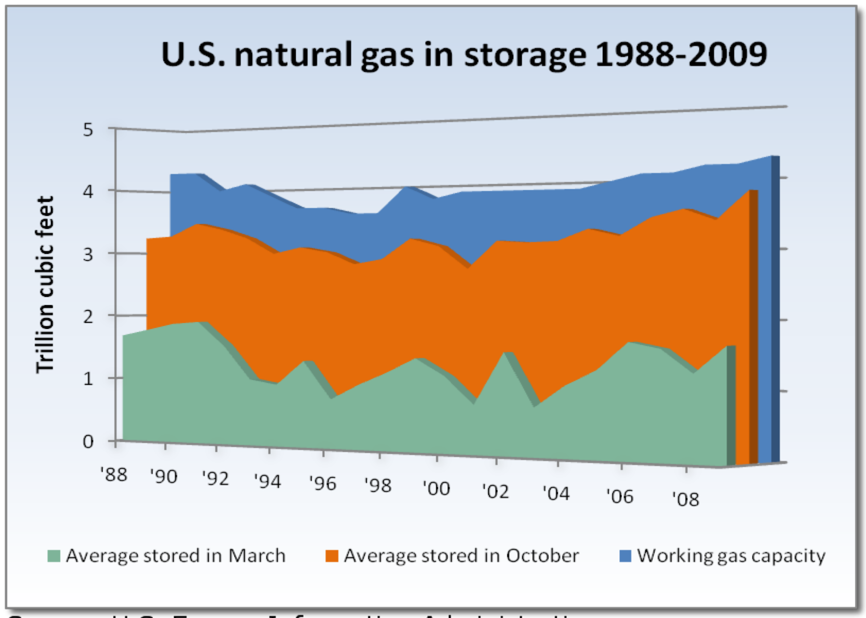
Besides saving spring, summer and fall gas production for the heavy demand months of winter, gas might go into storage for any of these reasons:

- A trader buys gas when prices are lower in hopes of selling it when prices rise.
- A local gas utility parks gas in storage to meet spikes in demand during cold spells.

- A lower power company holds spare gas in storage to use during times of extreme heat.

Stored gas also gets tapped when unexpected production disruptions occur, such as when a hurricane shuts in Gulf of Mexico wells.

Storage tends to stabilize natural gas prices, easing pressure on prices that might surge when demand is high and plunge when demand slackens.



Source: U.S. Energy Information Administration

In all, the Lower 48 had 409 underground storage sites at the end of 2009, with a capacity to hold 4.3 trillion cubic feet, or tcf, of working gas, which is gas that can be withdrawn. (The sites also have "base" or "cushion" gas that stays in place forever to provide the internal pressure needed to flow working gas up wells.) About 2.7 tcf was in storage during the year on average - more during the summer and less in winter. In both late 2009 and late 2010, stored gas topped 3.8 tcf, its highest level ever, raising worry that the country lacked enough storage. Winter demand for gas quickly saved the day, however.

Canada has over 50 storage sites that together can hold up to about 700 billion cubic feet of working gas.

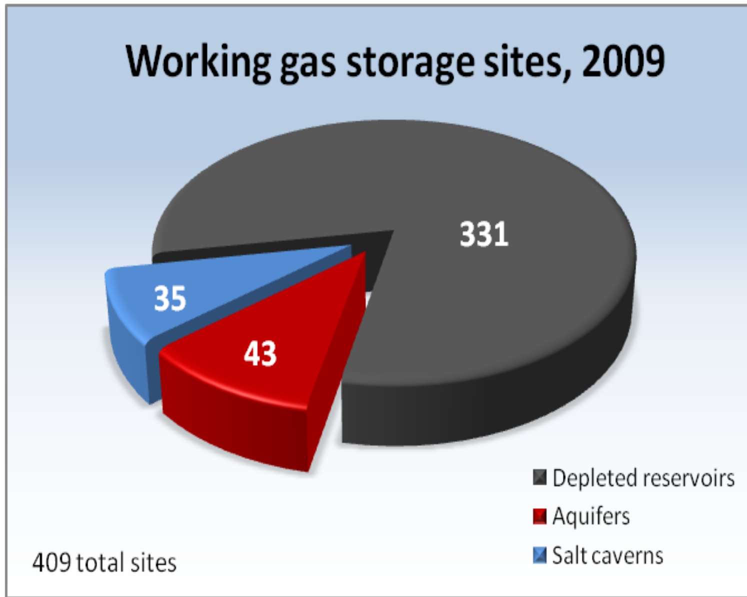
In Alaska, a company led by SEMCO, the parent of local utility ENSTAR Natural Gas Co., hopes to start up an 11 bcf storage site next year in a depleted reservoir the company is rehabilitating near Kenai. It will be the first open-access gas storage operation in the state. ENSTAR and regional electric companies plan to use the storage to serve peak demand in the winter, even if the proposed big pipeline from Prudhoe Bay starts delivering gas to Alaskans.

