Natural Gas Storage and End User Interaction -- A Progress Report

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In late 1994, ICF Resources began a contract with the Morgantown Energy Technology Center ("METC") to conduct a study of natural gas storage and end user interaction. This study is being conducted in three phases: the first phase is an assessment of the market requirements for natural gas storage and in particular to identify those end user requirements for storage that could benefit from METC-sponsored research and development ("R&D") in storage technology; the second phase will address the particular technical and economic feasibility for expanding conventional storage; and the third phase will address alternative, unconventional technologies.

ICF is approaching the conclusion of the first phase of the study and the second phase has begun. This paper summarizes the scope of the study and reports some of the preliminary findings of the first phase. We begin by providing an overview of the goals of the effort and of natural gas storage. We will address the evolving market requirements for storage and the regulatory and institutional changes that are having a major impact on the use of natural gas storage. We address the demand for storage and the alternatives for meeting this demand, with specific reference to regional and end use issues.

Overview of the Project

The overall objective of this contract is to identify whether there is a need for METC-sponsored RD&D into alternative gas storage technologies with that need specified in terms of the requirements of the users of gas storage, now and in the future. The contract is designed to identify where such storage may be needed, when it would be needed, and what the characteristics of such storage should be to meet end user requirements.
The contract is divided into two phases. The first phase is intended to identify the regional needs for storage and the capability of the current and planned storage infrastructure to meet these needs. This involves an assessment of storage markets (Task 1), the various alternatives to storage currently being pursued, and the physical and technological capabilities of existing conventional storage to meet these market requirements (Task 3). Because it is anticipated that a major source of new market demand will be for electricity generation, METC has specified that the analysis specifically address the storage requirements of this market segment. The product of Task 3 will be the specification, by region, of potential barriers to the more efficient use of gas storage, and the potential role of government in addressing these barriers.

The second phase (Task 5) is intended to characterize the technical possibilities for alternative storage. Conventional storage consists of underground storage situated in the traditional storage media: depleted oil/gas fields, salt formations, aquifers and reefs. Liquified natural gas using current liquefaction/vessel technologies can also be considered conventional storage. Alternative storage could include a broad array of new storage technologies or innovative uses of conventional storage, along with non-traditional storage reservoirs such as tight fractured formations, thin bedded salts, and non-reservoir rock formations.

**Expected Results of the First Phase Effort**

At the conclusion of the first phase, ICF will provide METC with the following:

- A description of the end user requirements for gas storage on a regional basis for the period 2000 through 2010. These requirements will consist of the following elements:
  - seasonal storage capacity for meeting seasonal demand variations
  - cycling storage capacity for meeting short term, operational demand for gas
  - estimates of the value of storage in each region and for each type of use
- A data base of storage reservoir characteristics consistent with production reservoir characteristics currently in GSAM.
- A complete representation of storage in GSAM, including demand and supply characteristics on a regional basis, for both seasonal and short-term cycling operations.
- An evaluation of capabilities of the current and planned storage projects to meet demand with an identification of the key technical parameters that may affect the performance characteristics of storage.
- An initial assessment of the need for RD&D to enhance capabilities from conventional storage formations and a characterization of possible alternative storage requirements.

**Expected Results of the Second Phase Effort**

This phase is designed to identify alternative (i.e., unconventional) storage possibilities and provide METC with the capability to analyze near and long term RD&D strategies for assessing these possibilities. Such unconventional storage may consist of (1) storage performance capabilities for meeting end user requirements at substantially lower costs than current technologies; (2) enhanced storage performance for meeting anticipated new demands for storage-type services; (3) identification of new unconventional storage media that can increase the availability of storage in regions where conventional storage (or its alternatives) is inadequate. From this task we will provide the following:
• A description of a range of possible alternative storage technologies.

• An assessment of storage technology possibilities in the GSAM framework to provide an initial analysis of realistic near-term and long-term R&D goals.

• A benefit/cost study of alternative storage R&D actions based on regional storage and gas market economics.

• Development of feasibility criteria for evaluating alternative storage RD&D activities.

