GTI ENERGY

GTI ENERGY
NZIP
Net Zero Infrastructure Program

JANUARY 2025

REPORT

Underground Gas Storage in Natural Gas Infrastructure: Gulf Coast Insights

Map Image Credit: U.S. Energy Information Administration

Table of Contents

Executive Summary 3

Background 4

UGS Policy, Regulation, and Standards 10

UGS in the Gulf Coast 15

Enhancing Reliability and Resiliency 17

State Level UGS Regulations, Standards, and Codes 21

UGS in the Decarbonization Landscape: Opportunities and Challenges 23

Conclusions 25

Table of Tables

Table 1: Operating characteristics for each type of UGS facility (Source: FERC) 8
Table 2**:** Primary codes, orders, and acts which form the regulatory framework for underground ga storage facilities at the federal level. 10
Table 3: Requirements for underground natural gas storage facilities (UNGSFs) described in the clauses of 49 CFR 192.12. 12
Table 4: Description of the recommendations, guidance, and requirements within API RP 1170 for UNGS. An asterisk designates recommendations not currently required by PHMSA. 12
Table 5: Description of the recommendations, guidance, and requirements within API RP 1171 for UNGS. An asterisk designates recommendations not currently required by PHMSA. 13
Table 6: Classification of wells under the EPA's Underground Injection Control Program. 14
Table 7. Distribution of underground storage types in the Gulf Coast 16
Table 8: Primary UGS Codes & Permitting Requirements for Gulf Coast states. 22
Table 9. Number of reporters and 2023 emissions (CO2e) per Petroleum and Natural Gas Systems industry subsector 24

Table of Figures

Figure 1. Natural Gas Inventories through Injection Season 6
Figure 2. Three Primary Underground Storage Types for Natural Gas (Source: Energy Infrastructure) 8
Figure 3. U.S. Underground Natural Gas Storage Facilities, by Type in December 2022 (Source: EIA) 9
Figure 4. Design Working Natural Gas Capacity by State in November 2023 (Source: EIA) 15
Figure 5. Average UGS facility max deliverability by state and reservoir type 16

Figure 6: County-level median values for average 2080 to 2099 RCP8.5 impacts. Southern States are predicted to experience more negative climate impacts, including an increase in energy demand to adapt to climate changes. (Source: Hsiang et al) 17
Figure 7: Damages by state from billion-dollar disasters (e.g., winter storms, droughts, floods, or wildfires) (Source: Fifth National Climate Assessment) 18
Figure 8: Weekly storage withdrawals from the EIA Central Region (TX, LA, OK, KS, MS, AR, and AL) (Source: Enverus) 19
Figure 9. 12 UGS facilities whose disruption could affect 2 GW or more of generation capacity (Source: Department of Energy) 20

GTI Energy launched the Net Zero Infrastructure Program (NZIP) in June of 2023. NZIP is a collaborative research effort among 25 companies, supported by a diverse array of environmental NGOs, investors, and academics focused on evaluating the role of natural gas infrastructure in reaching the nationwide net-zero goals affordably and sustainably. Because of the challenges and length of time to build new energy infrastructure, ***energy systems of the future must capitalize on the infrastructure of today to meet decarbonization targets.***

Executive Summary

For decades, Underground Gas Storage (UGS) has played a vital role in assuring that the demands of natural gas customers are met. Natural gas, a primary heating source for about half of U.S. homes, sees peak demand in winter and lower use in mild months. Storage is integral in helping to balance supply within both seasonal and intra-day demand shifts, while natural gas production remains steady year-round. Historically, natural gas has been stored seasonally by injecting it underground from April to October, then withdrawing it when demand is higher during the winter. Since 2015, natural gas has overtaken coal as the dominant source of electricity generation in the U.S., making up 43.1% of the 4.18 trillion kWh generated in 2023.[1] Storage, therefore, is crucial for providing protection against extreme weather events and unanticipated incidents that delay the production or delivery of natural gas.

Over 400 UGS facilities are currently in operation across the U.S., offering around 4.8 Tcf (trillion cubic feet) of working gas capacity and over 70 Bcf (billion cubic feet) per day of deliverability. These facilities include depleted oil and gas reservoirs, aquifers, and salt caverns, each with distinct physical and economic characteristics that determine their suitability for specific applications. Depleted reservoirs are the most common due to their availability and existing infrastructure, while aquifers, though requiring more base gas and offering less flexibility, are dominant in the Midwest. Salt caverns, primarily found in the Gulf Coast, offer high injection and withdrawal rates but are costlier to construct and have limited geographical availability. Each storage type plays a crucial role in ensuring reliable gas supply by balancing capacity, deliverability, and cycling rates (the number of times a facility can be filled and emptied in a year). Around 120 entities are managing more than 400 sites across the Lower 48 states, including interstate and intrastate pipeline companies, local distribution companies (LDCs), and independent providers.

The government has heavily regulated UGS operations to ensure the safety and integrity of storage facilities. Oversight by federal agencies like the Federal Energy Regulatory Commission (FERC) and the Pipeline and Hazardous Materials Safety Administration (PHMSA), as well as various state commissions mandate strict standards for the construction, operation, and maintenance of storage facilities. These regulations and

---

[1] U.S. Energy Information Administration, "What is U.S. electricity generation by energy source?". Source

standards ensure that storage facilities not only meet operational demands but also prioritize environmental and public safety.

This whitepaper explores the role of UGS in the Gulf Coast region, highlighting its essential contribution to reliable and responsive energy delivery. It covers key federal and state policy measures governing UGS facilities and provides data underscoring storage's critical role in supporting energy resiliency and grid stability by securing supply and stabilizing prices during peak demand. Additionally, the report examines the potential of active and inactive UGS facilities for repurposing to support decarbonization goals.

Background

Energy storage systems play a key role in managing peak demand in both natural gas and electric delivery systems, with additional services like frequency regulation provided by battery storage. The U.S. primarily relies on three types of storage: underground natural gas storage, pumped hydro, and battery energy storage, with UGS far surpassing electric storage in delivery capacity (over 20 times larger) and peak monthly energy delivery (over 100 times larger). While UGS and pumped hydro can provide essential seasonal storage, batteries lack this capability and are better suited for short-term services. UGS also leads in efficiency, with a 97-99% cycle efficiency compared to 82% for batteries and 79% for pumped hydro. As renewable energy and electrification initiatives rise, UGS remains vital for addressing large-scale, seasonal energy demands, especially in colder regions where battery storage alone cannot meet high heating loads.

While UGS today plays a critical role in addressing seasonal energy demands and ensuring efficient storage, its significance is rooted in a long history of development alongside the natural gas transmission network. The evolution of UGS from its early days to its current extensive capacity highlights its indispensable role in stabilizing supply and meeting market needs for flexibility, reliability, and efficiency.

The history of UGS is closely tied to the development of long-distance transmission lines, which began in 1891 with two parallel 120-mile, 8-inch lines from Indiana to Chicago. The first successful gas storage project was established in 1915 in Welland County, Ontario, followed by the Zoar field near Buffalo, New York, in 1916. However, rapid expansion of UGS did not take place until the 1950s when natural gas market expansion was seen to be impossible without adequate storage. Since then, UGS has evolved to meet the growing demand for flexible, reliable energy delivery. The evolution of UGS in the U.S. has been shaped by market needs for supply stability, storage accessibility, and operational flexibility. Currently, UGS storage sites are classified into two types based on their purpose: market area storage and production area storage. Market area storage focuses on meeting peak demands and stabilizing prices for long-haul transmission, predominantly found in the North Central and Middle Atlantic regions. In contrast, production area storage, located in the West South-Central region, enhances supply chain efficiency by leveling wellhead production.