It's common for local utilities to own storage sites in the Lower 48; it gives them peace of mind that they can handle fluctuating demand. Other storage owners include pipeline companies and independent operators.

Natural gas gets stored in three types of underground sites:

- Old, depleted oil and gas fields - by far the most popular form of storage.

- Aquifers - the most expensive site to develop.
- Salt caverns - an up-and-coming storage method.



Source: U.S. Energy Information Administration

The storage sites typically are located near gas fields, near population or industrial centers, and/or near major pipelines.

That's why the California sites are near Los Angeles or San Francisco; the Texas and Louisiana sites are near the Gulf Coast fields, petrochemical belt and major gas trunk lines; and many sites lie near the big northern cities of New York, Pennsylvania, Ohio, Michigan and Illinois.

Here's a closer look at the three kinds of gas storage sites.

Depleted reservoirs - the big daddy

Depleted reservoirs are the Wal-Mart of gas storage: They're big, almost everywhere and dominate the industry.

They're also cheaper to develop and expand than alternative storage methods.

The nation's 150-year history of oil development has pocketed the country with old reservoirs that petered out decades ago, particularly in parts of Appalachia - a storage-site epicenter.

Depleted Reservoirs

331	Number (2009)
3.7 tcf	Working gas capacity (2009)
70 bcf	Maximum daily delivery (2009)
$8.6 million	Development cost - new (per bcf)
$6.3 million	Development cost - expansion (per bcf)

Sources: U.S. EIA, INGAA Foundation

They're cheaper to develop in part because their geology is well understood already. Storage sites need host rock formations that are porous - rocks bearing tiny pores that can hold gas, like the way a sponge holds water - and permeable - pores that are connected so stored gas can flow up withdrawal wells. The host rock formations also need an impermeable rock layer above the reservoir that will hold the stored gas in place rather than let it leak away. Depleted reservoirs have proven themselves on these points, so the developer has less expense proving the reservoir works for storage.

Depleted reservoirs might also have wells sunk in them and they're likely near pipelines, further easing development costs.

Beyond this, base gas is already present in whole or part. Even though the reservoir is technically "depleted," it still contains lots of gas. What's actually depleted because of past production is the underground pressure that allows the gas to flow. The existence of the base gas means the storage site operator doesn't need to obtain and inject as much gas just to pressurize the storage site. (The normal practice is that customers storing gas pay a fee that over time covers the developer's cost of acquiring base gas.)

Of the nation's 409 storage sites at the end of 2009, 331 were depleted reservoirs. Of the 4.3 tcf of working gas capacity, 3.7 tcf was in depleted reservoirs.

Over half of the Lower 48 states host at least one depleted reservoir gas storage site. Many such storage sites are in Ohio, West Virginia and Pennsylvania, birthplace of the U.S. oil industry.

The mother lode of stored gas lies in the seemingly unlikely locale of Michigan. As 2010 began, one in eight of the Lower 48's depleted reservoir storage sites had a Michigan address, accounting for over one-sixth of the nation's working gas storage capacity in depleted reservoirs.