Overview of the Storage Industry

Underground natural gas storage has long been an integral part of the interstate natural gas delivery system. Storage has served several purposes in the gas system. Market area storage is used to meet seasonal peak demand, provide control for pipeline operations and assure the availability of gas for incremental sales. Supply area storage serves as a backup gas supply, a supply aggregation facility and a control for pipeline and production operations. Storage is also used midway along pipelines also as a control for operations and as a supplemental source of supply.

Underground storage is typically in geological formations with different operational characteristics. These include:

• depleted gas and oil reservoirs which are the most common type, located in the northeast, midcontinent and west coast

• aquifers, mainly in the upper midwest and Pacific northwest

• salt formations which are quite widespread but where most of the development to date has been in the Gulf coast

• marine reefs, located mainly in Michigan

In addition to these formations typical of U.S. storage, there are storage possibilities in underground caverns associated with mining. Finally, liquified natural gas facilities ("LNG") provide storage peaking capacity in a number of locales.

There are approximately 375 underground storage sites in the U.S. with a working gas capacity of approximately 4 Tcf. On a peak day, these storage reservoirs can deliver approximately 60 Bcf. As our figure indicates, most of the storage capability is located in the northeastern quadrant of the country. The largest concentrations of storage are in the producing areas throughout the midcontinent and gulf coast, and in former oil and gas production areas in the upper midwest (Illinois, Michigan) and the northeast in Pennsylvania.

As of late 1994, there were approximately 80 new storage developments announced. Of these, 47 were classified as "new" greenfield storage and 34 as expansions of existing storage.

The trend in new projects has been towards the development of high deliverability salt cavern projects, which constitute about 58 percent of the new projects proposes. Thirty-eight percent of the new projects are in depleted oil and gas reservoirs, with the rest proposed in aquifers. If all these projects are developed (and they will not be), they would contain about 495 Bcf of working gas capacity and 21,000 MMcf per day of deliverability. Almost 70 percent of the new deliverability will come from the salt cavern projects. Most of the proposed projects are located in the producing regions, although some are in the upper midwest and the northeast.

The trend in development reflects the changing market needs for storage. This market places high value on high deliverability relative...
to storage capacity and to a quick responsiveness to demand. The popularity of salt cavern storage is its ability to be drawn down and refilled several times per year. Traditional storage can only be drawn down over an entire heating season.

**Market Trends**

The focus of the first phase in this research effort has been on end user interaction. This interaction comes about in several ways. First, is to identify those growth areas for gas consumption that can benefit from storage services. That is, where new markets are developing, can storage enhance the ability of the gas system to meet these market requirements? This also involves understanding how patterns of energy consumption affect fuel choices and choices between gas services. In addition it is necessary to understand how the market is evolving in response to institutional and regulatory changes.

The basis of the market trends analysis has been the 1994 GRI Baseline Forecast. The 1994 forecast shows a natural gas market of just over 21 Tcf in 2000 and a market of about 24 Tcf by 2010. Gas prices over the period increase fairly moderately, reaching $2.50 in 2000 and $3.20 in 2010 (1994 dollars). Growth in consumption is expected to occur in all sectors, but major growth is expected in the electric generation and industrial markets. (In the GRI forecast, industrial consumption includes cogeneration.) As such, gas for electricity generation will be the major source of growing gas consumption in the GRI forecast. This view is generally held by most forecasters. By the year 2010, GRI expects about 80,000 MW of new gas fired generation.

Much of this new electric capacity will be combined cycle ("CC") plants and in gas/oil turbines. Gas fired CCs are becoming increasingly attractive to electric system planners. Improvements in gas turbine technology have brought about great advances in CC heat rates. Many operate well below 8,000 Btu/Kwh down to 6,500 Btu/Kwh in some units, which depending on gas prices can make gas-fired CCs competitive with coal plants. Lower environmental impacts and certification costs of CCs also make these units more attractive than coal units. The shorter lead times and lower costs per MW of installed capacity (currently around $600 to $800 per MW) make CC investment less risky given the uncertainties of electricity demand and pricing. Finally, CCs typically have superior load following characteristics and can be brought on and off line quicker than other units.

