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Working Committee 2

– Underground Gas Storage –

Report
Study Group 2.1 - Basic UGS Activities

Chairman

Joachim Wallbrecht

Germany

ABSTRACT

This report includes a summary of the work undertaken in the Basic UGS Activity Study Group of WOC 2-UGS - and is part of the WGC report.

The report includes the following sections:

- **Underground Gas Storage World Data Bank**
- **Underground Gas Storage World Map**
- **UGS Glossary**
- **Trends in the UGS business.**

The major part of the study is built up out of the **UGS World Data Bank** and the **UGS World Map**, which allows for a geo-referenced visualisation and fast derivation of UGS data in the world.

The **UGS Glossary** of the relevant technical storage terms is included.

The report describes **Trends in the UGS business** with respect to general, legal, environmental and technological issues and trends from a national perspective.

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1. Introduction

The Basic Activity Study has been established for the first time as part of the IGU Triennium work programme 2000 - 2003. The Study Group 2.1 -Basic UGS Activities- continued this work within the Triennium 2003 – 2006, developing a new improved study. Results are to be presented during the World Gas Conference 2006 in Amsterdam.

2. Study Group Members

The study has been developed by the WOC 2 Basic UGS Activities Study Group 2.1 consisting of members of 12 countries. The study group included members from Austria, Croatia, Czech Republic, France, Germany, Japan, The Netherlands, Romania, Russia, Slovakia, Spain and USA. Germany was the study group leader. The members are listed in attachment 1.

3. Objectives and Scope

The objectives of the Basic UGS Activities Study were:

- Statistical survey of existing/planned Underground Gas Storages (UGS) in the world
- Development/update of a database of underground gas storage facilities in the different regions of the world
- Development/update of a UGS World Map
- Development of the UGS Glossary of relevant technical UGS terms
- Summarizing general trends in the storage business.

The study covers the following types of storage facilities in:

Porous rocks
- storage in aquifers
- storage in gas fields
- storage in oil fields

Caverns
- storage in salt caverns
- storage in rock caverns (including lined rock caverns)
- storage in abandoned mines.

4. Way of Working

The report has been developed mainly from the feedback of a questionnaire which was sent out to gas associations and storage companies.

The questionnaire was split up into the following parts:

- Data questionnaire for existing UGS in operation and for planned UGS asking for relevant data from individual storage facilities/projects
- General questionnaire asking for trends in the storage business.

Data have been processed and analysed and additional study work, as e.g. the UGS Glossary, was carried out.

5. Structure of Basic Activity Study

Elements of the Basic UGS Activities Study are:

I. **UGS World Data Bank** - UGS in operation and planned (status: 2004/05)
II. **UGS World Map** - geo-referenced presentation of UGS data
in metric units and
in English units
III. **UGS Glossary** - Glossary of relevant technical UGS terms
IV. **Study Report on Trends in the UGS business**
V. **Attachments, incl. relevant terms, units and definitions**

The database and its visualisation comprise the major part of the study.

The world wide database on UGS facilities, including data about individual storage facilities in the world, and the graphical presentation of these data has been improved further.

The geo-referenced presentation within the UGS World Map is available in metric and for the first time English units, including UGS data from the USA and Canada.

A glossary of relevant technical UGS terms has been developed and trends in the UGS business are discussed in the report in general and from a perspective by nations.

6. Underground Gas Storage in the World
- UGS World Data Bank
- UGS World Map

Storage facility data were received from companies and gas associations about the following 23 countries in reply to the data request/questionnaire: Armenia, Austria, Canada, Belgium, Croatia, Czech Republic, Denmark, France, Germany, Hungary, Italy, Japan, Latvia, the Netherlands, Poland, Romania, Russia, Slovak Republic, Spain, Sweden, Ukraine, United Kingdom, USA. The American Gas Association (AGA) gave excellent support, thus resulting in profound data about the important American UGS industry.

In total present data from 584 underground gas storage facilities covering a working gas volume of some 319 10^9 m^3 (incl. long-term strategic reserves) were received. Those data received directly are equivalent to some 96% of the known total working gas volume of 333 10^9 in operation in the world.

In addition to the data received directly, data from previous studies (Study on UGS in Europe and Central Asia, UN ECE 1999/status: 1996, Basic Activity Study 2003) were available and additional publications were incorporated in the database.

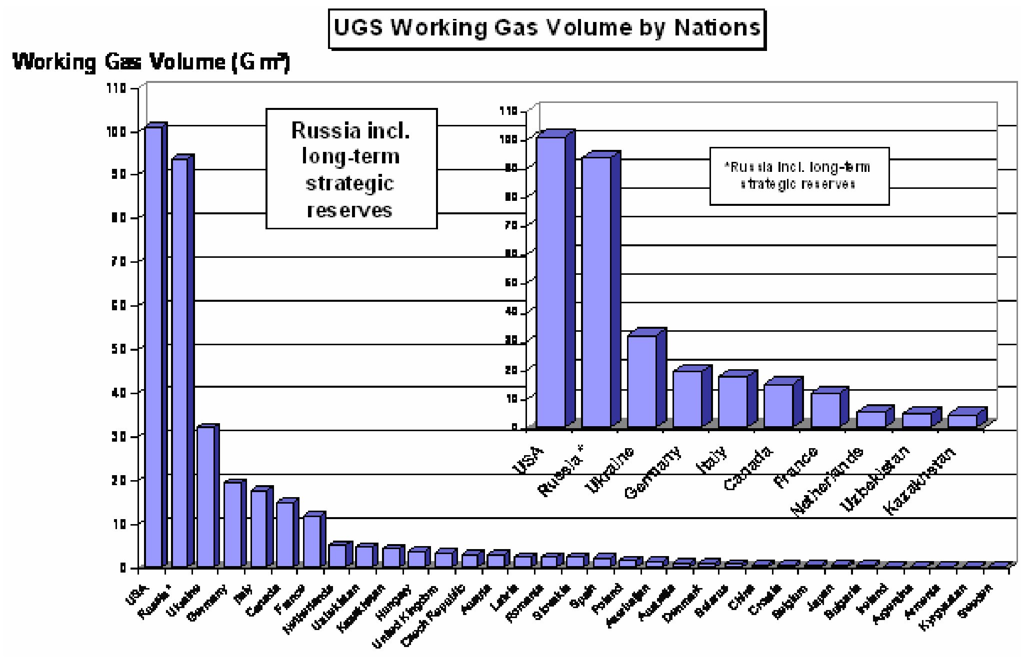
Thus in total an excellent database with the status and actuality of year 2004/2005 has been developed. Multiple pay horizons of a storage facility are reported separately, but are not added up necessarily to the installed max. capacities. Based on the applied definitions, reported storage capacities are related to the installed max. capacities the surface facilities allow for (see Glossary).

The working gas volume capacities of the countries with known underground gas storage facilities in operation, at reference year 2004/5, derived from company information received and from published data and national information, are enclosed in the following table.

Nation	No. of UGS Facilities	Total Installed Working Gas Volume of UGS Facilities
		$(10^6\ m^3)$
USA	385	100.846
Russia *	22	93.533
Ukraine	13	31.880
Germany	42	19.179
Italy	10	17.415
Canada	49	14.820
France	15	11.643
Netherlands	3	5.000
Uzbekistan	3	4.600
Kazakhstan	3	4.203
Hungary	5	3.610
United Kingdom	4	3.267
Czech Republic	8	2.891
Austria	4	2.820
Latvia	1	2.300
Romania	5	2.300
Slovakia	2	2.198
Spain	2	1.981
Poland	6	1.556
Azerbaijan	2	1.350
Australia	4	934
Denmark	2	820
Belarus	2	750
China	1	600
Croatia	1	558
Belgium	1	550
Japan	4	542
Bulgaria	1	500
Ireland	1	210
Argentina	2	200
Armenia	1	110
Kyrgyzstan	1	60
Sweden	1	9
Total	606	333.235

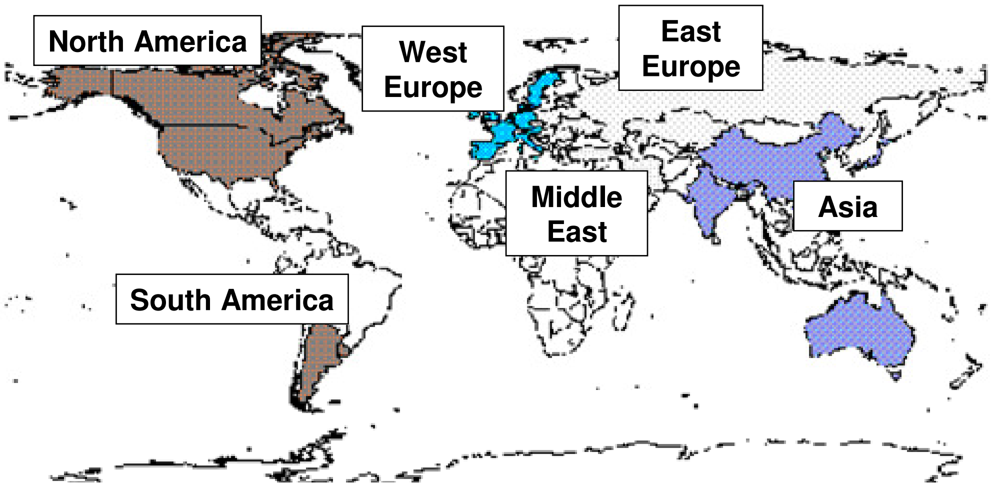
* including long-term strategic reserves

These data are visualized in the following graph.



Clearly the United States of America are operating the highest capacities, followed by Russia, Ukraine and Germany. It has to be noted, that the Russian working gas volume includes long-term strategic reserves.

The countries of interest for UGS were grouped into the following four regions: North America, South America, Asia, East Europe, Middle East and West Europe:



The data are included, apart from some adjustments, +/- as received. The database is still incomplete for some regions. The study does not claim to be complete. Applied units are defined in attachment 5.

Despite clear definitions, some operators did not deliver data consistent with definitions.

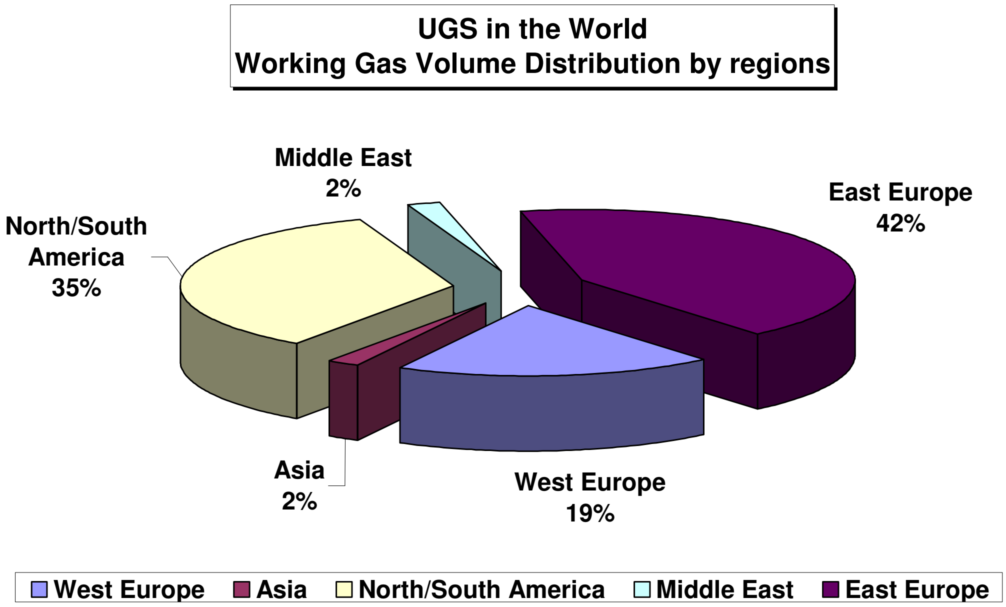
The data contained in the UGS World Data Bank differ from cumulative storage capacities of individual countries reported on a national basis. Differences exist between the individual summation of technical storage capacity data about UGS in operation compared to the reported national storage capacity. Thus differences may be due to different reference years, differing use of capacities (installed vs. utilized or available working gas volume) and included long-term reserves as e.g. in Russia, incl. 30 10^9 m³ of long-term strategic reserves.