What makes Michigan special? Beneath parts of the state are formations known as pinnacle reef reservoirs - tall vertical mounds of lime and limestone, coral and other materials, **according to one federal report**. These reefs are highly porous and highly permeable, making them choice storage sites.

As widespread as depleted reservoir storage sites are, they have an important drawback: The gas stored in them usually can't be withdrawn very fast. That makes them fine for long-haul pipeline owners that tap stored gas for load balancing and supply management. But they're ill-suited to meet the emerging storage trend of delivering gas on short notice.

Aquifers - choice of last resort

Storage in aquifers occurs most often when no depleted reservoirs or salt beds are nearby. Most of the nation's 43 aquifer sites are in Illinois and Indiana.

Aquifers	
43	Number (2009)
396 bcf	Working gas capacity (2009)
9 bcf	Maximum daily delivery (2009)
$17.2 million	Development cost - new (per bcf)
$14.2 million	Development cost - expansion (per bcf)

Sources: U.S. EIA, INGAA Foundation

Aquifers are the most expensive form of storage to create and expand - double the cost of converting a depleted reservoir. Their geology must be tested, wells drilled, pipelines laid and dehydration plants built - dry gas is injected but water can come up with the withdrawn gas. It can take up to four years to develop an aquifer into a storage site, twice as long as developing a depleted reservoir.

Aquifers also have another expensive drawback: Half to three-fourths of the gas injected in them will become cushion gas that might never be retrieved. Most aquifer sites were built when natural gas prices were low, so the cushion gas was relatively inexpensive to lose.

To minimize the chances that fresh water within an aquifer is contaminated, aquifer storage falls under U.S. Environmental Protection Agency rules.

Salt caverns - quick turnaround artists

The hot trend in gas storage is to park the gas in new or expanded salt caverns.

Salt Caverns	
35	Number (2009)
272 bcf	Working gas capacity (2009)
20 bcf	Maximum daily delivery (2009)
$10.9 million	Development cost - new (per bcf)
$8.7 million	Development cost - expansion (per bcf)

Sources: U.S. EIA, INGAA Foundation

Salt caverns are like the small basketball star who compensates for lack of height with his exceptional speed and agility. Their competitive advantage is that the gas stored in them can be delivered quickly. This makes them ideal holding sites for gas to meet demand surges or emergencies. In some cases, a salt cavern can begin flowing on an hour's notice, **according to naturalgas.org**, an industry website. Power companies with gas-fired electricity generators that switch on during peak demand have a particular affection for high-deliverability storage sites.

These numbers illustrate their workhorse productivity: The nation's 35 salt cavern sites could deliver 20 bcf of gas a day as of last year, while depleted reservoirs - with 10 times as many sites and 12 times as much working gas capacity - could deliver just 70 bcf a day, **according to U.S. Energy Information Administration data**. Straggling in last were the nation's 43 aquifers, which could deliver 9 bcf a day.

To create caverns, developers blast water into salt beds or salt domes. This dissolves the salt, flushes it to the surface and hollows out a chamber. The cavern is as air tight as a space capsule, allowing little injected gas to escape. And the cavern walls have the structural strength of steel, letting them hold up well over time, according to naturalgas.org.

Key drawbacks of salt caverns include their smaller size than the typical aquifer or depleted reservoir, and the amount of injected gas - about one-third - that must be reserved as cushion gas to pressurize the cavern.

The other major drawback is that almost all of the nation's salt caverns lie in Texas and Louisiana, particularly along the Gulf Coast. This geographic isolation limits their usefulness.

A new world for gas

Gas storage has been around for nearly a century, but it's only in the past 60 years that it has caught on in a big way, helping transform the gas industry.

The first successful storage site was developed in Ontario in 1915. By 1930, the United States had nine storage sites in six states. All involved depleted reservoirs.

But the world of natural gas was very different back then from what we know today, where the methane in natural gas heats homes, offices and schools; and fires power-plant generators nationwide.

