

Estimates of Maximum Underground Working Gas Storage Capacity in the United States

This report examines the aggregate maximum capacity for U.S. natural gas storage. Although the concept of maximum capacity seems quite straightforward, there are numerous issues that preclude the determination of a definitive maximum volume. The report presents three alternative estimates for maximum capacity, indicating appropriate caveats for each. It suggests that a conservative estimate of maximum capacity is in the neighborhood of 3,600 billion cubic feet, roughly equal to the sum of non-coincident peak volumes over all facilities during 2000-2004. A glossary with definitions of key terms is included. Questions or comments on the contents of this article should be directed to William Trapmann at william.trapmann@eia.doe.gov or (202) 586-6408.

Natural gas is commonly held in inventory in three types of underground facilities that are present across the lower-48 States. These are: (1) depleted reservoirs in oil and/or natural gas fields, (2) aquifers, and (3) salt cavern formations. Individual sites vary with respect to key physical and economic characteristics, such as porosity, permeability, retention capability, site preparation and maintenance costs, deliverability/injection rates, cycling capability, and proximity to market.¹

Working gas in storage as of September 8, 2006, was 3,084 billion cubic feet (Bcf), which exceeded recent historical levels at a comparable point in the gas injection season by a wide margin.² Consequently, the potential maximum volume of natural gas that may be held simultaneously by all storage operators has become an area of growing interest. At times during the refill months of 2006 high levels of natural gas already in storage have limited injection rates. Working gas capacity at some facilities, or fields, was heavily utilized and injection rates were less than historical averages for the corresponding time of year. The lack of ready storage capacity for incremental supplies occasionally resulted in restriction notices from pipeline companies to shippers.

This report identifies the types of companies involved in storage operations, discusses the concept of maximum capacity, and presents estimates of maximum working gas volumes.

Owners and Operators of Storage

The principal owners/operators of underground storage facilities are (1) interstate pipeline companies, (2) intrastate pipeline companies, (3) local distribution companies (LDC), and (4) independent storage service providers. About 123 entities currently operate nearly 400 active underground storage facilities in the lower-48 States. Owners/operators of storage facilities are not necessarily the owners of the natural gas held in storage. Indeed, most working gas held in storage facilities is held for shippers, LDCs, or end users who own the natural gas and hold rights to the storage capacity. On the other hand, the type of entity that owns/operates the facility determines to some extent how that facility's storage capacity is utilized.

For example, interstate pipeline companies rely heavily on underground storage to balance load and manage system supply on their long-haul transmission lines. Federal Energy Regulatory Commission (FERC) regulations allow interstate pipeline companies to reserve some portion of their storage capacity for this purpose. Nonetheless, the bulk of their storage capacity is leased to other industry participants. Intrastate pipeline companies use storage capacity for similar purposes, in addition to serving end-user customers.

¹ A more detailed discussion of underground storage terminology, and facilities and operations is available in the EIA report, *The Basics of Underground Storage*, http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/storagebasics/storagebasics.html.

² Terms such as working gas are defined in the Glossary.

LDCs generally have used underground storage to serve customer needs directly. LDCs both own and lease storage capacity. Some of the LDCs that own storage fields lease a portion of their storage capacity to third parties (often marketers), while still fully meeting their obligations to serve core customers. These LDCs tend to be the ones with large distribution systems and multiple storage facilities. LDCs generally store natural gas to shift supplies from the refill season (April-October) to the winter heating season (November-March).

Many salt formations and other high-deliverability sites are owned by independent storage service providers, which often are smaller companies started by entrepreneurs who recognized the potential profitability of these facilities. They are utilized almost exclusively to serve third-party customers, such as marketers and electricity generators, who can benefit most readily from the characteristics of these facilities.

Maximum Working Gas Capacity

Although the concept of maximum working gas storage capacity seems rather straightforward, certain aspects of capacity measurement and industry operations preclude the determination of a single, definitive estimate for maximum capacity. All facilities have a design capacity that is estimated on an engineering basis. Given the capacity estimates for individual facilities, one estimate of aggregate storage capacity is the sum of design capacity for all facilities. However, there are several reasons why the sum of working gas capacity across all facilities is a poor estimate for practical purposes. Although the fields generally contain peak storage volumes on October 31, some portion of capacity may not be fully utilized when the industry reaches its collective maximum. Under-utilization of working gas storage capacity can be partially explained by the following factors:

- Pipelines, both mainline and LDC, need spare storage capacity to operate efficiently, so some capacity is held in reserve.
- Some facilities are not operated at design capacity because of operational guidelines based on working experience.
- Levels of working gas in some fields depend on commercial arbitrage opportunities available at any point to the individual owners of the storage capacity rights. This is especially true for rapid cycle facilities (e.g., salt caverns), which generally are not operated on a seasonal schedule.
- Some facilities are operated on different seasonal cycles and peak volumes do not occur at the end of October.
- Some facilities may have relatively low injection rates that necessitate an extended injection period. Operators of such fields need to begin injections within a certain time period in order to be sufficiently on schedule so injection rates do not become a constraint that prevents the field from becoming full.
- Shippers holding capacity rights may elect to hold a portion of capacity in reserve for reasons particular to their firms. Alternatively, a firm may simply fall short of their storage targets and not achieve full utilization of their available capacity.
- Some storage facilities may be temporarily unavailable for maintenance or operating upgrades.
- Some storage facilities are shutting down, so the operators are removing the natural gas without intending to replace withdrawn volumes with injections.

- New storage fields may not be fully operational because prevailing high prices have led the operator to delay making the full investment in base gas.

The effect of these various factors on actual storage volumes is quite complex and very difficult to estimate. Further, regional market conditions may alter storage decisions for individual operators that can affect the performance of the industry as a whole.

Estimates of Maximum Working Gas Capacity

This section examines alternative approaches to estimate the volume of natural gas that can be held simultaneously in all U.S. storage facilities. All approaches focus on estimates of working gas capacity as the most relevant estimate because working gas, unlike base gas, is potentially readily available to the market.

Working Gas Design Capacity. Given that a storage facility holds only working gas and base gas, an estimate of aggregate working gas capacity based on the design capacity of the fields may be obtained by deducting the sum of base gas volumes from the sum of total design capacity for all fields. For example, the maximum working gas capacity for all fields as of the end of June 2006 implied by this method was 4,030 Bcf (Table 1).³ However, this engineering-based estimate of total storage capacity undoubtedly exceeds a reliable estimate of the aggregate capacity that industry would ever fill with working gas. The entire capacity is not expected to be utilized fully because of operational considerations and individual decision-making by the holders of capacity rights. This estimate would need to be adjusted to account for the factors that keep realized volumes in storage below the maximum engineering-based total.

Effective Working Gas Capacity. Another approach used to estimate maximum working gas capacity is to reduce the working gas design capacity using a recognized industry ‘rule-of-thumb.’ According to a recent study by Cambridge Energy Research Associates, the industry would operate with at least a 5-percent cushion of unutilized storage capacity as of October 31.⁴ This guideline, which is drawn from industry practice prior to unbundling, was deemed a prudent margin to handle potential load fluctuations and avoid curtailments of natural gas production. Large-volume interstate pipelines now operate as open-access transporters, but arguably the same rule may be expected to apply for the operations of LDCs and other shippers. Assuming a 5-percent cushion for all operators, maximum effective working gas capacity for all fields as of the end of June 2006 would be estimated at 3,829 Bcf. This estimate exceeds the largest recorded volume of 3,472 Bcf reported for the end of November 1990 by 357 Bcf, or more than 10 percent. The lack of historical precedent for approaching a storage level near 3,829 Bcf, and the need to consider the potential role of other limiting factors, suggest that even this adjusted estimate is likely to be too high

Non-Coincident Peak Working Gas Volume. A third option to estimate working gas capacity is to sum the peak volumes for each storage field reported at any time during a recent historical period. The non-coincident peak volume for all currently active fields during 2000-2004 is 3,609 Bcf.⁵ The non-

³ Total storage capacity and base gas volumes are reported in Table 14 of the *Natural Gas Monthly* (August 2006), http://www.eia.doe.gov/pub/oil_gas/natural_gas/data_publications/natural_gas_monthly/current/pdf/table_14.pdf. Data are presented by State, EIA storage region, and total lower-48 States.

⁴ Cambridge Energy Research Associates, “Gas Storage: How High Can Inventories Go?” *CERA Insight* (May 2, 2006).

⁵ These data are from the EIA-191 survey, “Monthly Underground Storage Report,” which collects data on storage volumes as of the end of the report month. Actual peaks would be higher if they occurred during the report month. The weekly storage data from the EIA-912, “Weekly Underground Natural Gas Storage Report,” is on a company level for each

coincident peak volume overstates the amount of actual storage achieved at a given point during the 5-year period because it does not account for differences in timing of occurrence. However, it is a data-driven estimate that reflects actual operator experience. Although the field-level volumes were the largest ones reported during the 5-year period, each storage field may not have achieved its practical maximum, which suggests that this calculation might yield a somewhat conservative result.