As the Basic Activity will commence in the next trienniums, the existing database will be broadened and updated successively.

Based on the country based data collected in the Basic UGS Activities Study an installed working gas volume of some 333 10^9 m³ is operated in about 610 storage facilities all over in the world. A withdrawal rate of some 205.000 10^3 m³/h is provided by some 23.000 storage wells.

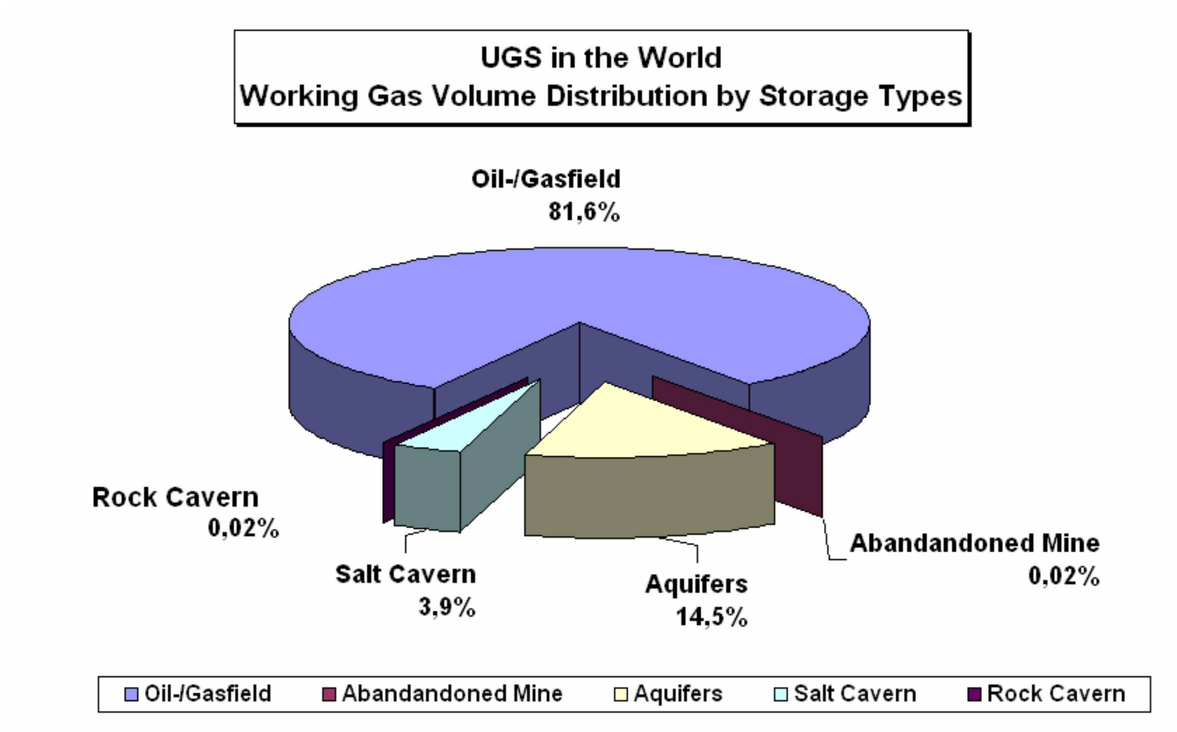
A summary of installed capacities and planned capacities in existing and in green field storage projects is given by regions in attachment 2.

The working gas volume of UGS facilities in operation of 333 10^9 m³ divided by regions is presented in the following chart.



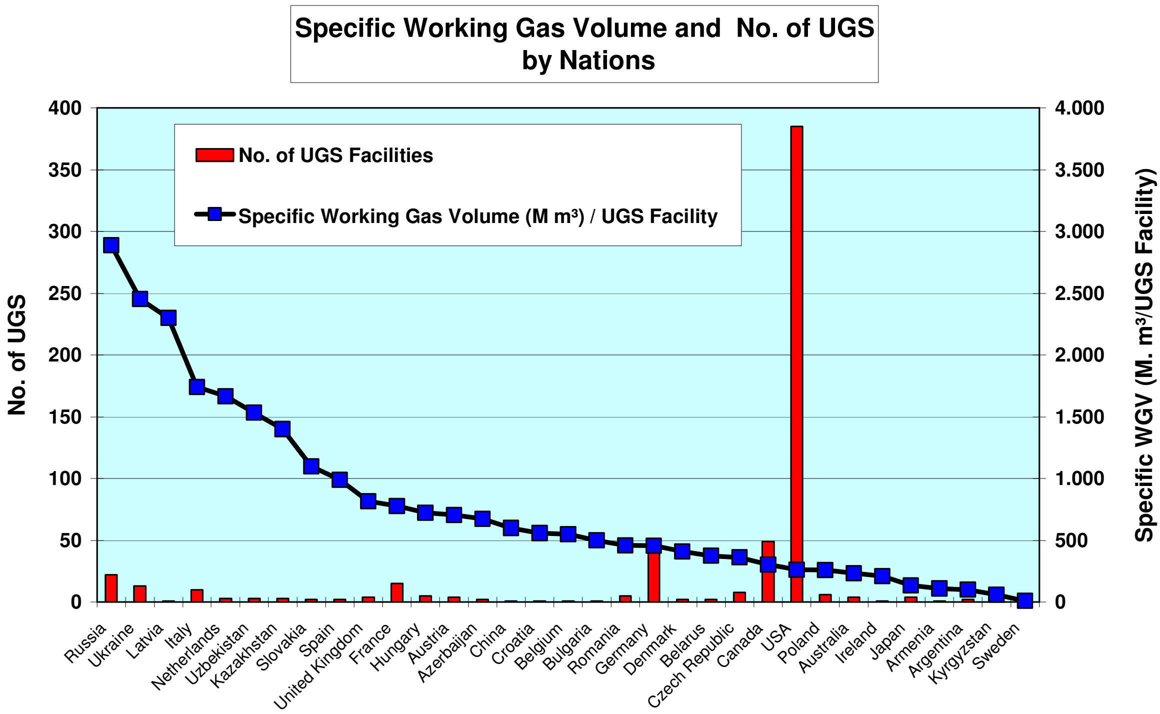
It is obvious, that the major part of the working gas volume is installed in East Europe and in America.

It is evident from the following chart that the greater part of the working gas volume is installed in UGS facilities in former oil/gas fields (82 %), followed by storage facilities in aquifer structures and caverns. Abandoned mines (0,02 %) and rock caverns (0,02 %) are of no great relevance on a world scale.



This distribution of storage types differs from region to region; in West Europe for example more storage capacities are available from aquifers (22%) and caverns (13%) relative to UGS in oil/gas fields (66%).

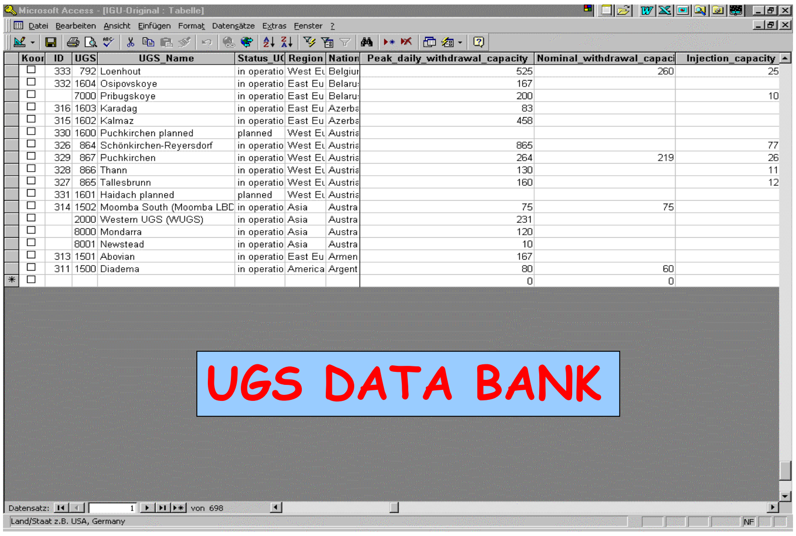
The ratio of national working gas volume vs. No of UGS facilities has been analysed. As an average, about 500 10^6 m³ of working gas volume/UGS facility can be derived just based on the real installed working gas volume without long-term strategic reserves. The specific WGV by nations (10^6 m³ WGV/No of UGS) and No of UGS by nations are presented in the following graph. Russia offers specifically the highest ratio, even when excl. long-term strategic reserves.



The database includes, in addition to the UGS in operation, planned UGS facilities and facilities under construction.

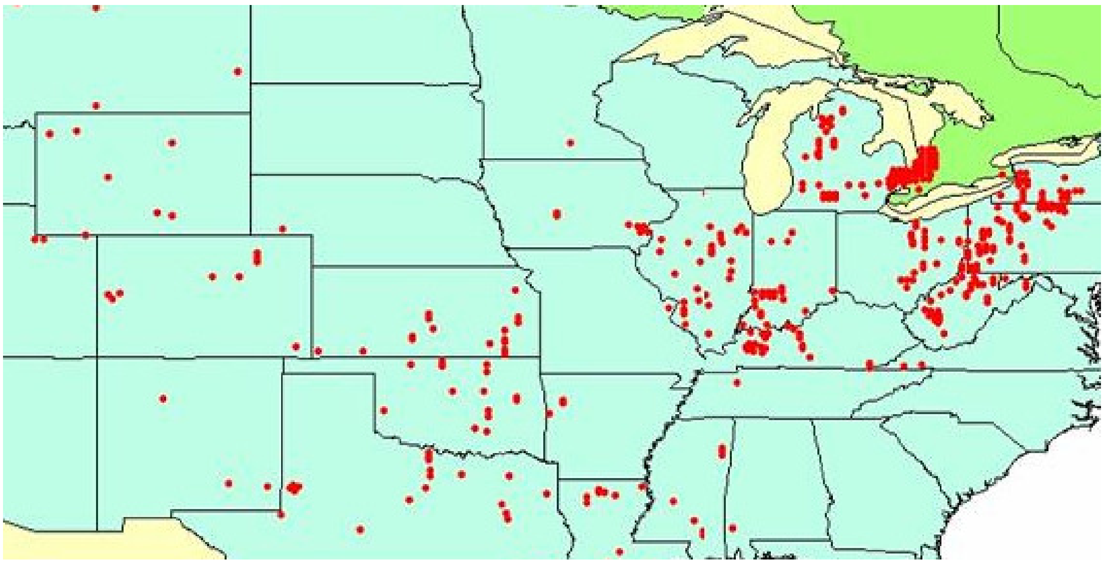
The database has to be completed successively in the future, especially on the planned UGS projects which have a more volatile character. As many project plans are coming up and are going it is always difficult to present the recent status.