Components of Natural Gas[1]	
70-90%	Methane
0-20%[2]	Ethane
0-20%[2]	Propane
0-20%[2]	Butane
0-8%	Carbon Dioxide
0-5%	Hydrogen sulfide
0-5%	Nitrogen
0-2%	Oxygen

[1]Trace amounts of argon, helium, neon, xenon
[2]Ethane, propane and butane together account for 0-20%

Source: Natural Gas Supply Association, naturalgas.org

Methane is the main component of natural gas, but before World War II methane use was confined mostly to local markets near oil and gas fields. Because many big gas fields were located in Texas, Oklahoma and Kansas, far from population centers, the surplus methane was vented, flared or reinjected to push more oil from a reservoir. The real money in natural gas involved extracting and selling its liquids - propane, butane and ethane - that could be used as fuel or chemical feedstock in industry. But liquids comprise just a fraction of the natural gas stream.

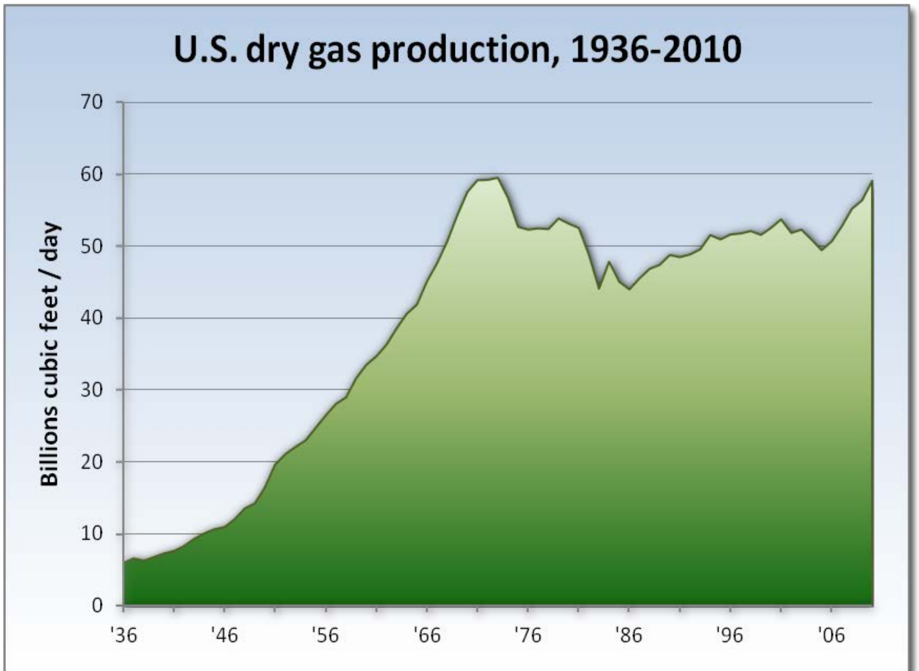
World War II changed much in America, including the long-distance transportation of oil and gas. Before the war, tankers carried virtually all of the oil shipped from Texas and Louisiana to East Coast refineries. But after the war began, German U-boats hunted tankers along shipping lanes and knocked down the fleet like ducks in a shooting gallery. The government issued an urgent call for new pipelines, and industry responded. After the war, when tanker sailings were safe again, some of these new long-distance oil pipelines were unneeded and two of them - called Big Inch and Little Inch - were converted to carry natural gas eastward instead.

A gas pipeline building frenzy then ensued.

Gas producers were finding new markets. U.S. natural gas production doubled from 11 bcf a day in 1946 to 22 bcf by 1953. All this new gas created its own crisis. Demand for gas was seasonal. The producers and pipelines had too much gas for some of the year and not enough at other times.

Storage was the solution.