As such, CCs typically operate at intermediate load factors of between 25 and 60 percent, although in some cases CCs can be operated as base load. The singular characteristic of CCs relevant to gas system planning is the fact that they can be stopped and started many times over the course of a year, month or week. Ramp up times usually are 2 to 3 hours. Thus, when the CCs are brought on line, the gas must be available on short notice.

Gas turbines have very low load factors, operating in some cases less than 100 hours per year. Turbines are used to meet needle peaks in electric demand. As such, the turbines are less cost sensitive than CCs or other steam plants. If gas is not available, turbines can use higher priced distillate oil without penalty.

Growing gas consumption in the generation of electricity will have an impact on the natural gas delivery system. Each region has a distinctive electric generation load profile. As more gas fired generation is added, gas consumption will increase consistent with that profile. An example of this is shown in this graph of national patterns. More gas fired generation will add considerably to summer gas demand, but should also add to gas demand in the winter. On a region by region basis, this will result in
additional demand for transportation and possibly storage requirements. At the same time, as more CCs are added, there will be a greater need for quick cycling storage capabilities.

Industrial gas consumption growth is largely driven by cogeneration demand. This will tend to have similar patterns to electric generation consumption to the extent that cogenerators sell power into the grid as opposed to simply serving as "inside the fence" steam/electric providers. Looking at industrial patterns of gas consumption suggests that while there is some seasonality associated with industrial uses, industrial demand tends to be flatter over the course of the year.

Turning to residential and commercial gas consumption -- the firm, core demand for gas services -- the forecasts indicate very modest growth in consumption. This, however, masks the effect of even small amounts of growth in this sector on deliverability. As this figure indicates, the growth in gas demand when viewed over the entire year shows winter peak month consumption increasing by about 200 Bcf. This assumes that conservation and improvements in technology do not reduce peak consumption or alter patterns significantly. (This may be the case, as most such technologies tend to lower gas consumption over the entire year and not on the peak.) Indeed, in many utilities that are experiencing residential growth, peak day send-out is also increasing, leading to more interest in storage or other peaking options.

The implications of these forecast trends are twofold:

- additional seasonal deliverability may be required in some regions as seasonal demand for gas increases

- additional rapid response deliverability may be necessary for winter and non-winter demands to enhance deliverability in a general way describes how we have been proceeding. The storage question is, however, much more complicated as anyone who has examined the economics and demand
for storage can attest. One indicator of this is the current diversity of opinion as to whether there is an excess of storage capacity in today's market. In addition, while a great many storage projects have been announced, not all of these are coming on line as planned. One of the major factors is the absence in some cases of adequate market interest and commitment to storage projects in light of the uncertainties of today's gas market and the alternatives available to storage.

Institutional and Regulatory Changes

FERC's Order 636 has had a major impact on storage planning and operations. Indeed, the changing rules in the gas marketplace have had by far the larger effect on storage than market growth or changing demand patterns.

Prior to FERC's Order 636, storage was a service provided by the pipelines as a bundled aspect of their merchant, contract demand service. While buyers could purchase storage service separately from regular CD service in some cases, the choices were limited. In the main, storage service was a relatively expensive, seasonal supply of gas used to supplement winter CD gas supply.

Order 636 made major changes in several areas that affect the need for storage services:

- It required the unbundling of pipeline services and the separate pricing of those services. Pipelines were no longer gas merchants, becoming suppliers of transportation and related services. Buyers could select from among the services they wanted to best meet their individual requirements. In unbundling their services, pipelines were required to transfer or assign ownership of storage and upstream pipeline capacity to customers. For storage, this has led many users to begin making their own independent judgements about filling and withdrawal.