The detailed information, at reference year 2004/05, is available in the **UGS World Data Bank**, which is Access based, via links on the front page of the report such as the following one for the UGS Data Bank. The data are made available for information purposes and for any further detailed analysis as Access and EXCEL-reports in metric and for the first time in English units.

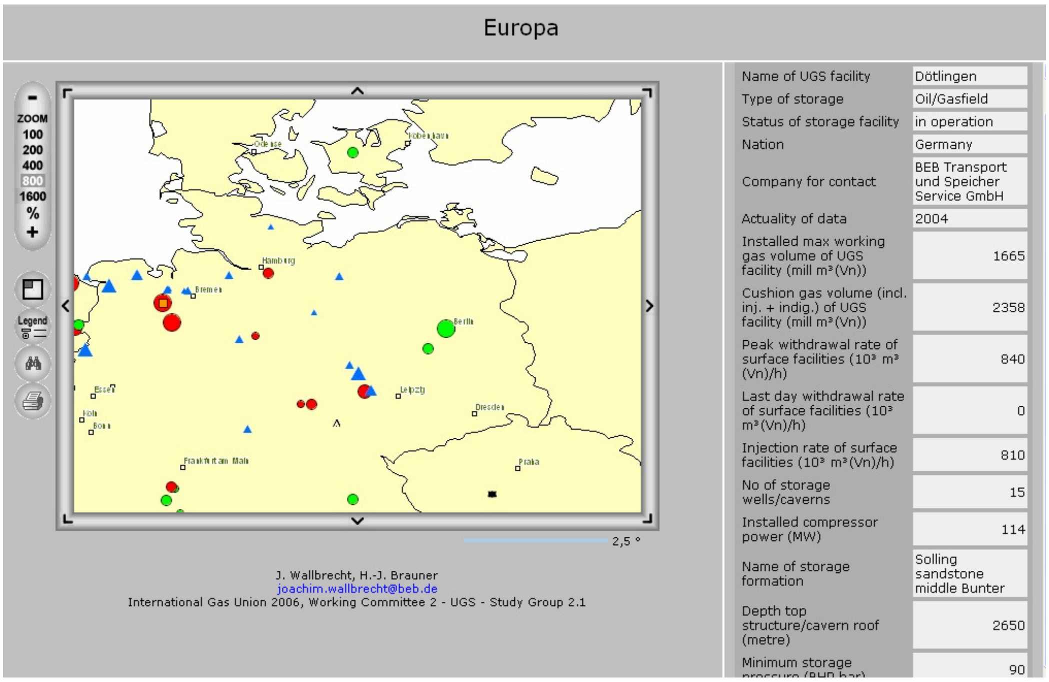


Koor	ID	UGS	UGS_Name	Status_UG	Region	Nation	Peak_daily_withdrawal_capacity	Nominal_withdrawal_capaci	Injection_capacity
☐	333	792	Loenhout	in operatio	West Eu	Belgiur	525	260	25
☐	332	1604	Osipovskoye	in operatio	East Eu	Belarus	167		
☐		7000	Pribugskoye	in operatio	East Eu	Belarus	200		10
☐	316	1603	Karadag	in operatio	East Eu	Azerba	83		
☐	315	1602	Kalmaz	in operatio	East Eu	Azerba	458		
☐	330	1600	Puchkirchen planned	planned	West Eu	Austria			
☐	326	864	Schönkirchen-Reyersdorf	in operatio	West Eu	Austria	865		77
☐	329	867	Puchkirchen	in operatio	West Eu	Austria	264	219	26
☐	328	866	Thann	in operatio	West Eu	Austria	130		11
☐	327	865	Tallesbrunn	in operatio	West Eu	Austria	160		12
☐	331	1601	Haidach planned	planned	West Eu	Austria			
☐	314	1502	Moomba South (Moomba LBD	in operatio	Asia	Austra	75	75	
☐		2000	Western UGS (WUGS)	in operatio	Asia	Austra	231		
☐		8000	Mondarra	in operatio	Asia	Austra	120		
☐		8001	Newstead	in operatio	Asia	Austra	10		
☐	313	1501	Abovian	in operatio	East Eu	Armen	167		
☐	311	1500	Diadema	in operatio	America	Argent	80	60	
☐							0	0	

For the first time, North American storage data are presented in this geo-referenced way in the **UGS World Map**. Data are accessible just by clicking on the locations on the map as follows.

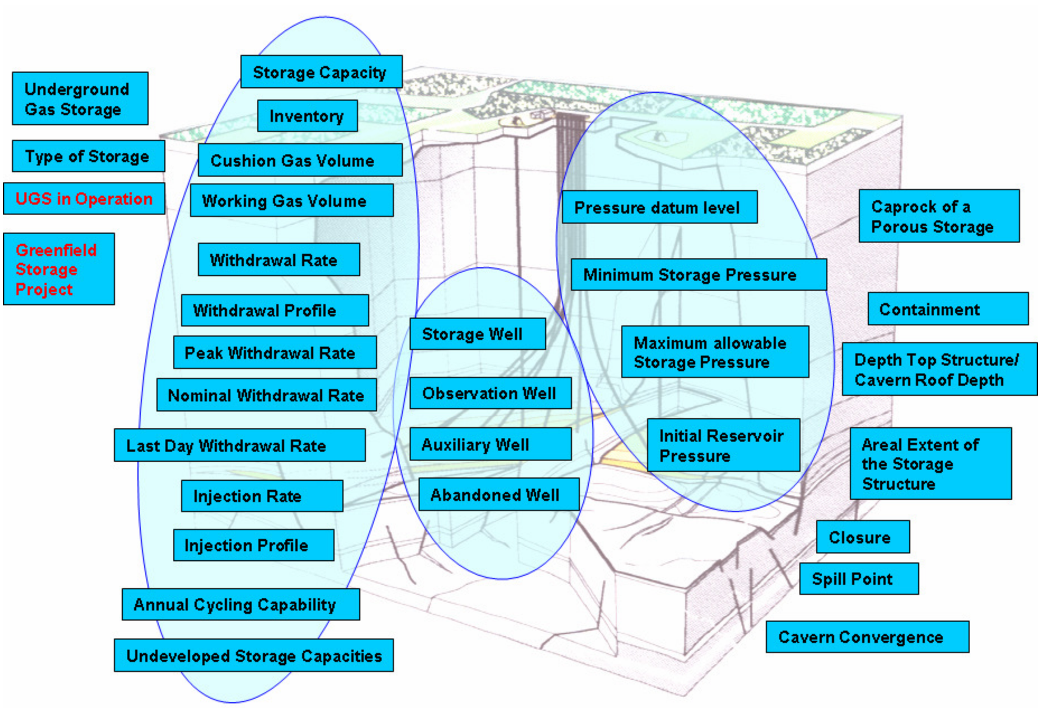


Key data of the UGS facilities in the world, as in the following graph, are available geo-referenced in the **UGS World Map** via links on the front page of the report.



7. UGS Glossary

As there are too many different storage related definitions available, mainly E&P and marketing related, a consolidated glossary of the relevant terminology related to the storage of natural gas in underground gas storage facilities was developed. As the technology is similar, the terminology can be applied for the storage of hydrogen, CO_2, O_2 and other gases. The glossary covers the following terms:



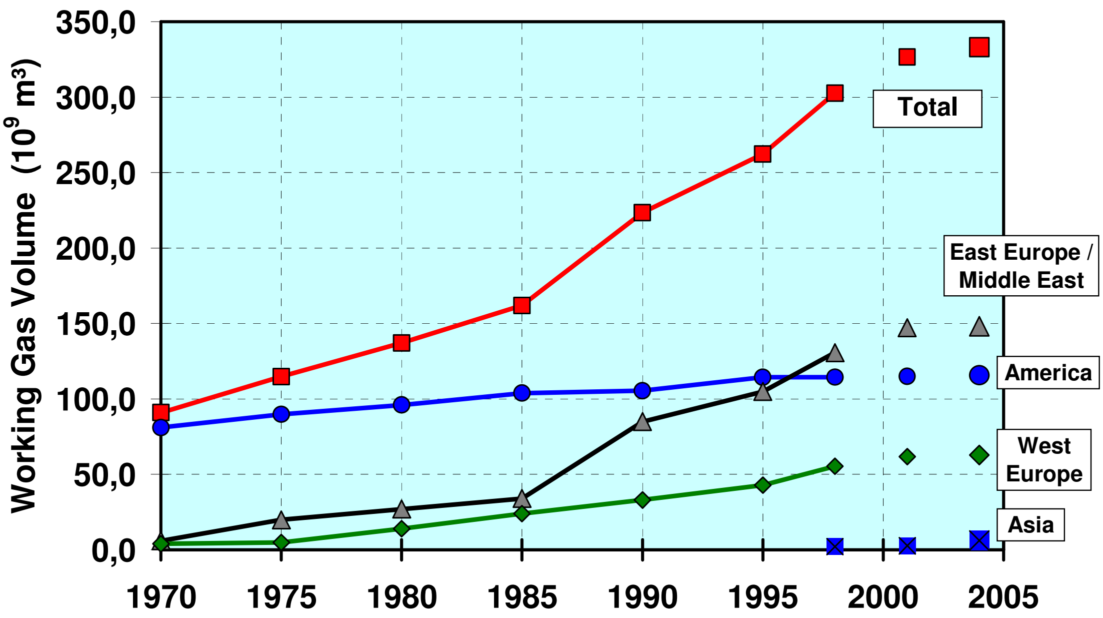
The glossary is included in attachment 4. The enclosed glossary was translated to glossaries in several other languages available via links on the frontpage.

8. Trends in the UGS Business

Based on 16 replies from 9 countries limited feedback on the general questionnaire request was received. Therefore additional sources were utilized to derive some trends in the storage industry business. In general the database was insufficient and does not allow for a comprehensive analysis.

8.1 Storage capacity and demand trends

From the data sources the historical development of the installed working gas capacity by regions was derived as presented in the following graph:



The data compilation was carried out very detailed, identifying some data differences to previous years.

From 2000 onwards only gradual increases in storage capacities can be observed.

Contributions received from different countries indicate increasing storage demand (see chapter 9. Trends in the UGS business from a national perspective).

Company comments received in reply to the questionnaire are indicating increasing storage demand with increasing gas consumption. Reported increases of storage demand differ from country to country between 4 % to18 % till 2010 and 30 % till 2020. Some companies comment, that sufficient storage capacities are installed for the time being in some countries.

The load factor of gas supplies is expected to rise in Europe, due to higher import volumes compared to a declining indigenous production. Increasing utilization and increasing storage demand may result in increasing capacities, assuming a reliable economic and political environment.

UGS facilities are the essential tools to match supply and demand on a peak and a seasonal basis. The importance for the storage service will grow further as long-distance base-load supply continues to rise. New storage facilities will be developed linked to new big pipeline projects as in China (West-East pipeline), North East Europe.

Due to the ongoing liberalisation process of the gas market the importance of storage capacity in the gas chain is recognised and new products can be made available from underground gas storage facilities. UGS in a liberalised market environment should, in addition to conventional tasks, be used as a trading tool to enhance the value of gas. New business opportunities for UGS are related to the development of gas hubs in Europe. The liberalised gas market in West Europe can be looked at as well as an opportunity for the storage industry by offering in addition to the "old" tasks new storage products as: parking, balancing, loaning and wheeling linked to hubs. In general higher deliverability will be requested. Withdrawal capacity consequently has to be increased.