Before 1992, interstate pipeline companies, regulated by FERC, had exclusive control over their natural gas storage and capacity. FERC Order 636 mandated open access, requiring these companies to lease a significant portion of storage capacity to third parties, allowing marketers and other users to store and trade gas as market conditions shift. This shift broadened storage's role beyond backup supply, enabling more strategic uses tied to market fluctuations and financial instruments. High-deliverability sites, like salt caverns, have since grown to meet flexible demand, while conventional storage remains essential to the industry.

Modern gas storage facilities have evolved significantly from traditional setups in several key ways. Storage developers now represent a more diverse group, with many operating on a stand-alone basis where economic feasibility, rather than bundled service requirements, determines success. Additionally, many storage projects are structured as joint ventures, combining resources and expertise. Some of these projects have secured FERC approval to offer services at market-based rates, allowing for competitive pricing. Storage providers are also promoting more flexible, often "custom-tailored" services designed to meet the specific needs of their customers, reflecting a shift toward adaptability and client-focused solutions in the industry.

Figure 1 below showcases the seasonal nature of UGS. Working gas, the volume of natural gas that is available to be withdrawn from a given facility, normally peaks at the start of winter (October-November) before being depleted to its lowest capacity at the start of refill season (April). Two other aspects of underground storage that are important to consider are base or cushion gas as well as deliverability. Base or cushion gas is the volume of natural gas used as a permanent inventory which is needed to maintain adequate reservoir pressures while deliverability is the maximum amount of gas that can be withdrawn from storage in one day.

It is important to note that while storage capacities are typically measured by the volume reported by FERC and Energy Information Administration (EIA)[2], the exact total working gas capacity is uncertain, as it has not been fully tested in operation. Working gas capacity is often used to compare storage regions and facilities, reflecting the available supply. From 1968 to 2003, the total volume of base gas increased significantly with the addition of new fields, reaching 4,300 Bcf by 2003 and constituting nearly 60% of total gas volume. Although capacity rose, working gas, corresponding to the actual demand, did not grow at the same rate. More recent EIA data show a steady increase in working gas from 2008 to 2015, with base gas averaging around 50% of total storage capacity.

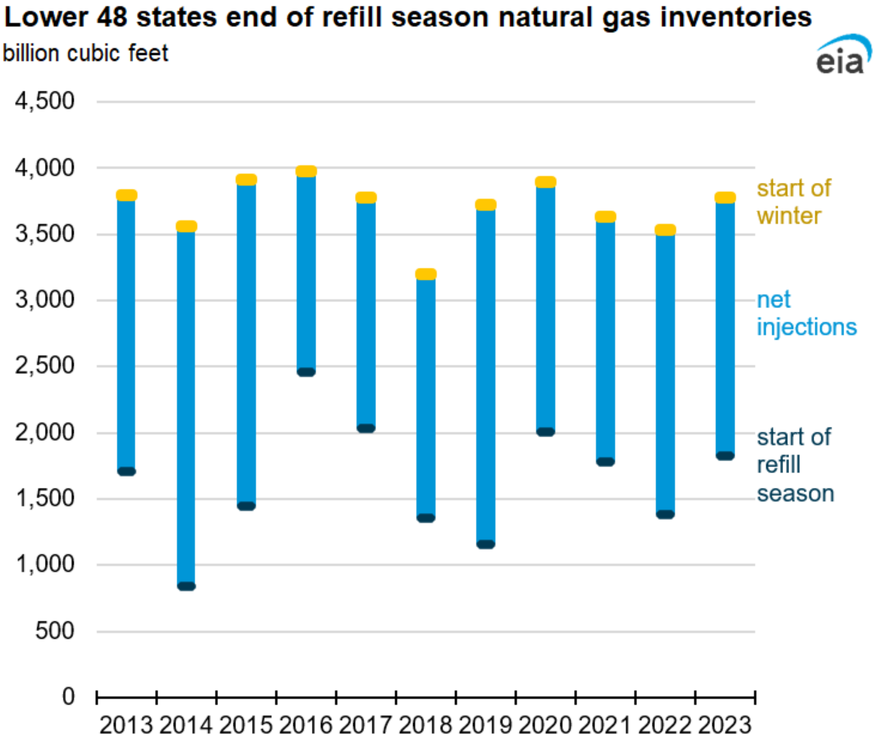


Figure 1. Natural Gas Inventories through Injection Season

As shown in Figure 2, there are three main types of underground formations where natural gas can be stored, including depleted reservoirs, salt formations, and aquifers. Depleted reservoirs comprise approximately 78% of the 412 active UGS facilities and are

---

[2] FERC tracks certified facilities and EIA covers both certified and non-certified facilities

widely available in nearly all regions of the US. One reason depleted reservoirs are popular is that operators can take advantage of the many pre-existing wells, gathering systems, compressor stations, and pipeline connections that have already been installed at the depleted field. Another reason is that their geological characteristics are already well known, often making them the easiest and least cost-intensive reservoir types to develop, operate, and maintain.

Salt caverns, created in salt domes and bedded salt formations, comprise approximately 7% of existing facilities and are primarily located in the Gulf Coast region of the US. Salt caverns are formed through leaching, a process where water is injected into the salt formation to dissolve the salt, it is then pumped out, leaving a hollowed-out cavern suitable for gas storage or other uses. These types of facilities are often characterized by high deliverability and injection capabilities, allowing for the working gas to be recycled 10-12 times a year. With salt caverns, natural gas leakages are rare, and the facilities tend to be especially resilient to degradation over their lifespans. Because of their ability to be filled and emptied frequently (as shown in Table 1), salt caverns are ideal for short peak-day deliverability purposes.

Aquifers, which comprise around 15% of storage facilities, are mostly found in the Midwest, and tend to only be used in areas with no nearby depleted reservoirs. Aquifers can be difficult to develop in large part due to the cost and time required to evaluate their storage suitability. Additionally, environmental assessments for aquifers can take much longer as operators must ensure that the formation is not connected to any other existing aquifer of drinking water.