These estimates of capacity presume that all facilities are being utilized normally with regular injections and withdrawals. However, a small number of marginal storage fields either are dormant with no withdrawal or injection activity, or appear to be shutting down operations evidenced by a continuing sequence of withdrawals for at least 12 consecutive months.⁶ As of the end of 2004, it is estimated that working gas capacity in these marginal fields totaled 16 Bcf. The previously cited estimates for working gas capacity all need to be reduced by 16 Bcf to account for the marginal fields (Table 1). Even with this adjustment, maximum working gas capacity according to the non-coincident peak estimate is almost 3,600 Bcf.

Table 1. Alternative Estimates of Maximum Working Gas Capacity.

Working Gas Capacity Estimate	Estimate for all fields	Estimate excluding marginal fields
Working Gas Design Capacity	4,030	4,014
Effective Capacity	3,829	3,813
Non-coincident Peak Volumes	3,609	3,593

Sources: Energy Information Administration (EIA), Natural Gas Division. Working gas design capacity: derived from data in the *Natural Gas Monthly* (DOE/EIA-0130), August 2006, Table 14. Effective capacity: derived from the working gas design capacity. Non-coincident peak: derived from the EIA-191M, “Monthly Underground Gas Storage Report.”

Conclusions

One specific level that may be considered to constitute a ‘hard’ threshold for maximum storage capacity is the sum of engineering design capacity for all facilities.⁷ However, this estimate is not relevant for practical analysis because the industry is extremely unlikely to approach this level. The correct adjustment to account for limiting factors that would reduce this figure is confounded by regional variation in market and industry conditions. The use of a rule-of-thumb to adjust total design capacity is difficult because of a lack of consensus on an accepted capacity factor for storage given the diversity of facilities and operating practices throughout the industry. The non-coincident peak volume of roughly 3,600 Bcf, which is based on data for 2000-2004, provides a more conservative estimate for maximum working gas capacity, since some facilities during the 5-year period may not have been at their practical maxima. Thus, estimates of maximum storage capacity should be considered with the limitations of the estimation approach in mind.

of three regions and it has not been active for 5 years, so a comparable estimate cannot be derived from those data.

⁶ These fields are retained in the data base for some time because unless a field is plugged and abandoned, it could be restored to normal service by either the current owner or by a new owner after a sale of the field.

⁷ Even this isn’t absolutely true in practice, because some fields have reported working gas and base volumes that exceed the available design capacity.

Glossary

Several terms are used to quantify or distinguish between *capacity* of a storage facility and the natural gas *volume* within the storage facility. These terms are as follows:

Base gas is the volume of natural gas intended as permanent inventory in a storage reservoir to maintain adequate pressure and deliverability rates throughout the withdrawal season.

Deliverability is most often expressed as an estimate of the amount of natural gas that can be delivered (withdrawn) from a storage facility on a daily basis. Also referred to as the deliverability rate or withdrawal rate, deliverability is often expressed in terms of millions of cubic feet per day (MMcf/day). The deliverability of a given storage facility is variable and depends on factors such as the amount of natural gas in the reservoir at any particular time, the pressure within the reservoir, compression capability available to the reservoir, the configuration and capabilities of surface facilities associated with the reservoir, and other factors. In general, a facility's deliverability rate varies directly with the total amount of natural gas in the reservoir; it is at its highest when the reservoir is at or near full and declines as working gas is withdrawn.

Design capacity is the estimated maximum volume of gas that can be stored in an underground storage facility indefinitely without incurring permanent damage to the reservoir.

Injection is the volume of gas injected into storage fields during a given period.

Total natural gas in storage is the sum of base gas and working gas.

Withdrawal is the volume of gas withdrawn during a given period.

Working gas capacity is the present developed maximum capacity of natural gas in the reservoir that is in addition to the base gas.

Working gas is the volume of natural gas in the reservoir that is in addition to the base gas.

None of these estimates for any given storage facility are fixed or absolute. The rates of injection and withdrawal change as the level of natural gas varies within the facility. Additionally, in practice a storage facility may be able to exceed certificated total capacity in some circumstances by exceeding certain operational parameters. The facility's total capacity also can vary, temporarily or permanently, as its defining parameters vary. Further, the estimates of base gas, working gas, and working gas capacity also can change from time to time. This occurs, for example, when a storage operator reclassifies one category of natural gas to the other (i.e., between base gas and working gas), often as a result of new wells, equipment, or operating practices. However, such a change generally requires approval by the appropriate regulatory authority).