Discussions about security of supply may trigger additional storage demand.

New developments are underway in the United Kingdom, the Netherlands, Germany, China, Russian Federation, Spain, Turkey and Iran. New projects may come up in Brazil, India, China, etc., especially as two-thirds of the increase in global energy demand will come from developing countries.

As an example for new developments, the United Kingdom is discussed in the following. UK has very limited gas storage facilities, providing less than 4 per cent of annual consumption, compared to normally 18-25% in gas storage developed nations, thus showing the need for more storage developments.

The following table is indicating projects in the United Kingdom currently constructed, respectively in the planning phase. Including the project Saltfleetby 10 new projects are under investigation.

Facility name	Operator	Capacity (mcm)	Start	Total capacity	Planning status
Humbly Grove	Star Energy	290	2005	2005	Planning approved
Aldbrough	SSE	409	2007	2009	Planning approved
Byley	Scottish Power	170	2008	2009	Planning approved
Welton	Star Energy	436	2008	2008	Planning submitted
Fleetwood	Canatxx	1,662	2009	2019	Planning submitted public enquiry Oct 05
Albury Phase 1	Star Energy	160	2007/8	2007/8	Pre planning
Bletchingley	Star Energy	Up to 875	2009	2009	Pre planning Drilling required
Aldbury Phase 2	Star Energy	Up to 715	2010	2010	Pre planning Drilling required
Caythorpe	Warwick Energy	189	2007	2007	Pre planning

Ref.: StarEnergy, IEA Seminar June 2005

Assuming all the projects are developed as planned, UK working gas volume will more than double till 2010.

Every current forecast of global energy consumption for the next decades concludes that the use of gas will substantially increase.

The World Energy Outlook 2004 of the International Energy Agency (IEA) is stating that the world primary energy demand in their Reference Scenario is projected to expand by almost 60% between 2002 and 2030. The projected annual rate of demand growth, at 1,7% is slower than the average of the past three decades, which was 2%. Among the fossil fuels, demand for natural gas will grow most rapidly. The worldwide consumption of natural gas will almost double by 2030.

According to the International Energy Outlook 2005 of the Energy Information Administration (EIA), natural gas is projected to be the fastest growing primary energy source worldwide, maintaining average growth of 2,3% annually over the 2002 to 2025 period. Total world natural gas consumption is projected to rise according to EIA from 2002 by some 40% till 2015 and 69% till 2025.

Independent from variations in different prognosis, the gas demand will grow and increasing gas consumption will consequently result in a higher storage demand. In addition higher load factors and changes in the demand structure can be expected in mature gas countries, due to higher import volumes compared to a declining indigenous production. Although the demand for storage will grow in the future, the exact timing of that demand growth remains uncertain.

Some reports are indicating a shortage in seasonal storage in Europe.

A comprehensive analysis of the expected storage demand is strongly recommended. Variables has to be included on a national basis as: total primary energy consumption, energy mix, energy efficiency, alternative flexibility energy sources, gas demand by segments (e.g.: gas power plant), population, demand/supply load structure (swing), gas utilisation (e.g.:air condition), import dependency, origin/distance of gas sources, change in the cost of gas and alternatives, interruptible supply contracts, social/political implications, security of supply requirements.

Further details will be presented in the course of the WOC 2 presentations during the WGC 2006.

8.2 General, legal, technological issues

Based on the replies from 16 companies, which were received as feedback to the questionnaire sent out, the following trends were derived with respect to general, legal and technical topics. Further comments are given in chapter 9 - Trends in the UGS business from a national perspective.

General issues

Based on the feedback received the following remarks about Third Party Access (TPA) are mainly related to Europe.

Third Party Access (TPA) and the liberalisation of the European gas market, looked out for in the Madrid Process by all parties involved, have the biggest impact on the underground gas storage industry. It is essential to secure economic operation of UGS in the liberalised gas market environment.

Despite there was already competition in the storage industry, a further increase of storage capacity demand/requests and competition can be observed and UGS facilities will be the essential tools to match supply and demand on a peak and a seasonal basis.

The role of old storage companies will change in a liberalised market. Security of supply, which may be provided by UGS, is of vital importance in some countries. Nowadays storage system operators (SSO) normally do not have to fulfil security of supply provisions anymore, as this is the task of merchants, but they have to provide availability of storage capacities. There are some exemptions in Spain, The Netherlands and Italy.

The way to fulfil TPA to storage capacities differs from country to country in Europe, mainly by the selected option for access - negotiated or regulated access to storage capacities - and different conditions.

Due to all requirements of the Gas Directive and the Guidelines for Good Practice for Storage System Operators (GGPSSO) corresponding modifications of the storage facilities, systems and conditions have to be carried out. Increasing efforts to fulfil the requirements and inquiries were reported. More efforts due to regulation is expected.

As the consequences of the liberalisation process for the future of the storage business is not totally clear, some storage system operators (SSO) indicated a certain reluctance in the development of new projects. Uncertainties are especially related to potential insufficient regulated tariffs and non-committed storage capacities, due to a lack of long term contracts.

Essential concerns were raised concerning the question, whether the liberalisation process allows for sufficient <u>incentives for new developments</u> and whether the operation of existing UGS can be carried out economically in the future.

In case of mandatory regulated TPA to UGS, together with low uneconomic storage tariffs, a major impact on the UGS industry is expected. New storage capacities will not be developed, shut-in of existing UGS facilities is possible, or withdrawal from the storage business seems to be a realistic option in the future for some operators.

The expected increasing long-term storage demand cannot be fulfilled under these circumstances. As for new storage developments longer lead times will be required in the future, the covering of storage demand will be aggravated.

Future environmental requirements and revamping requirements for existing “old” UGS-facilities is expected to increase operating costs.

Cost cutting initiatives and efficiency improvements are strongly recommended anyhow and necessary in preparation for a more competitive market.

Assuming an economic development environment, adjustments of the existing facilities to new demand requirements offer good business opportunities in the future. This is mainly related to <u>new storage products</u> compared to the historical use of UGS. For example, peak capacities are becoming more important and cycling capacity can be improved by the development of additional injection capacities. The use of an UGS as marketing tool (wheeling, parking, etc.) in connection with a hub seems to be a useful complement.

Asides new products in a liberalised market environment, new projects may offer new business opportunities. But some countries see, related to their local situation, no new opportunities for gas storage developments, as limited possibilities exist in their country. The required storage service may be carried instead in neighbouring countries.

As new business opportunity the use of caverns in combination with wind energy plants is proposed. Compressed Air Energy Storage (CAES) can balance power demand and fluctuating wind power production (s. SMRI, Crotogino et al Oct. 2004, Berlin and following graph).

Crotogino, Jacobsen, Leonhard: COMPRESSED AIR ENERGY STORAGE (CAES) PLANTS FOR BALANCING WIND-POWER

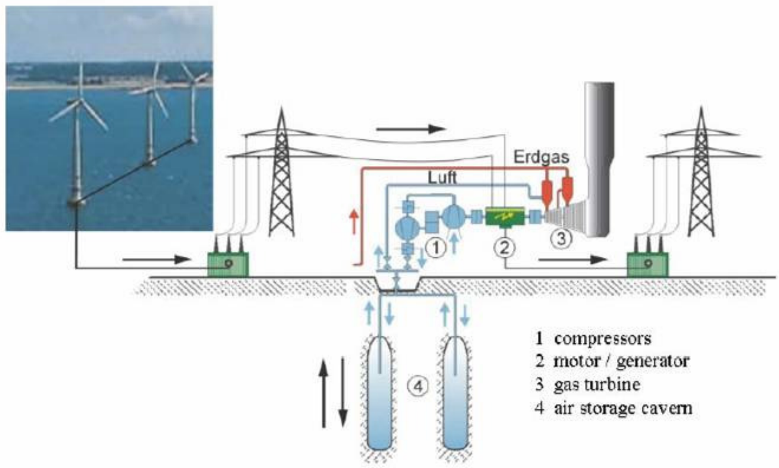


Fig. 3: Concept of a CAES power plant combined with a wind farm

Further new alternative opportunities for the UGS industry asides the storage of natural gas are limited. The topic of CO_2 storage is under intensive investigation in several countries and is looked at as a promising opportunity midterm. The storage of hydrogen is considered to be a long-term option. Helium storage has only a limited application.

In general SSO's don't encounter severe problems concerning legal and environmental aspects. Some SSO's see increasing environmental protection activities and legal requirements, probably related to some projects. Approval procedures should be streamlined.

Concerning lead times for new storage project developments no clear trend could be observed. About half of all comments indicated no increase in lead times. On the other hand increasing lead times were reported in some countries/companies related to some projects due to the specific project, respectively to the public/local authorities or due to administrative permits as in Spain.

Consequences from CO_2-emissions and the related emission rights may have some impact; in general it is too early to tell.

Further developments of storage capacities is planned in some countries but cannot carried out so far without strengthening the pipeline system (Japan).

Concerns were raised about the level of qualification and expertise of staff in the future which is required for oncoming tasks and to maintain core competences

Legal issues

Third Party Access is the most relevant topic for the storage industry in Europe for the time being. According to the survey, the transformation of TPA to storage is quite advanced in Europe up to the complete access to storage capacities for third parties in many countries.

The basis for the liberalisation of the European gas market was laid by the European Gas Directive in June 2003. Beyond the transformation of the Gas Directive into national law, companies have to transpose the related requirements. This requires as well re-organisation of company structures to some extent because of unbundling requirements.

The Gas Directive allows for regulated or negotiated access TPA, to be opted by the nations dependent on the status of competition.

Since April 2005 the European "Guidelines for Good Practice for Storage System Operators" (GGPSSO), approved by the Madrid Joint Working Group, are in force. Those guidelines are released by the European Regulatory Group for Electricity and Gas (ERGEG) as recommendations. In principle the compliance of the guidelines is voluntary, but the guidelines are expected to be followed by storage system operators (SSO). European regulators monitor the process of liberalisation.

Concerning the storage related aspects of the Gas Directive and the GGPSSO the following elements are essential:

- access to storage capacities for third parties granted on a non-discriminatory, transparent basis
- either regulated or negotiated Third Party Access to storage capacities
- SSO's have to operate storage facilities based on economic conditions in a safe, reliable and efficient way
- relevant data of UGS facilities and services have to be published as e.g.: installed, booked and available capacities, utilization, conditions, etc.
- confidentiality has to be guaranteed
- SSO's shall offer bundled storage services and unbundled storage services
- storage services shall be offered with the duration of one year and longer (long term contracts) and short term contracts on a daily respectively monthly basis. These services shall be offered as firm and interruptible capacities
- rules for congestion management
- promotion of the development of a secondary trading market e.g. by bulletin boards, i.e. free trade of storage capacities between storage customers
- close cooperation between SSO's and TSO's.

Thus the storage business is influenced significantly by the liberalisation process and the SSO's had to implement the provisions on access to storage and the publication duties and to adjust there systems (IT, Operations, General Conditions, etc.).

The degree of fulfilment of all requirements, which came up in 2005, has been monitored by corresponding European inquiries (EU Commission, ERGEG). Despite all new complex developments, including requirements of infrastructure modifications, the degree of accomplishment was quite satisfactory.