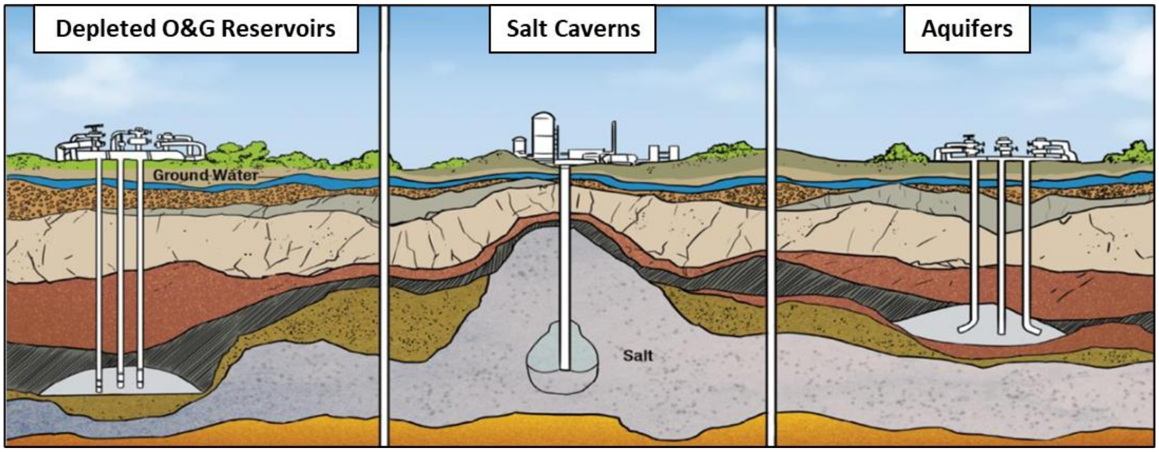


Figure 2. Three Primary Underground Storage Types for Natural Gas (Source: Energy Infrastructure[3])

Table 1: Operating characteristics for each type of UGS facility (Source: FERC[4])

Storage 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 and Gas Reservoir	Cushion 50%	200 to 250	100 to 150
Salt Cavern	Cushion 20% to 30%	20 to 40	10 to 20

Overall, the suitability of a reservoir for storage is influenced by geographic and geological factors. Key geological characteristics of a desirable storage facilities include high withdrawal and injection capability with quick turnaround times, a high proportion of working gas relative to total gas for minimizing cushion gas requirements, strong pressure integrity to avoid gas leakage, the option to use native gas as cushion gas, and location in shallower reservoirs to reduce drilling costs. Geographical location is also an essential consideration in UGS, affecting facility use, ownership, and economic viability. Storage can be categorized as either market or production area storage. Production area storage, commonly located close to gas production sites, helps improve delivery efficiency by leveling production rates and pipeline throughput, and recently, it has gained value as a marketing asset, often linked with market center hubs as it enhances market efficiency by balancing supply before gas enters the pipelines. Market area storage, on the other hand, is usually positioned near demand centers such as cities and industrial hubs. It enhances market efficiency by meeting peak and seasonal demands,

---

[3] Energy Infrastructure, 2021. Underground Natural Gas Storage. Source

[4] Current State of and Issues Concerning Underground Natural Gas Storage, 2004. Source

increasing long-haul transmission capacity use, and offering reliability and flexibility for consumers during demand surges. Figure 3 displays the geographical distribution of UGS facility in the U.S. It divides the Lower 48 states into the 5 regions outlined by the EIA in the administration's natural gas market dynamics and storage reports.[5]

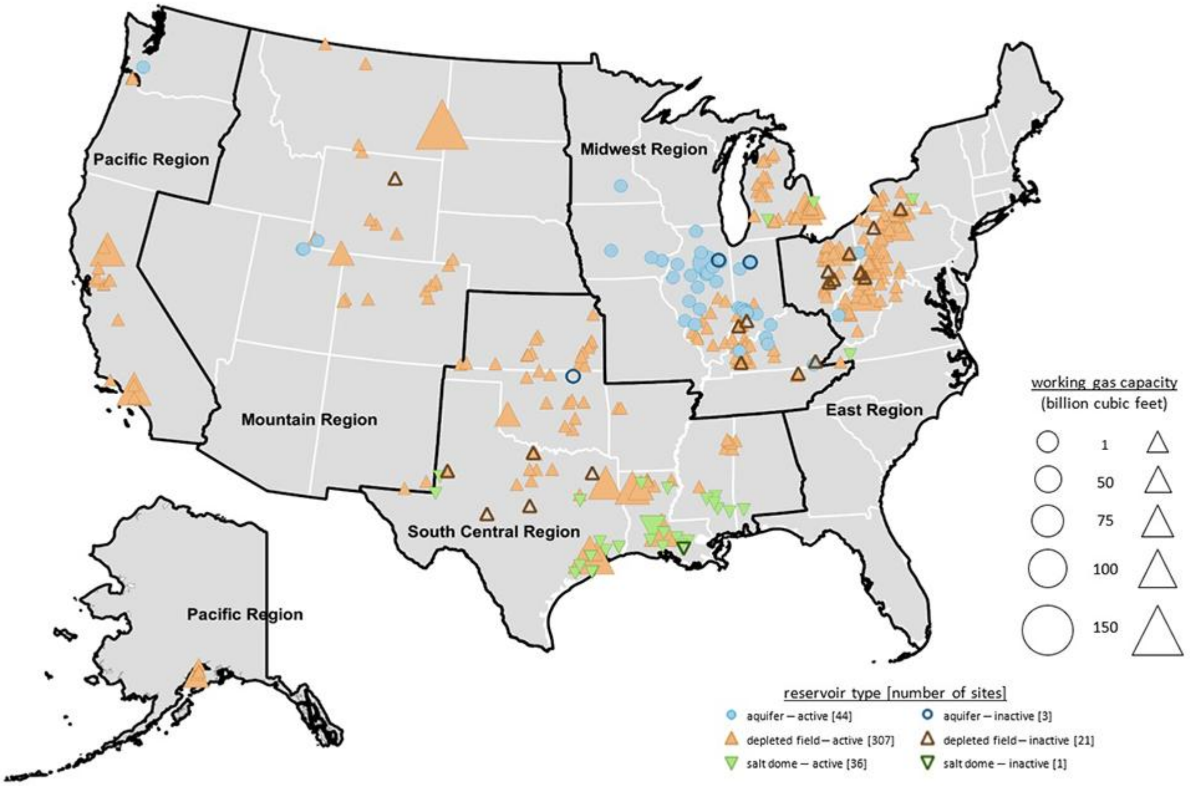


Figure 3. U.S. Underground Natural Gas Storage Facilities, by Type in December 2022 (Source: EIA[6])

As we look to the future, the demand for additional storage capacity remains pressing but uncertain. Estimating the need for additional underground gas storage requires a comprehensive analysis of projected national and regional natural gas supply and demand. Estimations must consider potential expansions in transmission and distribution networks to meet seasonal and peak demands. Market participants value storage based on varied methods such as cost of service, seasonal arbitrage, and

---

[5] U.S. Energy Information Administration, "Weekly Natural Gas Storage Report". Source

[6] U.S. Energy Information Administration, "U.S. Underground Natural Gas Storage Facilities, by Type". Source

option-based strategies, which can lead to differing conclusions about the necessity and value of storage. Natural gas prices and their volatility also impact conclusions and decisions about storage needs while regulatory requirements could also present financial hurdles.

UGS Policy, Regulation, and Standards

UGS facilities are regulated by the same authorities as natural gas pipeline infrastructure, and must comply with regulations, codes, and standards set by FERC, PHMSA, and the Environmental Protection Agency (EPA).

FERC oversees underground natural gas storage facilities owned by interstate pipeline companies or independent operators engaged in interstate commerce, focusing solely on project access and tariff design, not facility design, operation, or maintenance. For safety regulation of underground storage facilities, however, the jurisdiction is not clear. Generally, the responsibility for facility design, safety, operation, and maintenance lies with PHMSA under the PIPES Act of 2016. Table 2 provides an overview of federal regulations, codes, and standards governing UGS development, operation, and maintenance, and a brief discussion on each can be found below.