- The imposition of straight-fixed-variable rates fundamentally changed the price signals to purchasers of storage and pipeline capacity. Under previous rate regimes, modified-fixed-variable rates, the Seaboard and United formulas, more or less of the pipelines' fixed costs were recovered in the commodity charge. Under SFV all fixed cost are paced in the demand charge. The effect of this, as shown in the slide, is to penalize low load factor users of capacity. This in effect makes storage, or some equivalent a critical element in the local distribution company system planners' decision making.

- The order allows holders of pipeline capacity and storage capacity to remarket that capacity. Pipelines are no longer the sole providers of pipeline capacity. The impact of this is still being worked out. The initial observation, however, is that the price of spare capacity has collapsed in many regions to the variable cost of transportation. At the same time, this is leading to a more intensive use of the pipeline system, as new customers seek out assigned capacity deals rather than new constructed capacity. As the system is more efficient employed, the need for new construction has diminished.

- While not a direct requirement of Order 636, a major consequence of the order has been a proliferation of pipeline and related services. These include the market hub services, balancing, no notice services, seasonal swing services and alternative storage services (i.e., Columbia's Storage in Transit Service). In particular, the pipelines' new restrictions on balancing have enhanced the value of short term storage
access. At the same time, some of the services compete with new, third party storage offerings.

Other market changes are also affecting the uses of and need for gas storage. These include the volatility of gas prices and the success of the futures market for managing commodity risk in the industry. The result of this is that storage is now used in many cases to "park" gas, either to take advantage of gas price changes or to meet other operational needs.

Options Analyses

What is becoming apparent in this new regime is that gas storage can be used in a wide variety of ways. The value of storage depends on how it is used and the alternatives for that use. In sorting out the kinds of possible uses of storage for R&D planning, we have focused on the uses of storage that require the delivery of natural gas. We have found the following construct helpful for identifying the market uses of storage and how to begin to evaluate the enhancements that R&D can make.

This figure shows the cost of storage compared with the major physical delivery alternatives. These include, pipeline capacity, propane air or LNG, and distillate fuel oil. What we see in this picture is that the economics of storage vary relative to the other options depending on the capacity factor or length of time the option is available. That is over a range of low capacity uses, storage is more economic than new, full cost pipeline capacity. On the other hand, traditional storage is more costly than propane air/LNG for very low capacity factor uses. Similarly, it can be less costly to interrupt some dual fuel customers with distillate backup than it is to supply those needs with storage (depending on the cost of fuel oil). We have identified three market segments useful for characterizing storage and its physical substitutes relative to end user requirements and for establishing the value of storage in each region.

- **Short term peak shaving** -- this is storage used to supplement peak day requirements or daily swing requirements on the pipeline system. This form of storage requires high deliverability. Traditional storage can meet this albeit at relatively high cost since the amount of gas in inventory necessary to support high deliverability is considerable: typically 100 or greater to one. The substitutes for this form of storage can be interruption, propane air, LNG, and in some cases cheap pipeline expansion. Salt cavern storage is aimed at this market.

- **Intermediate winter service** -- this is thought of as 30 to 90 day services. This is probably the dominant storage market since propane air or fuel oil can be expensive over this period due to high variable costs. Such storage is vulnerable to pipeline capacity, especially where excess capacity may exist or substantial amounts of capacity can be controlled by a single entity. Traditional storage fields can meet these requirements. In addition, large, baseload LNG plants such as Cove Point and Distrigas can compete with underground storage in this market segment.

- **Full winter service** -- this is the full 151 day winter service for which traditional storage services were designed. The value of storage in this market is set by the gas pipeline alternative and in the east by the costs of LNG.

Our study is working through these markets in each of the GSAM region. The intent is to identify the value of storage in these markets as an indicator of how R&D can reduce the cost of storage and enhance the overall deliverability of the gas system.
Possible generic RD&D initiatives include increasing the short term deliverability from existing reservoirs by increasing flow rates, decreasing base gas costs by substituting lower cost gases or increasing allowable pressures without causing additional migration, reducing reservoir costs to improve the economics of low inventories by allowing greater deliverability per Mcf of gas stored. Research can help in a greater diversity of storage sites by reducing the costs of smaller facilities or identifying new potential storage media.