The Directive about major hazards (Seveso directive) has been applied for storage differently in some European countries but without any problems.

Concerning the approval of new developments, in some West European countries a lack of public acceptance and increasing environmental requirements are observed. For some companies future does not look too promising in this respect.

In some East European countries financial problems are hindering new developments and economical barriers are the main problem for potential investors.

Technological issues

General

The technological trends derived from the received questionnaire replies are mainly related to four major items :

- Operation of storage

Surface facilities of UGS are revamped ensuring their compliance with the latest environmental and safety standards and regulatory requirements: remote control operation of UGS operation, automatization, computer aided expert system.
Special attention was dedicated to the safety of UGS operation and the analysis of the influence of UGS performance on the environment. Regarding this aspect, there is more need for monitoring of “older” underground facilities.
Optimum modes of underground gas storage operation have been developed, together with the development of control algorithms and adequate computer programs.

- Development of capacities

Regarding the development of capacities, the trend is towards the development of huge UGS and small city gate UGS and concerning cavern facilities, as well the development of mega size caverns, where salt conditions allow for.

The increase of the maximum allowable storage pressure is the preferred measure for increasing storage capacities dependent on detailed engineering studies and the authority approval.

- Subsurface

Concerning subsurface aspects, 3D seismics, new methodologies and software packages are applied to describe as precisely as possible geological reality, i.e. geological structure and its extension and reservoir characteristics. The proof of cap-rock and trap tightness is of great importance.

Deliverability tests are recommended to characterise productivity parameters of a particular storage well and reservoir behaviour. Data can be used for calibrating reservoir simulation models, thus improving the prognosis quality. Moreover, complex reservoir models are applied to provide a tool to optimise storage processes and forecast different scenarios of its development. One of the main goals of simulation models is to be able to predict and guarantee capacities in the future.

- Wells

There is a strong tendency towards reduction of the number of storage wells, strengthening wells with higher deliverability. The horizontal well technology is applied when appropriate and possible.
Wells are re-completed to optimise completion and to install surface controlled subsurface safety valves. Improved well completions are installed for sand control purpose in unconsolidated reservoirs and slightly cemented reservoirs.

Main topics of interest and for improvements

Based on all the received questionnaire replies a summary was derived. The following areas of interest and of technological improvement and the main topics for the optimisation of existing storage facilities were summarised as the most relevant topics:

- increase of the operational flexibility and storage performance
- re-design of UGS facilities in order to adapt to new requirements in a liberalised gas market
- increase of cavern size (mega caverns up to a geometrical volume of $1x10^6$ m^3)
- welded casing/tubing
- horizontal wells
- multilateral technology to produce several zones from one well
- integrated subsurface/surface reservoir management
  - application of integrated systems, incorporating subsurface and surface models in order to allow for fast system analysis and improved performance prognosis of the storage facility
- subsurface optimisation / performance improvements by:
  - decrease of min. storage pressure in order to increase WGV and to reduce required cushion gas volume
  - increasing of max. allowable storage pressure in order to enhance WGV and storage performance
  - increasing max. withdrawal rates, for example by debottlenecking, increasing velocities, optimising completion, increasing tubing size
  - 3 D seismic, seismic reprocessing
  - monitoring of inside/outside casing conditions by casing inspection tools
  - assessment of casing cementation
  - improvement in casing cementation technology especially honouring the specific conditions of storage operation (changes due to load, temperature and pressure).
  - application of smart well technology
- enhancement of surface facilities –
  - new dehydration technology (Vortex tube)
  - online monitoring of wells/facility
  - remote control
  - environmental monitoring
- total facility
  - reliability improvement
  - start up time reduction
  - “unmanned“ operation
  - application of HAZOP etc. procedures and validated operational instructions
  - cost reduction.

New requirements/tasks induced by recent market developments are coming up:

- storage developments in combination with hubs
- increased deliverability
- improved technology application - multilateral well technology in storage facilities
- reduction of minimum injection/withdrawal rate
- injection capacity enhancements – resulting in an enhanced cycling capacity
- fast changes of operational mode
- production data management with respect to TPA
- cost cutting analysis of facility
- technology for the application of CO_2 sequestration should be developed.

9. Trends in the UGS business from a national perspective

Direct valuable contributions about the national situation and trends in the underground gas storage business were received from Austria, France, Germany, Italy, the Netherlands, Poland, Russian Federation, Slovakia, Spain, Ukraine and North America. The contributions are included in this report +/- as received.

Austria

General

In the year 2004 Austria has imported 5840 10^6 Nm³, domestically produced 1963 10^6 Nm³ and consumed 8563 10^6 Nm³. The difference covers own use for domestic production and movements from / into storage inventories.

Available volumes in UGS and send out capacities in 2004 were 2820 10^6 Nm³ and 32 10^6 Nm³/d. The split for the two providers of the gas storage services is presently OMV Gas 2120 10^6 Nm³ and 25 10^6 Nm³/d respectively RAG 700 10^6 Nm³ and 7 10^6 Nm³/d.

Due to the different locations, OMV has the bulk of its facilities in the eastern part of Austria and RAG has its facilities near the German border.
Both storage operators consider a lack of send out capacity while working gas volume is still sufficient. Additional to the use of storage to balance the seasonal swing as the basis, OMV and RAG see changes in the demand structure leading to new products like unbundled services, i.e. the splitting of the three components of UGS and providing working gas volume, withdrawal rate and injection rate as separate products to the market.

RAG with its centre of E&P activities in the federal provinces of Upper Austria and Salzburg, both located near the German border forecasts an additional demand for storage in the gas markets of Central Europe. For this reason a new storage is under construction in the depleted gas field of Haidach. The available gas volume in 2007 will figure at 1200 10^6 Nm³ and 12 10^6 Nm³/d and will be increased to 2400 10^6 Nm³ and 24 10^6 Nm³/d in 2011. This new UGS will be operated by RAG.

OMV has its main E&P activities in the federal province of Lower Austria close to the gas hub Baumgarten at the intersection of big pipeline systems coming from the East and leading to the West (West-Austria-Gasline and Penta West), South (Trans-Austria-Gasline and SOL) and South-East (Hungarian-Austrian-Gasline). At this point OMV Gas predicts an additional demand in the future at the latest when Nabucco pipeline will come into operation.

Hence, OMV Gas is working out a pre-feasibility study to investigate a reservoir located directly below Baumgarten in about 3.000 m depth with high permeability. A volume of up to 2000 10^6 Nm³ with very high deliverability is probable. This study will be presented in 2006.

Legal

The gas law from 2002 governs as far as gas storage is concerned the following:

- Access to gas storage has to be granted to producers, traders and suppliers on non-discriminatory and transparent terms.

- Tariff has to be negotiated based on costs and equal treatment. Provable technical and geological risks, together with opportunity costs have to be adequately considered.

- In case tariffs for comparable and equal services provided in EU-member states, are 20 percent above the average, the Austrian regulator E-CONTROL can stipulate by decree cost elements to be used.

- Holders of storage contracts are obliged to present all contracts to the regulator.

Construction and installations related to an UGS is regulated by the Austrian mining law (MinroG Nov 2002) together with other laws as needed. Deviating from EU standards an UGS in Austria does not require an Environmental Impact Assessment (EIA) Report. Commissioning and supervision of an UGS facility is in the hands of the Austrian Mining Authority.

Environmental

Since safety and environmental matters are of major concern to the general public it is the good policy of companies involved in Austria's gas storage activities, to make abundant information available in due time und during all phases of planning, construction and operations to all which might be concerned.
Emission levels of all kinds and treatment of waste are regulated by a framework of laws and supervision and control rests with the Mining Authority or an agency appointed for a specific task by the Mining Authority (e.g.TÜV).

Gas turbines in the UGS compressor stations have been adapted to Low-Nox operation.

Injecting inert gas as cushion gas has been considered but has not yet reached a status to be a viable solution.

Technical

As in the past construction of a new, or expansion of an existing facility will always be governed by techniques available at the time.

Recent project works are all based on 3D seismic to allow the drilling of optimum well patterns. But it had to be realised that due to complicated geological conditions drilling of pilot wells cannot be avoided in some instances.

Reservoir simulation studies are worked out to find the optimum location for drillings and concentrate wells in clusters. Horizontal wells have been considered to supplement the existing vertical wells if it is feasible. Recent studies recommend to expand the diameter to 9 5/8".

Safety valves have been used on all recently completed new storage wells and will be used in alls re-completed old storage wells.

France

NATURAL GAS IN FRANCE AND UNDERGROUND GAS STORAGE

NATURAL GAS IN FRANCE - A QUICK OVERVIEW

In 2005, the proportion of total French energy consumption accounted for by natural gas is currently about 15% or around 528 10^9 kWh.
This represents 34% of the total energy demand for industry and 32% for residential and tertiary sectors. In this last sector, gas represents a less important part than in others main European countries. But the growth is there quite fast, with 3,5% per year in average since 1995.

In 2004, 11 million customers are served by a 174.500 km distribution network.

France is seeing an increasing number of vehicles running on natural gas, more than 1300 bus and 5500 utility vehicles. Nevertheless, consumption of natural gas for cars, around 550 000 kWh, remains low compared to all energies of this sector.

Cogeneration has been expanding during the last years, with a total of 26,5 10^9 kWh of natural gas being consumed.

The natural gas supply policy in France is based on diversification of gas sources, with long-term contracts which maintain security of trade. In 2004, 32% of sales of natural gas came from Norway, with 24,5% from Russia, 16,5% from Algeria, 20% from the Netherlands, 5,5% from United Kingdom and 4% from other sources (Nigeria, spot and short term). Total of imports are of 515TWh.
Compared to previous years, part of short terms contracts is growing, representing 20% of the supplies; imports from Netherlands have increased. In 2007, Egypt should provide around 10% of supplies; first deliveries have been received in July 2005.

The national production represents less than 3% of the gas resources. The Lacq field, located in the south west, supplies most natural gas produced in France. At the beginning of the year 2005, the reserves are of 10 $10^9 m^3$ or 100TWh, which represents five years of production or 3 months of national consumption. End of exploitation is planned for 2010.

UNDERGROUND NATURAL GAS STORAGE IN FRANCE

There are 15 underground gas storage facilities in France, comprising :

- 12 facilities located in aquifer layers
- 3 facilities located in salt cavities.

Two facilities are run by Total Infrastructures Gaz France (TIGF) and thirteen by Gaz de France (GDF).
Role of UGS in France has been detailed in the IGU report “Basic Activities” 2000-2003.

In France, a Third Party Access to storages has been implemented since the law from 9th August 2004, on a transparent and non-discriminatory basis; tariffs are ruled on a "negotiated approach".

The two french operators, Gaz de France and TIGF, therefore elaborated commercial offers for UGS capacities respectively since April and October 2004.

Total Infrastructures Gaz France (TIGF), subsidiary of Total, has been created in January 2005 for the facilities held in Southwest of France.
For Gaz de France, the management of storages is undertaken by a specific division DGI (Direction des Grandes Infrastructures), in charge of the development and the industrial and commercial management of underground storage facilities since 1st January 2005.