*Table 2**:** Primary codes, orders, and acts which form the regulatory framework for underground ga storage facilities at the federal level.*

Code/Order/Act	Agency	Description
Order 636 (1992)	**FERC**	Mandated unbundling of pipeline services and required interstate pipeline companies to operate their storage facilities on an open-access basis. Before this order, pipeline companies bundled these services, giving them an advantage in selling gas to customers since they controlled both the transportation and the supply. Order 636 mandated that pipeline companies allow open access to their transportation and storage services on a nondiscriminatory basis, enabling customers to choose suppliers and transportation options independently. Order 636 also established a capacity release market, where customers with unused pipeline or storage capacity could release it to other parties, maximizing the efficient use of existing infrastructure.
Order NO. 678 (2006)	**FERC**	Established criteria for obtaining market-based rates for storage services, allowing storage providers to charge market-based rates if they can demonstrate that they lack significant market power. Prior to this, storage facilities typically charged cost-

		based rates unless they could meet strict requirements proving a competitive market. Order 678 aimed to simplify this process, acknowledging that increased storage capacity could improve supply stability and reduce price volatility in the natural gas market. This order enables storage operators to set prices based on market conditions as long as FERC's standards for market power are met, thus fostering a more flexible and efficient pricing structure that better aligns with market needs and incentives for developing additional UGS capacity.
PIPES Act of 2016	**PHMSA**	The Act defined UGS as facilities that store natural gas in various underground formations, such as depleted hydrocarbon reservoirs, aquifers, or salt caverns. It mandated that PHMSA establish minimum safety standards for UGS within two years, addressing regulatory gaps in the oversight of well integrity and downhole piping, particularly for interstate facilities and intrastate sites lacking consistent safety standards. These measures were intended to create a unified regulatory framework for UGS safety across the U.S.
49 CFR 192.12 (2020)	**PHMSA**	Sets requirements for construction, maintenance, risk management, and integrity management for two categories of underground natural gas storage facilities and incorporates concepts from the recent American Petroleum Institute (API) industry Recommended Practices (RP) 1170 for salt caverns storing natural gas and 1171 for storage in depleted hydrocarbon reservoirs and aquifer reservoirs. API RP 1170 and 1171 were originally published in 2015, with the most recent update published in 2022. Further details on 49 CFR 192.12 and API 1170/1171 are provided in Tables 3-5.
Safe Drinking Water Act (1974)	**EPA**	Required EPA to develop minimum federal requirements for Underground Injection Control programs and other safeguards to protect public health by preventing injection wells from contaminating underground sources of drinking water. EPA regulations (40 CFR Part 144-148) classify wells into six categories based on their purpose, including Class II wells, which are used for injecting fluids related to oil and natural gas production, including hydrocarbon storage wells for natural gas. More information can be found in table 6.

Table 3: Requirements for underground natural gas storage facilities (UNGSFs) described in the clauses of 49 CFR 192.12.

Clauses	Requirements
(a) Salt cavern UNGSFs	Facilities must meet: - All provisions of RP 1170 - Provisions of sec. 8 of RP 1171 - Clauses (c) and (d) of this section
(b) Depleted hydrocarbon and aquifer reservoir UNGSFs	Facilities must meet: - All provisions of RP 1171 - Clauses (c) and (d) of this section
(c) Procedural manuals	UNGSF operators must: - Prepare and follow written manuals of procedures for conducting operations, maintenance, and emergency preparedness and response activities - Keep records necessary to administer procedures and update manuals annually - Have manuals accessible at locations where work is being performed
(d) Integrity management program	Each UNGSF must: - Implement and continuously improve an integrity management program developed under section 8 of RP 1171 - Complete a baseline risk assessment of all reservoirs and caverns - Determine an appropriate interval for risk re-assessments under RP 1171 (not exceeding 7 years) - Establish and follow procedures for carrying out program and maintain records demonstrating compliance

Table 4: Description of the recommendations, guidance, and requirements within API RP 1170 for UNGS. An asterisk designates recommendations not currently required by PHMSA.

RP	Section	Description
1170 **Design and Operation of Solution-mined**	5*	**Recommendations for:** - Evaluating a potential salt cavern site for natural gas storage - Siting considerations (confining formations, caprock, cavern geomechanical properties and structural integrity)
	6*	**Process for:** - Designing the well - Selecting equipment for operation (wellhead, casing)
	7*	**Guidance for:** - Drilling into the wells - Selection of drilling equipment

RP	Section	Description
	8*	**Recommendations on elements to include in a risk assessment, including:** - Data sources - Common threats and hazards
	9	**Discusses:** - Cavern geometry design - Considerations for solution mining Requirements for geochemical analysis
	10	**Requirements on:** - Gas storage cavern and facility operation Regular corrosion and gas leakage monitoring
	11	- **Requires operator to maintain a cavern integrity monitoring program**

Table 5: Description of the recommendations, guidance, and requirements within API RP 1171 for UNGS. An asterisk designates recommendations not currently required by PHMSA.

RP	Section	Description
1171	5*	**Explains considerations for:** - Designing the gas storage reservoir - Includes geomechanical & engineering characterizations
Functional Integrity of Natural Gas Storage in Depleted Hydrocarbon Reservoirs and Aquifer Reservoirs	6*	**Discusses:** - Design and construction of storage well, including - Stipulations regarding suitable equipment, casing and tubing properties - Cementing, remediation, closure, and testing - Monitoring
	7	**Requirements for:** - Testing, confirming, and monitoring well structural integrity - Well properties that should be monitored
	8	**Details risk management practices** that apply to both solution-mined salt caverns and depleted natural gas reservoirs
	9	**Instructions for demonstration, verification, and monitoring** of the well and reservoir
	10	**Requirements** for site security and safety
	11	**Recommended** procedures and training protocol for operators

Table 6: Classification of wells under the EPA's Underground Injection Control Program.[7]

Well Class	Description
I	Used to inject hazardous and non-hazardous wastes into deep, isolated rock formations
II	Used exclusively to inject fluids associated with oil and natural gas production
III	Used to inject fluids to dissolve and extract minerals
IV	Used to inject hazardous or radioactive wastes into or above a geologic formation that contains a USDW
V	Used to inject non-hazardous fluids underground
VI	Used for injection of carbon dioxide into underground subsurface rock formations for long-term storage or geological sequestration

While FERC has jurisdiction over many interstate storage facilities, federal regulators have historically deferred to states due to regional geological differences. The RSPA's 1997 Advisory Bulletin encouraged state-specific safety regulations. Although the EPA regulates underground fluid injection under the Safe Drinking Water Act (SDWA), natural gas storage facilities are exempt, based on the belief that these facilities don't threaten drinking water and that economic incentives align with preventing gas leaks. States may apply for authority (primacy) to manage Class II wells under Sections 1422 or 1425 of the SDWA. Under Section 1422, states must adhere to EPA's minimum Underground Injection Control (UIC) requirements, covering construction, operation, monitoring, testing, and closure standards. Alternatively, Section 1425 allows states to demonstrate that their existing standards effectively protect underground sources of drinking water, provided they meet requirements for permitting, inspections, monitoring, record-keeping, and reporting.

Therefore, states are primarily responsible for protecting the environment, particularly drinking-water aquifers, from potential risks associated with underground natural gas storage. They may enforce stricter standards for intrastate facilities if they align with federal minimums. Permit issuance requires facility operators to demonstrate compliance with federal, state, and local regulations. Applicants must confirm that the chosen reservoir is safe, prevents resource waste, controls gas leaks, and protects water sources and public safety.