At the end of World War II, about 50 underground storage sites existed in the United States, most of them built during the war. By 1956, the nation had 188 sites - about half the number of

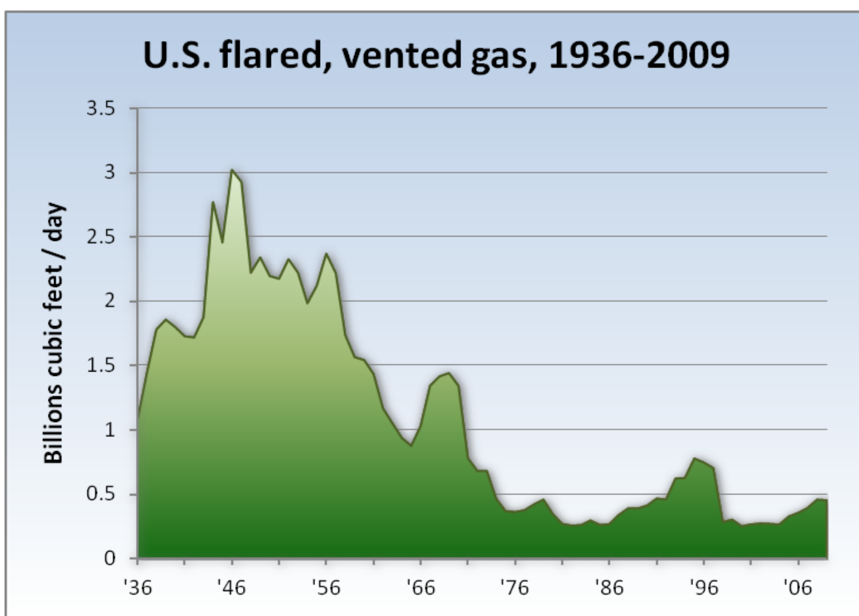


Source: U.S. Energy Information Administration

today. Depleted reservoirs remained the storage method of choice, but the industry was experimenting with other ways to store gas and gas liquids. They tried abandoned mines. They tried digging chambers out of underground rock formations. Many ideas flopped quickly as too expensive to build or too inefficient - gas would leak away or not enough injected gas could be withdrawn later.

A breakthrough innovation occurred in 1949, when the Sid Richardson Gasoline Co. built and tested a salt cavern at its Kermit, Texas, gas processing plant. The company injected propane and later withdrew almost all of it with virtually no contamination. And the cavern cost relatively little to build.

Good news traveled fast, and within a year five more salt-deposit storage sites were under way, including one in Michigan, according to an industry history.



Source: U.S. Energy Information Administration

Storage allowed the natural gas and gas-liquids industries to blossom. Dry gas production nearly tripled from 22 bcf a day in 1953 to 59 bcf in 1973 as more and more American homes burned gas in their furnaces.

Meanwhile, by the early 1980s flaring and venting of natural gas had plunged by over 90 percent from its 1946 peak.

Future favors salt caverns

Much of today's innovation involves using new technology and techniques that reduce the amount of cushion gas needed, or that extract stored gas faster to meet short-term demands.

Another trend involves who is entering the business once exclusively the domain of pipeline companies and local gas utilities. Storage owners increasingly are businesses devoted exclusively to providing gas storage for a fee.

The storage industry continues to grow as U.S. gas demand rises. Gas consumption last year reached a record 66 bcf a day on average, according to the EIA.

The Federal Energy Regulatory Commission oversees about half of the nation's storage sites - those involved in interstate movement of natural gas. The other sites, connected to intrastate pipelines and local gas companies, answer to state regulators. The Regulatory Commission of Alaska is overseeing the rates charged to use the new Kenai Peninsula storage set to open next year.

As was said earlier, the Lower 48 working gas storage capacity was 4.3 tcf in 409 sites as 2009 ended. Since 2000, FERC has certificated 98 new or expansion projects totaling 1.1 tcf of working gas capacity, although not all have been built.

Just this year through June 3, FERC certificated four projects - two in Louisiana, one in Utah and one in Iowa - totaling 100 bcf of working gas capacity. As of a month ago, FERC had six more applications pending.

A **report last month** by the Interstate Natural Gas Association of America Foundation, a trade group, forecasts the United States and Canada will need another 589 bcf of working gas storage capacity by 2035, with salt caverns dominating the new capacity. The capital cost would be $4.8 billion (in 2010 dollars).