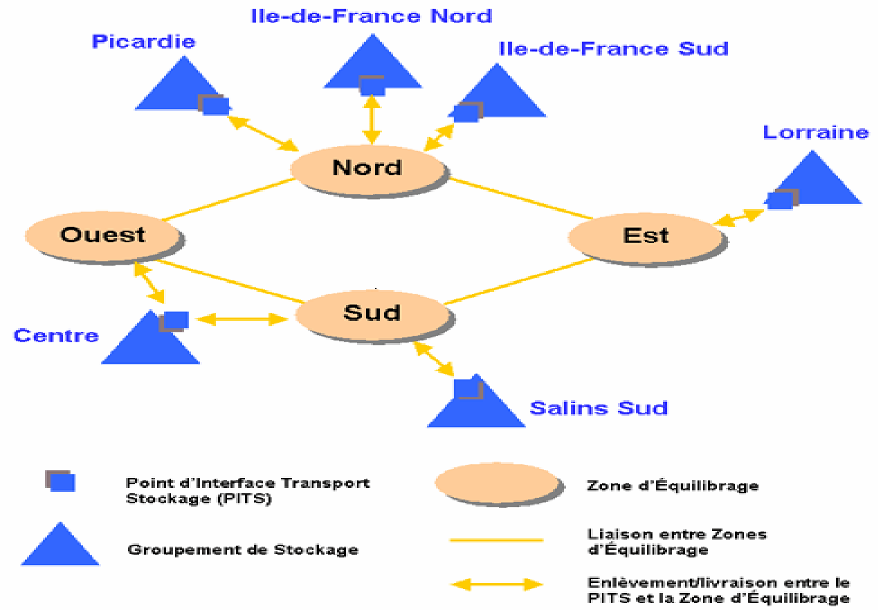
OPERATORS	STORAGES	TYPE	CAPACITY
GDF	Soings, Céré, Chémery	Aquifer	46 TWh
	Saint-Clair, Germigny	Aquifer	13 TWh
	Saint-Illiers, Beynes	Aquifer	13 TWh
	Etrez, Tersanne, Manosque	Salt Cavity	9 TWh
	Cerville	Aquifer	7 TWh
	Gournay (B gas)	Aquifer	10 TWh
TOTAL	Lussagnet	Aquifer	2,4 Gm^3
	Izaute	Aquifer	2,8 Gm^3

Underground gas storages in France (from Europ Energies Mars 2005)

Gaz de France UGS facilities are pooled into six storage groups, according to their geographical position, type of gas and physical characteristics :
- Picardie,
- Ile de France Nord
- Ile de France Sud
- Lorraine
- Centre
- Salins Sud.

Each group of storages is characterised by the UGS facilities, a point of interface transportation /storage, the number of injection days and the number of withdrawal days.

The commercial offer has been posted on GDF web site on 19th april 2004 and is regularly reviewed: www.stockage.gazdefrance.com.
The offer, which concerns all suppliers for the needs of their customers, reflects the physical constraints of access to storages. In the contract are defined the rules of utilization regarding injection and withdrawal rates, or inventory during the year.



Gaz de France storage groups

THE TRENDS IN THE UGS BUSINESS IN FRANCE

On the legal point of view, activity of underground storage of gas is submitted to specific rules and laws. Application of rules for safety to UGS facilities now integrate them in the "Seveso 2" regulation.

The main applicable texts are :
- the Seveso 2 directive, which has been transposed into French law for UGS activity in January 2003
- the mining law, with UGS included in law of January 2003, related to gas and electricity markets and public energy service

Some general European directives may also apply to UGS, for example :
- IPPC directive (Integrated Pollution Prevention and Control)

- "CO2 quotas" directive
- other directives, concerning wastes for example, as electric equipments.

The national environmental regulation also concerns UGS facilities :
- general environmental regulation on air, water and wastes
- specific regulation for industrial "risky" facilities: those facilities are subject to an administrative authorisation or declaration before the start of exploitation

The storage facilities are therefore subject to authorisation of exploitation (law of July 1976).

On an environmental point of view, important efforts have been made to develop integrated management systems for the environment protection. The implementation of environmental management system is made on a voluntary basis based on international norm ISO14001. This is also described in European regulation EMAS (Eco-Management and Audit Scheme).
In terms of recognition, the norm allows to obtain international certificate when EMAS allows to be registered on a list held by the European commission.

Gaz de France plans to obtain in 2006 an ISO 14001 certificate for all UGS facilities. In year 2005, seven of the UGS have already obtained the certification.

NEW DEVELOPMENTS

In order to accompany the increasing demand in natural gas, France carries on the development and optimisation of its facilities.
It has been for example the case for the storage of Chemery, where development and extension have been undertaken in the last years.

On the other hand, some development or exploration works are carried out for optimising existing facilities or finding possible new sites in salt or aquifer layers. Some projects are almost decided or are at exploration step.

Future developments will depend on the development of the gas market together with a clear understanding of the regulatory environment.
The program of development of capacities will take into account the renovation and upgrading of the existing facilities in order to keep an availability of installations. Related to the average age of storage facilities, large investments will be necessary in the forthcoming years.

Germany

General

In 2004 the primary energy consumption stayed nearly constant compared to previous years. In 2005 a slightly reduced primary energy consumption (PEV) (1%) was observed compared to 2004.

Natural gas, as the second important source of energy behind oil (36,4 %), provides about 22,5 % of the total primary energy. In 2004 about 100 10^9 m^3 of natural gas were consumed. The significant increases of gas consumption from previous years can not be observed any more.

As Germany is an energy importing country several countries contribute to the supply of gas according to the following shares:

Country	Share in %	
	2003	**2004**
Germany	18	16
Netherlands	17	19
Norway	26	24
Russia	32	35
Denmark and United Kingdom	7	6

The storage of gas is looked at as an essential tool within the gas chain, with increasing importance in the future because of declining gas production in West Europe and increasing imported gas volumes via long distance pipelines.

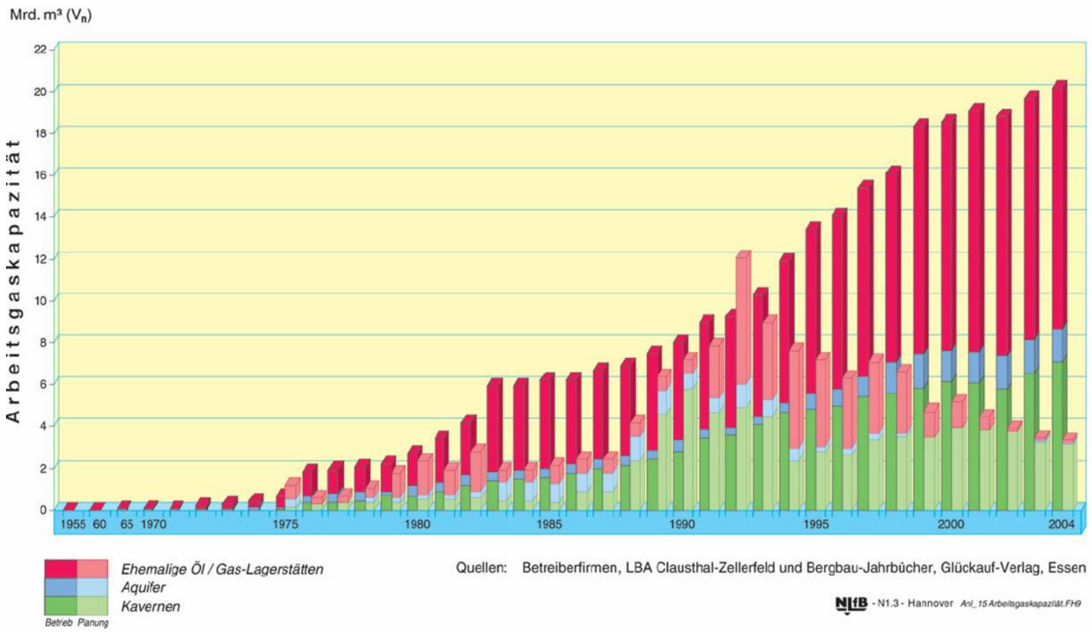
The UGS industry has a long history in Germany. The first UGS was developed in an aquifer near Hannover in 1953 by Ruhrgas AG and was abandoned in 1999 for economic reasons.

In Germany, 42 underground gas storage facilities, operated by some 20 companies, provide a total of 19,18 10^9 m³ of installed working gas volume as shown in the following table:

	Porous Rock	**Caverns**	**Total**
Total installed working gas volume of UGS in operation (10^9 m³)	12,833	6,346	19,179
Total peak withdrawal rate in operation 10^6 m³/d	204,65	272,52	477,17
Number of storages in operation	22	20	42
Total working gas volume from planned storage projects (10^9 m³)	0,6	2,7	3,3
Expected total max. working gas volume in operated and planned storage facilities (10^9 m³)	13,44	9,04	22,48

Reported new storage capacities are mainly developed in salt cavern facilities as well obvious from the following graph.

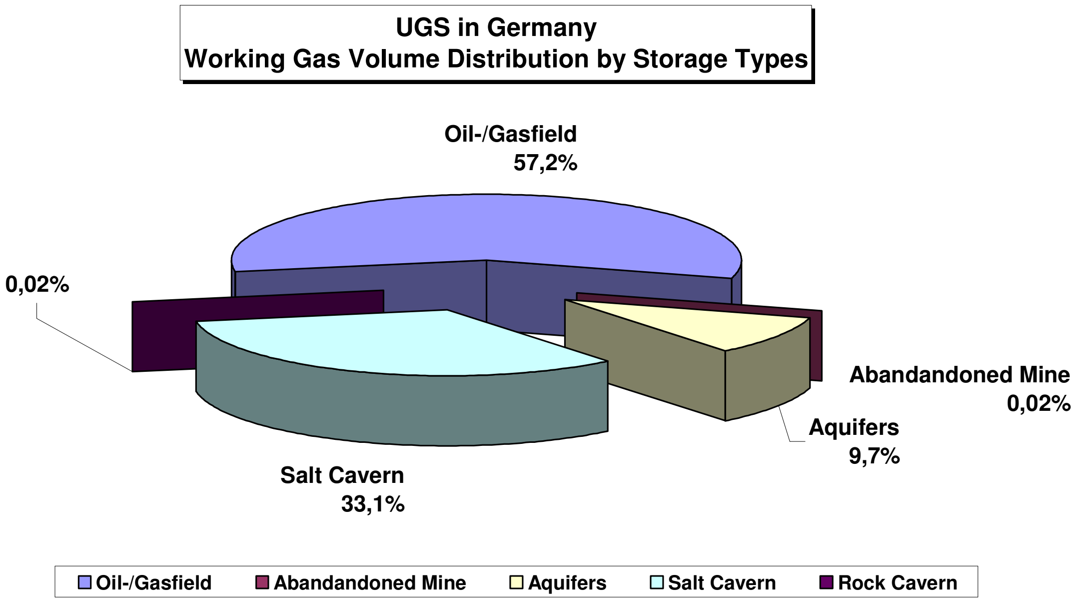
In the following graph, the development of working gas volume (10^9m³) since the beginning of UGS operation in Germany is shown.