---

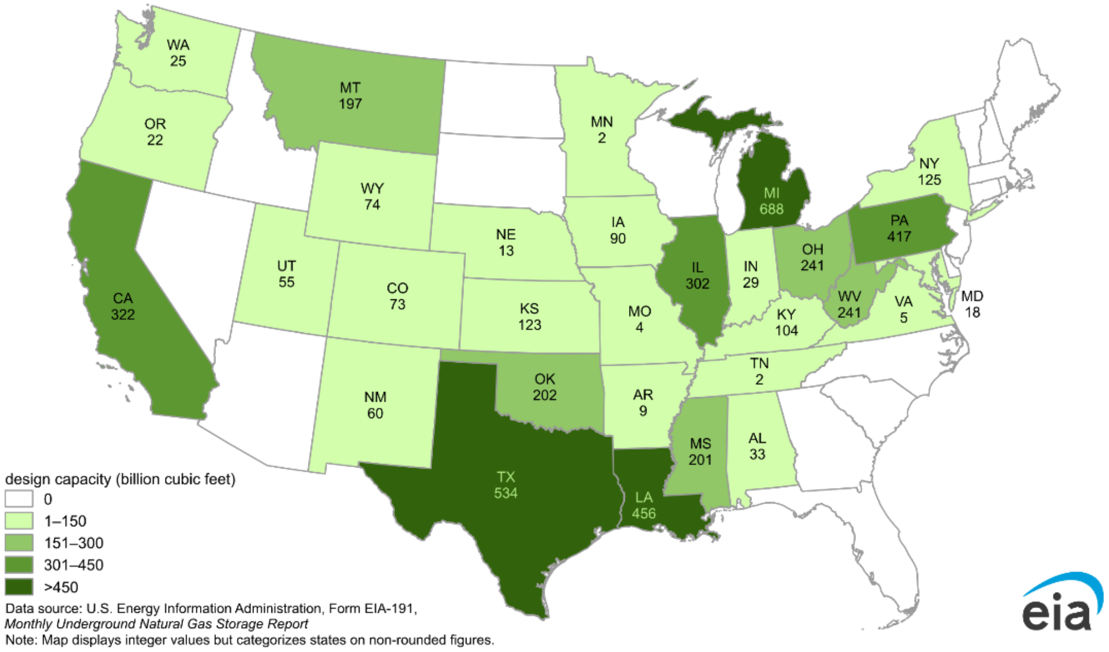
[7] EPA, Underground Injection Control Well Classes. Source.

State regulations vary significantly. For example, Pennsylvania's Department of Environmental Protection conducts regular inspections and well monitoring to prevent leaks, while California's oversight is more stringent. In 2018, spurred by the Aliso Canyon leak, California's Department of Conservation (DOC) implemented new permanent regulations pertaining specifically to underground gas storage that are even more prescriptive than API RP 1171.

UGS in the Gulf Coast

Overview

UGS is a key part of the energy mix in many of the Lower 48 states, and it is especially prevalent in the Gulf Coast region. As shown in Figure 4 below, of the three highest designed working gas capacities of any state, two (Texas and Louisiana) are in the Gulf Coast. Mississippi is not far behind them with over 200 Bcf, and additional capacities are provided by Alabama, Arkansas, and New Mexico as well.



Data source: U.S. Energy Information Administration, Form EIA-191, *Monthly Underground Natural Gas Storage Report*
Note: Map displays integer values but categorizes states on non-rounded figures.

Figure 4. Design Working Natural Gas Capacity by State in November 2023 (Source: EIA[8])

Interestingly, the 71 UGS facilities in the Gulf Coast are made up of only depleted fields and salt caverns. Table 7 shows this distribution broken down by state, and Figure 5 shows how this enables the Gulf Coast to be particularly adept at delivering its stored

---

[8] U.S. Energy Information Administration, "Underground Natural Gas Working Storage Capacity". Source

natural gas in a short period of time. Many other regions have large working gas volumes, but no other region has the quantity of salt caverns that the Gulf Coast possesses. With salt cavern storage, Louisiana, Mississippi, and Texas have a uniquely high potential for deliverability in winter seasons, emergency situations, or any other possible disruption of natural gas production/transportation. Salt domes/caverns are excellent in times of unexpected demand surges due to their ability to cycle gas multiple times per season. As evidenced by Figure 5 average deliverability of salt domes is often more than triple that of depleted reservoirs.

Table 7. Distribution of underground storage types in the Gulf Coast

States	Depleted Field	Salt Cavern	Total
Alabama	1	1	2
Arkansas	2	0	2
Louisiana	8	11	19
Mississippi	6	5	11
New Mexico	2	0	2
Texas	19	16	35
TOTAL	**38**	**33**	**71**

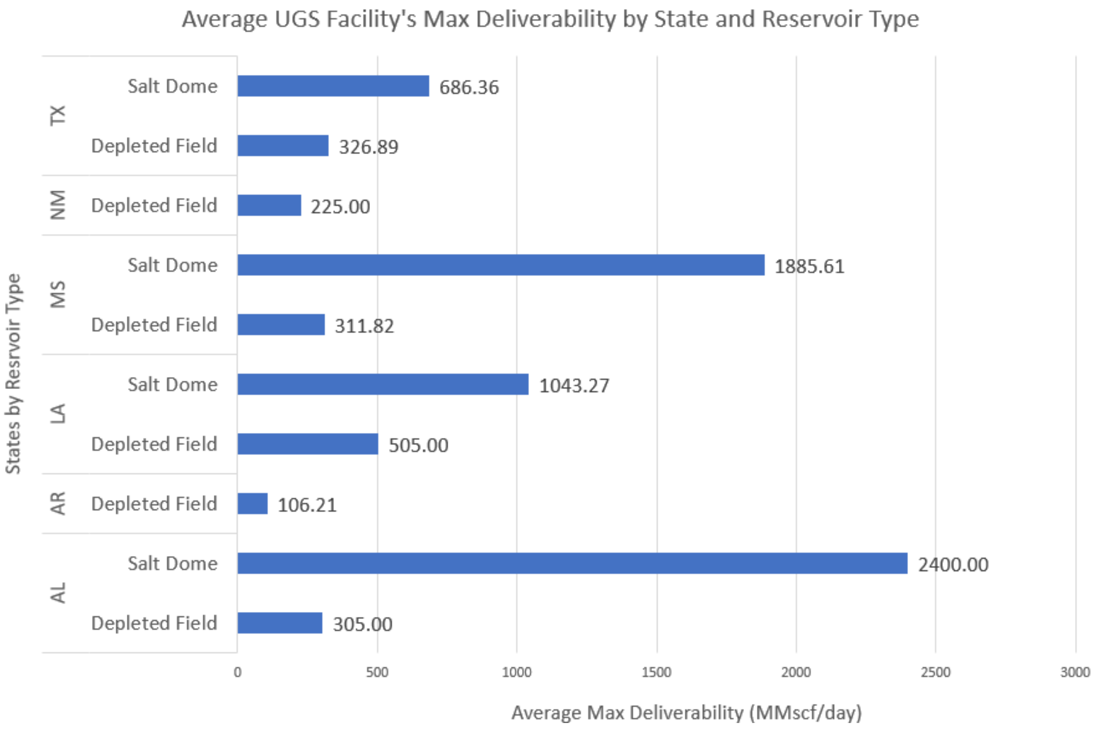


Figure 5. Average UGS facility max deliverability by state and reservoir type

Natural gas storage costs depend on factors such as geology, infrastructure requirements, compression horsepower, pipeline proximity, and permitting levels. Leveraging existing infrastructure to expand older depleted reservoirs can reduce costs and environmental impact. Of the three storage types, salt caverns are the most expensive to develop due to their higher cycle capacity, which offsets costs per cubic foot through frequent injection and withdrawal. A 2016 ICF study prepared for the DOE found that new facilities cost an average of $32 million per Bcf of working gas, while expansions average $27 million per Bcf[9]. Regional cost variations exist, with the Gulf Coast as the low-cost benchmark, and higher costs reported in regions like the Northeast and Pacific Northwest.

Enhancing Reliability and Resiliency

UGS enhances the energy system's reliability and resiliency by supporting quick responses to supply-chain disruptions or sudden supply and demand shifts. The Gulf Coast's substantial UGS capacity is essential for swiftly adapting to such events, ensuring a reliable natural gas supply even during extreme weather. This role of UGS becomes increasingly critical as climate change impacts and risks intensify across interconnected sectors and regions. In addition to expected seasonal variability, the Gulf Coast region in particular is projected to have higher energy needs over time to adapt to climate change, as shown in Figure 6.

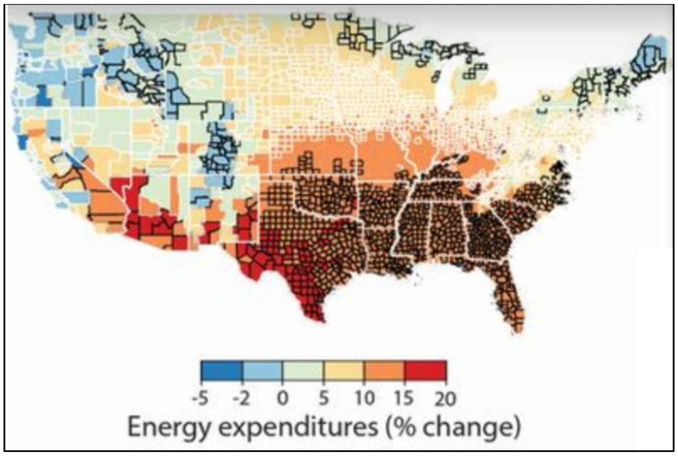


Figure 6: County-level median values for average 2080 to 2099 RCP8.5 impacts. Southern States are predicted to experience more negative climate impacts, including an increase in energy demand to adapt to climate changes. (Source: Hsiang et al[10])

---

[9] U.S. Department of Energy, "U.S. Natural Gas Storage Capacity and Utilization Outlook", 2016. Source

[10] Solomon Hsiang *et al.* Estimating economic damage from climate change in the United States. *Science* 356, 1362-1369 (2017). Source

The Gulf Coast's heightened vulnerability to climate-driven disruptions underscores the importance of UGS in maintaining energy stability as the region confronts both rising energy demands and more severe weather events. Figure 7, from the Fifth National Climate Assessment, further illustrates the financial impact of these billion-dollar disasters across states[11]. With Texas and Louisiana being among the most affected, having amassed substantial cumulative damage in recent decades.

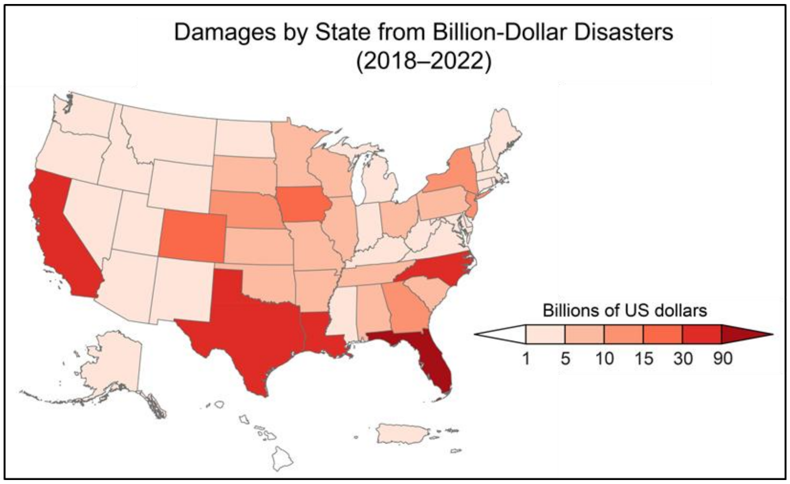


Figure 7: Damages by state from billion-dollar disasters (e.g., winter storms, droughts, floods, or wildfires) (Source: Fifth National Climate Assessment[12])

From a reliability standpoint, seasonality of natural gas load is very important, but extreme weather events (e.g., Winter Storm Uri) serve as a great example of how indispensable storage can be. The Texas Oil and Gas Association contracted Enverus to analyze some of the factors involved in Winter Storm Uri which caused significant damage to the Electric Reliability Council of Texas (ERCOT) power grid and resulted in nearly 4.5 million Texans losing electricity. In this analysis, they found that a record 156 Bcf was withdrawn from the EIA South Central region during the week of February 19, 2021, as shown in Figure 8. Power outages caused by the extreme temperatures limited the deliverability of many UGS facilities, which could have been even higher without the operational failures. This large-scale withdrawal from storage was due to local demand increasing immensely while transmission of production to demand centers was constrained in the extreme temperatures. If there had not been significant natural gas

---

[11] Billion-dollar weather and climate disasters are defined as "events where damages reach or exceed $1 billion, adjusted for inflation"

[12] The Fifth National Climate Assessment, 2023. Source

available in storage, the effects of the storm may have been much worse for residents, businesses, and communities in the Gulf Coast.

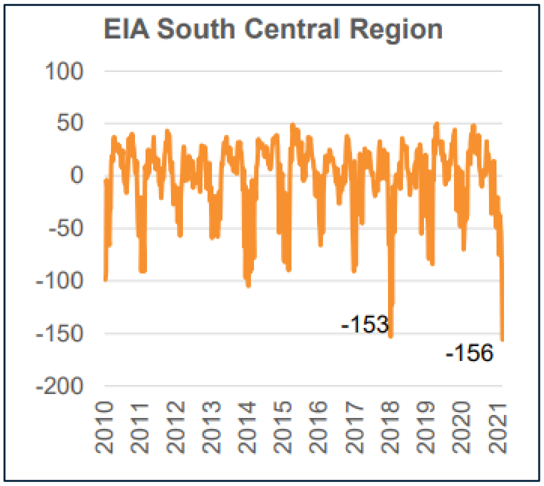


Figure 8: Weekly storage withdrawals from the EIA Central Region (TX, LA, OK, KS, MS, AR, and AL) (Source: Enverus[13])

This real-world example is somewhat in line with an analysis done by Argonne National Laboratory in 2016 as part of an interagency task force on natural gas storage safety. The analysis identified 12 UGS facilities (Figure 9) where disruption could potentially affect 2 GW or more of generation capacity. Eight out of the 12 of those facilities were in the Gulf Coast region, with 5 being in Mississippi and 3 being in Louisiana. The hypothetical loss of a high-deliverability UGS facility could pose one of the greatest risks to natural gas-fired electricity-generating plants and thus electric reliability in downstream communities.