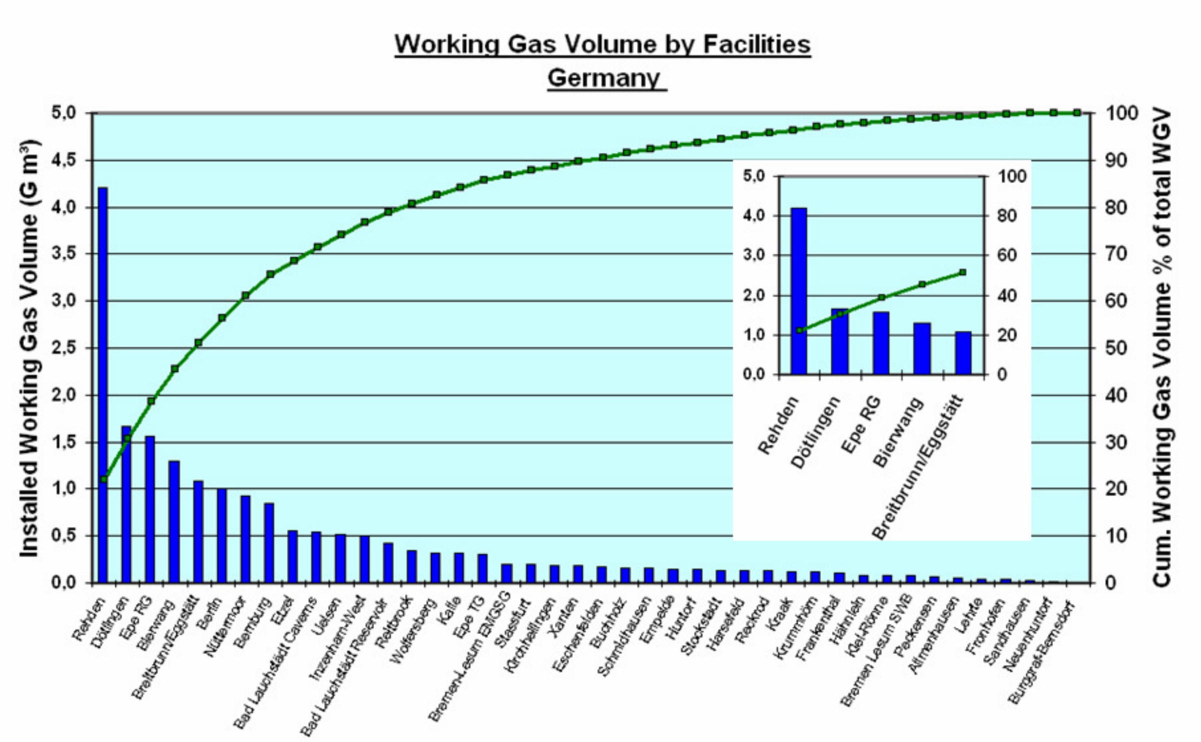
Since 1990 the existing working gas volume has more than doubled. About 19% of the total gas consumption is available in UGS facilities. A further increase of installed storage capacities is forecasted.

Due to favourable geological conditions in North and South Germany sufficient additional storage volume can be developed in salt rock (only in N Germany) and porous rock (mainly in depleted hydrocarbon reservoirs in both areas) to meet the needs of future UGS capacities.

Compared to the distribution of storage types in the world major storage capacities are installed in salt caverns. On a working volume basis for salt caverns, 33 % compares to 3,9 % in the world, and more pronounced on a peak withdrawal rate basis, 57% vs. 15%.



Only 5 storage facilities (Rehden, Dötlingen, Epe E.RG, Bierwang, Breitbrunn/Eggstätt) provide about 50 % of the installed working gas volume. Most of the planned volume will be developed in salt caverns in existing storage facilities by leaching additional salt caverns.



Some of the German storage companies are involved in the domestic E&P and in the storage business. The holders of an exploration permit do not implicitly have the right in North Germany to obtain a permit to operate storage facilities. New applications for storage permission ("Betriebsplanantrag") are required independent of existing exploration or production permits. This application and the operation of UGS are subject to regulations according to the mining law (“Bundesberggesetz”). The acquired subsurface (geological) data are submitted to the geological surveying authorities in accordance with the mineral law ("Lagerstättengesetz"). There is no specific tax on exploration and operational activity at underground storage sites.

Legal

The basis for the liberalisation of the European gas market was laid by the Gas Directive in June 2003. In July 2005 the European Gas Directive from June 2003 has been transferred in Germany by the new German energy law (EnWG). Since April 2005 the European “Guidelines for Good Practice for Storage Operators” (GGPSSO), approved by the Madrid Joint Working Group, are in force. Those guidelines are released by the European Regulatory Group for Electricity and Gas (ERGEG) as recommendations. In principle the compliance of the guidelines is voluntary, but the guidelines are expected to be followed by storage system operators (SSO). A new regulatory authority – the Bundesnetzagentur (BNA) - has been established in Germany, which monitors the process of liberalisation.

According to the German energy law Germany opted for negotiated Third Party Access to storage capacities which have to be granted for third party access on a non-discriminatory, transparent basis.

The storage business in Germany, which is built up by a variety of different facilities and operators compared to other European countries, is influenced significantly by the liberalisation process especially as the SSO's had to adjust there systems (IT, Operations, General Conditions, etc.).

The degree of fulfilment of all requirements, which came up in 2005, has been monitored by corresponding European inquiries (EU Commission, ERGEG). Despite all new complex developments, including requirements of infrastructure modifications, the degree of accomplishment was quite satisfactory in Germany.

Technology:

Due to favourable geological conditions (overburden rocks) high operational pressures are run in some UGS. Due to this fact a high standard of monitoring of the technical integrity of the storage wells and the overburden rocks is ensured.

In general approved E&P-technology is applied, which is adjusted for storage requirements. In new cavern projects, installation of welded casing and tubing strings are preferred.

A large number of horizontal UGS wells have been drilled during the last years. In depleted reservoirs with a low reservoir pressure new types of low pressure mud systems are used to prevent formation damage. Generally, drilling of new wells is based on 3-D seismic surveys, followed by comprehensive 3-D modelling and simulation of the storage dynamics. Most of the UGS have installed subsurface safety valves (SSSV).

The trend to leach a higher geometrical volume in salt caverns, thus reducing specific investment, is increasing; e.g. the salt cavern Huntorf K 6 planned for a geometrical volume of 750.000 m³ could be enlarged to 1,1 10^6m³ because favourable geology, shape and rock mechanics allowed for this enlargement.

Several re-leaching projects in existing caverns are planned respectively carried out. In some cases leaching was carried out under gas.

Italy

General

According to storage service demand in terms of working gas and peak capacity, referred to the last winter (year 2004-05) and reasonably also winter 2005-06, storage needs in the short term appear higher than the available storage capacity.

Great interest from gas operators (mostly shippers) in UGS is demonstrated from the attention to the first round of bidding for the development of new gas storages, both depleted gas reservoirs both acquifers. After the evaluation by the Production Activity Ministry (Ministero Attività Produttive) only few projects have been accepted so far.

This interest of shippers in obtaining licences for new UGS is due also by the possibility to dedicate to itself up to 80% of the developed working gas, leaving only the remaining capacity to the regulated market.

In orders to comply with the increasing storage demand, the present UGS operators have provided a short term program to improve mostly working capacity.
In thermal year 2005-06, the capacity offered by present operators is about 8 10^9 m³ of working gas. Within the next 3 years the development of an additional capacity of more than 1 10^9 m³ is expected.

Legal

From the point of view of Italian laws, the gas market is completely liberalised. TPA access to the storage system and transmission system is fully guaranteed.

Nevertheless in UGS there is a dominant position (more than 95% of storage total capacity) of Stogit (ENI Group). Therefore the Electricity and Gas Authority (Autorità per l'Energia Elettrica e il Gas) have regulated the storage system and imposed storage service tariffs.

As required, Stogit has prepared and sent, on 26 September 2005, to the Electricity and Gas Authority its proposal of Storage Code, for the verification process. At the moment this proposal is under discussion between Shippers and is waiting for the final approval of the Electricity and Gas Authority.

In August 2005, the Production Activity Ministry issued a new decree in witch are reported new requirements for the storage, mainly related to open access to new operators and give the opportunity to improve the performances of the system, as operating the field at pressures higher than the original pressure and developing other types of UGS (i.e. aquifer).

Environmental

It appears that there will be no particular constraints, on present or future UGS, from present or next future environmental laws except for the necessity to comply with the Kyoto Protocol for greenhouse effect emission.
In case of planning and construction of new UGS, special attention must be paid in order to comply with all the requirements regarding in general environmental aspects and impacts finalised to obtain all necessary authorisations.

Technical

In order to increase the performances of the storage system, the technical solutions that have been applied or planned are mainly managing the fields at maximum pressure or overpressure, improving horizontal drillings and utilisation of structured packing in dehydration column.
A Low Temperature Separator plant (LTS), that dehydrates the gas by mean of the Joule-Thompson effect instead of traditional glycol system, is already in full operation.
Finally enhancements have been implemented in reliability of static and dynamic models of the reservoirs and in upgrading tools for the optimisation of the fields management.

The Netherlands

Background

In the Netherlands the so-called "small fields policy" has successfully promoted exploration for and exploitation of new gas reserves since 1974. The main source of flexibility of the gas supply system is provided for by the Groningen system, allowing the "small fields" to produce at a relatively high load factor. The Groningen system consists of the Groningen field (320 wells) and three UGS facilities.

The Groningen gas field is operated by NAM (50% Shell, 50% ExxonMobil) and has an expected ultimate gas recovery of 2881 10^9 Nm³, of which 60% has been produced to date. Currently a 2 10^9 € investment programme is being executed which comprises out of a full facilities upgrade of 22 production clusters and 7 satellite locations, whilst 22 new depletion compressors are being installed (at 23 MW each). The field can ramp-up capacity with 120 10^6 Nm³ in one hour whilst it supplies a maximum 350 10^6 Nm³/d capacity. The Groningen system is designed around a capacity failure criterion of 1 hour per 50 years.

UGS

Of the three UGS facilities, two are operated by NAM (Grijpskerk, Norg) and one is operated by BP-Amoco (Alkmaar). The UGS facilities were built in the mid 90's and can provide a total send out (end winter capacity) of 140 10^6 Nm³/d (5,8 10^6 m³/h). These UGS reservoirs have currently a total working volume of 2,4 10^9 Nm³ at the above stated capacity.

The UGS's were designed to cater for winter peak demands, to accommodate for the declining reservoir pressure and production capacity of the Groningen field. Relatively small injection capacity was installed, with limited flexibility in order to accommodate gas from small fields in the summer periods. The UGS's have long-term contracts with Gasunie. Expansion plans are being considered to meet future capacity and work-volume demands.

Legal

As part of the ongoing European liberalisation efforts the Dutch regulator (DTe) has indicated that a substantial part of the Dutch UGS's should be made available for Third Party Access (TPA). The objective of the regulator is to increase trade and the efficient operation of the UGS by both owners and users whilst creating a healthy investment climate. In order to achieve these objectives the DTe has issued guidelines, which the storage owner should adhere to when offering storage services to the market.

Although the NAM UGS's have been designed, built and operated for production purposes and therefore do not fall under the Gas Act and under the jurisdiction of DTe, NAM, together with Gasunie, has decided to make a certain amount of capacity available as NAM/Gasunie wish to co-operate with the overall EU liberalisation efforts.

Environmental/social

There is a general trend to increase energy efficiency and to limit the environmental impact of operations as much as reasonably possible (zero impact if possible). This involves a "no flaring" policy, whilst CO2 emissions are minimized. The extension and/or construction of new facilities require involvement of all stakeholders (i.e. neighbouring communities, local government, Dutch mining authority) in the design of facilities (visual impact, safety, noise contours) and landscaping around facilities.