---

[13] Enverus, "Winter Storm Uri – Natural Gas Analysis", 2021. Source

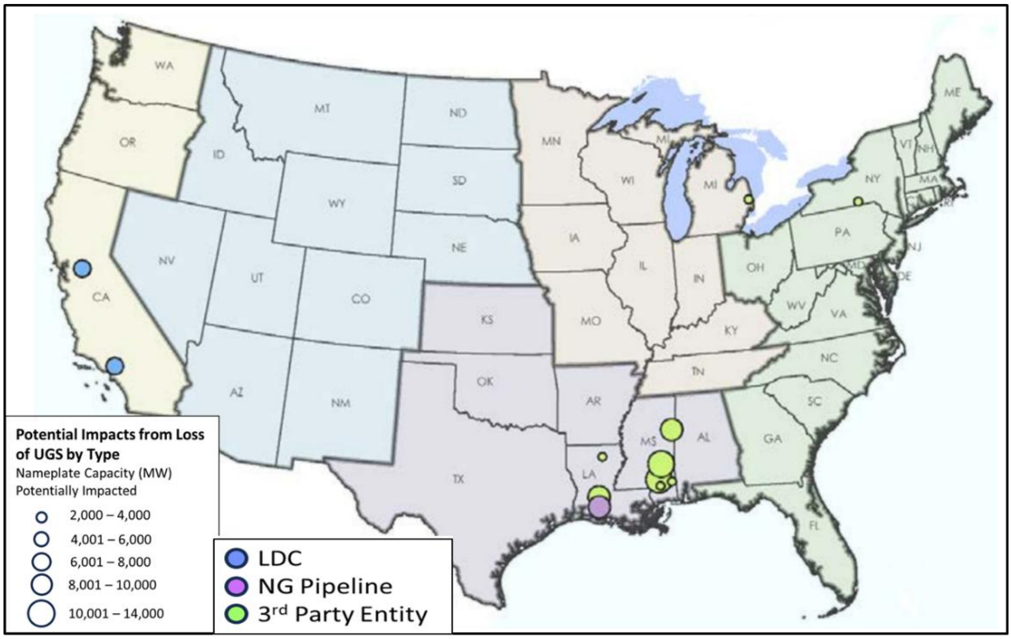


Figure 9. 12 UGS facilities whose disruption could affect 2 GW or more of generation capacity (Source: Department of Energy[14])

The importance of high-deliverability UGS in the Gulf Coast becomes evident when considering the potential impacts on power generation and grid stability. Given the Gulf Coast's concentration of facilities, particularly in Mississippi and Louisiana, any disruption could significantly affect natural gas-fired electricity generation and thus downstream electric reliability. This critical role of UGS in maintaining supply security has fueled investment in Gulf Coast salt dome storage. Just within the past year, there have been three proposed storage projects aiming to build or expand on salt cavern UGS facilities. These expansions would add nearly 58 Bcf of capacity in the Gulf Coast. Enstor Gas in Mount Olive, Mississippi, Golden Triangle Storage in Beaumont, Texas, and WhiteWater Midstream in Pecos County, Texas proposals would increase working gas capacity of salt dome storage by 8 percent and greatly increase energy system reliability in the area.[15] Salt domes offer the flexibility of multiple injection and withdrawal cycles annually, allowing investors to capitalize on price fluctuations. Industry demand for salt dome storage is driven by growing peak gas needs for power generation, fluctuating LNG export demands, and the essential backup role of natural gas storage in supporting renewable energy. Additionally, off-season withdrawals during hotter-than-expected

---

[14] Department of Energy, "Ensuring Safe and Reliable Underground Natural Gas Storage", 2016. Source

[15] Oil & Gas Watch, "As LNG industry booms, salt caverns converted into massive underground gas storage facilities", 2024. Source

summers in 2023 and 2024 underscore the strategic advantage of Gulf Coast salt domes, which provide adaptable storage solutions to meet unpredictable market needs, from high electricity demand to regional supply adjustments such as maintenance work in the Permian Basin.

State Level UGS Regulations, Standards, and Codes

Similar to the organization of standards in 49 CFR 192.12, Gulf Coast state codes for UGS are separated by facility type and are either for salt formations (solution-mined salt caverns) or for depleted reservoirs. Unlike other classes of injection wells, the provisions related to Class II hydrocarbon storage wells are typically included within the greater regulation of the storage facility. There are several components within state UGS regulations, codes, and standards that are similar across the region and require the same type of information and planning. Commonly required components are:

- Well and cavern permit application requirements
- Design and construction plans for caverns
- Operating pressures and volume verification
- Casing requirements and proposed programs
- Gas measurement and analysis
- Financial responsibility
- Well and cavern mechanical integrity testing
- Safety and Environmental requirements

States within the Gulf Coast have various and similar regulations, codes, and standards for UGS facilities (Table 8). A clearer understanding of their robustness can be found by examining each state’s processes and requirements for well and facility permitting, as these requirements must be planned for all stages of development and operation.

Texas and Louisiana are the two Gulf Coast states with the most natural gas storage capacity. Among the top five national states for storage capacity, Louisiana has minimal specific laws on natural gas storage. Under Revised Statute 30:22, a public hearing with the Commissioner of Conservation is required before using a reservoir for storage. The Commissioner must confirm that the facility is suitable, will not contaminate water or other resources, and will not pose risks to lives or property. Additionally, the Commissioner is authorized to issue rules that regulate drilling near storage reservoirs and prevent pollution and gas leakages.

In Texas, the Texas Administrative Code, under Rule §3.96, establishes a comprehensive regulatory framework for gas storage in productive or depleted reservoirs, overseen by the Railroad Commission of Texas (RRCT). The RRCT regulates oil, gas pipelines, storage, and natural gas utilities, while groundwater protection is managed by the Department of Agriculture, the RRCT, and the State Soil and Water Conservation Board. Key regulations in Texas include permitting, well casing, leak detection, emergency response plans, monitoring, record-keeping, integrity testing every five years, and plugging requirements for inactive wells.

Table 8: Primary UGS Codes & Permitting Requirements for Gulf Coast states.

State	Primary UGS Codes & Permitting Requirements
AL	- Al Admin Code Title 400-5: Governing the Underground Storage of Gas in Reservoirs - Al Admin Code Title 400-6: Governing the Underground Storage of Gas in Solution-Mined Cavities
	Additional Guidance: - Step 1 and Step 2 requirements for Underground Storage Well Permitting Process
AR	- 118.03.24 Ark. Code R. 002: General Rule D-23: General Rule for the Regulation of Underground Natural Gas Storage Projects
LA	- LAC 43:XVII Subpart 3. Statewide Oder No. 29-M: Hydrocarbon Storage Wells in Salt Dome Cavities - LAC 43:XVII Subpart 7. Statewide Order No. 29-M-5: Storage Wells in Solution-Mined Salt Dome Cavities
	Additional Guidance: - Class I, Salt Cavern & Class V Wells Presentation - Class I, Caverns & Class V Wells Handout - Financial Security for Class I, II, III, V, and VI Injection Wells - Minimum standards for sonar caliper survey reports in solution-mined salt caverns - Standards in the Public Participation Process Regarding Permitting Activities for Salt Caverns - Permitting UIC- Injection & Mining Division - 2025 Salt Cavern Compliance Checklist
MS	- 26 Miss. Code. R. 2-1.63: Underground Injection Control - 26 Miss. Code. R. 2-1.64: Underground Storage Wells of…Natural Gas in Reservoirs Dissolved In Salt Beds - 26 Miss. Code. R. 2-1.67: Underground Storage of Natural Gas and Air in Reservoirs
NM	- 20.5.101-20.5.125 NMAC
TX	- Rule §3.96: Underground Storage of Gas in Productive or Depleted Reservoirs - Rule §3.97: Underground Storage of Gas in Salt Formations
	Additional Guidance: - Underground NG Storage Inspections: A Regulatory Perspective - Cavern Storage Permit Procedures

UGS in the Decarbonization Landscape: Opportunities and Challenges

As discussed in the above sections, UGS plays a key role in enhancing energy system stability and can also support decarbonization by enabling the large-scale storage of low-carbon fuels, such as renewable natural gas, synthetic natural gas, and hydrogen, while also supporting carbon sequestration initiatives.

As UGS facilities evolve to accommodate hydrogen, adapting federal standards like API 1170 and 1171 for these facilities could streamline hydrogen integration, providing a basis for hydrogen-specific operational protocols. Research is needed to assess additional technical requirements for hydrogen storage, such as gas deliverability and optimal reservoir characteristics, to ensure efficient cycling and secure long-term storage. By broadening UGS application across both energy and non-energy sectors, the frequency of cycling could increase, thus lowering the per-unit storage cost. This approach not only makes green hydrogen more economically viable across a range of applications but also strengthens the role of UGS as a linchpin in the transition toward a lower-carbon energy landscape.

A key difference between UGS and CO_2 geologic storage lies in regulatory oversight. While natural gas storage is exempt from the EPA's UIC requirements, the UIC Program poses distinct regulations for activities like CO_2 storage, CO_2-enhanced oil recovery, waste disposal, and solution mining. States can gain primary responsibility for UIC enforcement upon EPA approval, tailoring oversight to local conditions. In addition to UIC well regulations, CO_2 storage operators must comply with EPA's greenhouse gas reporting requirements under Subpart RR (40 CFR 98.440–449). These rules ensure consistent GHG records for all geologic storage projects and require facilities to report CO_2 injection volumes, implement an EPA-approved monitoring, reporting, and verification (MRV) plan, and detail the CO_2 stored. The MRV plan must outline monitoring strategies for surface CO_2 release and establish baselines, defining a maximum monitoring area (MMA) and an active monitoring area (AMA) to capture potential CO_2 plume movement. Operators must phase in monitoring within the AMA to ensure containment, with periodic EPA reviews to adjust monitoring boundaries as needed. These regulations work alongside UIC Class VI well standards to assure safe and effective CO_2 storage.

While UGS facilities can also contribute to GHG emissions, primarily through methane leaks, the emissions profile of UGS facilities is quite small when compared to other subsectors within all petroleum and natural gas systems. Table 9 below is drawn from the EPA's Greenhouse Gas Reporting Program's 2023 Reporting year. Since 2011, there haven't been any large fluctuations in the emissions of UGS facilities, with the figure generally falling between 1-2 million metrics tons CO_2 equivalent.

Table 9. Number of reporters and 2023 emissions (CO2e) per Petroleum and Natural Gas Systems industry subsector

Industry Sector	**2023 Number of Reporters**	**2023 Emissions (million metric tons CO_2e)**
Onshore Production	445	91.4
Offshore Production	109	6.8
Gathering and Boosting	349	89.5
Natural Gas Processing	445	61.0
Natural Gas Transmission Compression	653	36.0
Natural Gas Transmission Pipelines	42	1.5
Underground Natural Gas Storage	**51**	**1.2**
Liquefied Natural Gas Import/Export	13	16.6
Liquefied Natural Gas Storage	6	< 0.05
Natural Gas Distribution	157	11.4
Other Petroleum and Natural Gas Systems	53	7.1

In 2024, the Greenhouse Gas Inventory released an update discussing how they plan to incorporate emissions from anomalous large emission events at UGS facilities and wells. Although the change was somewhat inspired by the leak at Aliso Canyon in California, two of the four largest emissions from incident events occurred in the Gulf Coast. These events happened in Texas in August 2004 at Moss Bluff Storage, and in Louisiana in December 2003 at Magnolia Gas Storage.[16] There have not been any large, anomalous gas releases recorded in the GHGI within the Gulf Coast region in the past 20 years.

Balancing these opportunities and challenges will require investment in enhanced regulatory standards and new engineering solutions to ensure that UGS facilities can meet the evolving demands of a low-carbon economy in the long run without compromising on emission reduction targets in the short term. As such, UGS remains a

---

[16] Environmental Protection Agency, "Updates for Underground Natural Gas Storage Well Emission Events", 2024. Source

key yet complex element in the decarbonization landscape, where maximizing its benefits will require balancing energy stability with environmental commitments.

Conclusions

UGS plays a critical role in maintaining the reliability and resiliency of energy systems. For decades, UGS has been instrumental in supply and demand balancing throughout the year, providing protection against excess demand, market volatility, extreme weather events and other supply chain disruptions. During winter months, for instance, UGS enables rapid withdrawal of natural gas to meet heightened heating demands, preventing supply shortages and reducing the risk of price surges. Additionally, as renewable energy sources like wind and solar grow, UGS serves as a vital backup, filling in the gaps when renewable output falls short, such as during periods of low wind or solar irradiance. In the Gulf Coast, UGS plays a strategic role in supporting the LNG export industry, which relies on storage flexibility to manage variable production and demand. High-deliverability facilities, particularly in salt caverns, allow for quick switching between gas withdrawal and injection, providing both local businesses and global markets with a steady, responsive supply.

UGS facilities operate under a comprehensive policy framework aimed at ensuring safety, environmental protection, and reliable service. Federal oversight by FERC and PHMSA, along with state-level regulations, sets strict standards for UGS design, operational integrity, and environmental safeguards, including well integrity protocols, pressure monitoring, and regular inspections to prevent methane leaks and minimize risks associated with subsurface storage.

In the Gulf Coast region, specific policies protect aquifers and coastal environments, often exceeding federal requirements. Recent policy developments have also emphasized the need to strengthen UGS infrastructure against single-point-of-failure risks and to enhance resilience to extreme weather, which is crucial in the Gulf Coast. As UGS increasingly supports decarbonization efforts, additional regulatory considerations are emerging for facilities repurposed for hydrogen storage or exploring carbon sequestration. Such adaptations may require updated standards for material compatibility, well design, and monitoring to prevent environmental impacts. Additionally, any further development of storage reservoirs and caverns to support a hydrogen economy would need to account for hydrogen’s energy density being one third that of natural gas. Together, these policies not only ensure safe, reliable UGS operations but also support innovation and adaptability as UGS evolves to meet the dual demands of energy stability and decarbonization goals, positioning the Gulf Coast as a model for balancing stringent safety standards with flexibility in a transitioning energy landscape.

Looking ahead, research into optimizing UGS will help better serve vulnerable areas and support decarbonization goals. Repurposing UGS for hydrogen storage could significantly bolster low-carbon energy storage markets, while future developments may even enable the use of carbon dioxide in UGS operations. NZIP aims to provide further analysis on the evolving role of UGS and natural gas infrastructure in shaping a resilient, sustainable energy future for the entire U.S.