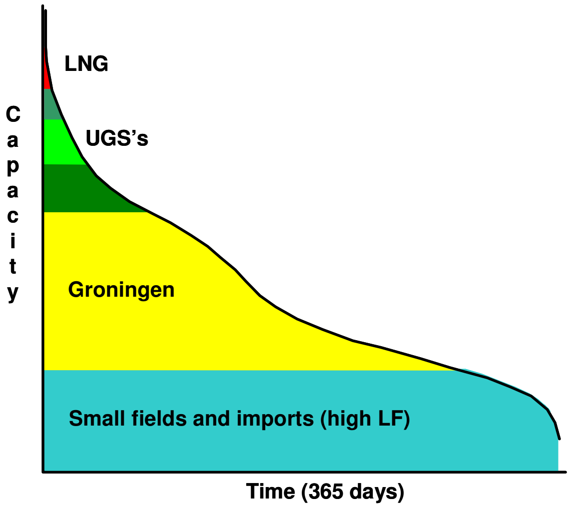
Technical aspects

State of the art technology is employed in the Groningen system in order to maximise operational flexibility and minimise cost. After finalisation of the Groningen Long Term investment project in 2009, the Groningen field can be operated remotely. The UGS's Norg and Grijpskerk are also designed around a minimal manning philosophy. On the UGS's, big bore wells have been drilled with 7 5/8" completion strings that deliver typically some 7,5 10^6 m^3/d.

Business

With a gradual decline of available production capacity in a relative mature hydrocarbon province such as The Netherlands, it is expected that – during the coming decades - there will be an increasing demand on capacity provision at both the high-end and the low-end of the Load Duration Curve (LDC), in order to guarantee security of Supply.

At the high-end of the LDC, capacity is provided for by sizeable investments such as cavern UGS's that deliver peak capacities when required. Such utilities are already being built just across the Dutch border in Germany.



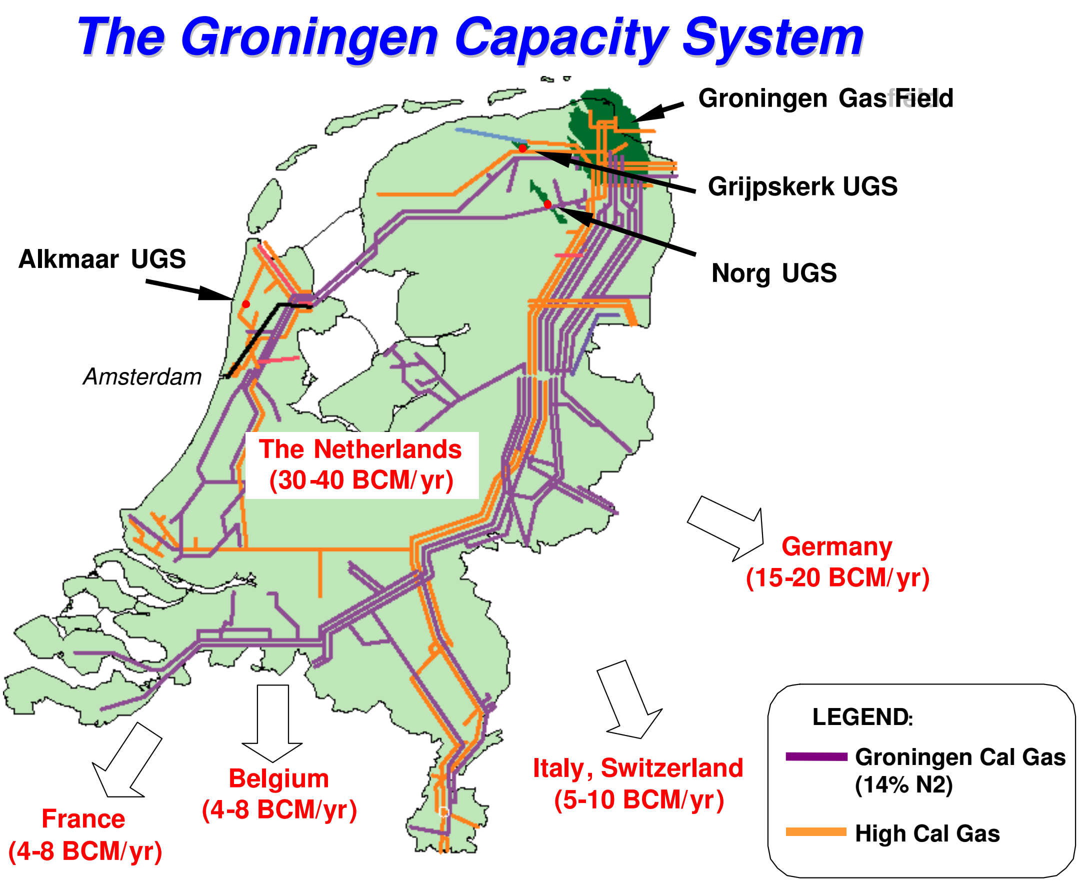
Load Duration Curve

Much higher capital investments will however be required to accommodate seasonal modulation of relatively large working volumes at the low-end of the LDC (figure below). These type of investments require long planning and engineering lead times, before such large UGS's can be taken into operation. At the moment there is a general trend to postpone such investment decisions, given the uncertainty of regulation issues that may be implemented by the European Union and (consequently) the Dutch Government.

The legal framework for the gas industry in the Netherlands is currently under political review. A first step has been taken by the government in 2005 , that separates Gasunie's gas transport network services from the "trade and supply" department. The Dutch Government is also expected to put measures in place that constrain the average volume offtake from the Groningen Field over a number of years.

Attachments

<u>**Overview of Dutch Gas Distribution System**</u>



Poland

General

One storage concession is required according to geological & mining law and another one regarding to energy law. A fee is 1,51 PLN/1000 m^3 of injected gas according to geological & mining law (a fee re. to energy law is unknown). A company which is engaged in turnover of natural gas with foreign company should maintain stock of 3% planned annual import of natural gas.

UGS

-UGS Wierzchowice
The first stage of UGS development is planned to be completed after 2006. Working volume will reach 1,2 10^9 m³. The realisation of the project depends on growth of the gas market and a tariff policy.

- UGS Mogilno

The first stage of UGS development is completed. Working volume is 416,73x10^6 m³ with the maximum daily withdrawal rate of 20x10^6 m³ in the withdrawal season 2005/2006. A decision about extension of the UGS will be taken after assessment of the economy and needs of the transmission system.

- Two UGS for low methane natural gas (LMNG) system will be developed in the near future:

UGS Daszewo – planned in oil field for gas of nominal Wobbe index of 35 MJ/m^3. It will provide 30x10^6 m^3 working volume and 17x10^3 m^3 withdraw capacity in the first stage. The facility would switch to storage of HMNG after depletion of the local LMNG fields.
UGS Bonikowo – a facility for LMNG gas of nominal Wobbe index of 41,5 MJ/m^3; it is planned to have 32x10^6 m^3 working volume and 11x10^3 m^3 withdraw capacity in 2006.

- Odolanow
The nitrogen removal plant in Odolanow, as a regulator for LMNG of nominal Wobbe index of 35 MJ/m³, provides arbitrage between two gas systems: LMNG (nominal Wobbe index of 35 MJ/m³) and high methane natural gas (nominal Wobbe index of 45,0-54,0 MJ/m³).

- So far POGC has not been offering UGS services separately. No UGS tariffs are published so far.

- Some projects for developing independent UGS facilities have been prepared – none seems feasible before real deregulation of the gas market.

Russian Federation

UGS facilities in Russia are currently operated by nine gas transmission and one gas production wholly - owned subsidiaries of Gazprom.
Part of Russia's United Gas Transmission System, the UGS depots help secure reliable gas supply to domestic and foreign customers over the autumn-winter heating season.
Today Gazprom owns UGS facilities with a total working capacity of 62,6 10^9 m³, and over 30 10^6 m³ stock piled as long-term reserves.
As of the beginning of the withdrawal season the UGS's maximum and average daily send-out capacity over December to February reaches 568 10^6 m³ and 477 10^6 m³, respectively. In January 2005 the maximum daily send - out was 493,9 10^6 m³ and within the 2004-2005 retrieval period the combined maximum daily send out accounted for 537 10^6 m³.

In 1958 first gas was injected into a depleted gas field and in 1959, into a new water - bearing structure not far from Moscow (nowadays the Kaluga UGS facility). At present Gazprom operates 24 UGS reservoirs including seven and seventeen constructed in aquifers and depleted gas fields. Some UGS facilities are unique by technological and geological parameters listed below:

- The world's largest depleted gas field-based UGS depot with the 20 10^9 m³ active capacity
- The world's largest UGS facility built in an aquifer (19,0 10^9 m³ of overall capacity)
- UGS facility constructed in a practically horizontal aquifer
- UGS facility in low-amplitude aquifer traps
- UGS facility in an aquifer with non-hermetic fractures
- UGS facility in fully flooded gas fields with maximum working pressure exceeding initial layer pressure by an up to 1,45 coefficient
- UGS facility with unconsolidated sands
- UGS with an hard water drive
- Other UGS facilities

Gazprom's future projections include developing UGS networks in Russia with a focus to be placed on increasing the UGS daily send out planned to reach 700 10^6 m3/d over the nearest five - year period.

Currently Gazprom is involved in the construction of new UGS in aquifers including two in rock salt caverns, with a string of several more geological structures under survey & scrutiny. An upgrading & an automation program for existing UGS facilities is in a progress.
While implementing the intra-corporate policy of dividing its multi profile subsidiaries by business types, Gazprom intends to spin out UGS units from transmission affiliates and consolidate the former within the Gazprom-UGS company.
Establishing Gazprom-UGS Ltd will enhance the underground gas storage business efficiency and will bolster better management and economic transparency of Gazprom in general.

Slovakia

General

Natural gas is an important energy source for Slovakia with a total year consumption amounted to nearly 7 10^9 m^3. Slovakia operates one of the most developed distribution networks in Europe as 94 % of Slovak inhabitants have been connected to a gas distribution network in the previous years. Taking that into account, the growing potential for households achieved its limits especially after deregulation of gas prices. Over the next decade, there is estimated only a slight growth of natural gas consumption which is believed to be driven mainly by the sector of combined heat and power generation.

Most of natural gas consumption is covered by supplies from Russia. At the present time, domestic production does not represent a considerable amount and continues to be slightly decreasing. The main transmission system, delivering natural gas from Russia to Western Europe, leads through Slovakia, which guarantees certain security of gas supply for the domestic market. As declared, within a draft of a document of Slovak energy policy, security of supply is to be influenced by UGS capacity and mutual interconnections of gas grids.

UGS facilities are located only in the southwestern part of Slovakia near Slovak-Austrian borders. Thanks to favourable geological conditions of the northern part of the Vienna basin, existing UGS provide sufficient storage capacity for Slovakia. The UGS were originally designed mainly for seasonal balancing of gas consumption; however, during a winter period, they can provide a very responsive tool even for covering fluctuations on daily basis.

Legal

Since joining EU, Slovakia has experienced a completely changed environment. New energy legislation speeds up liberalization of gas market and strictly separates gas supply from a process of gas transmission and distribution. Moreover, it strengthens rights of customers and creates conditions for gas market.

The framework of storage business is laid down mainly in two acts: the Energy Act and Regulation Act. The primary legislation is developed by secondary legislation as Gas market rules and decrees issued either by the Ministry of Economy or the Regulatory office.

The Energy Act stipulates rights and responsibilities of parties involved in energy market. Furthermore, the Act puts emphasis on safe, reliable and effective operation of storages with minimum environmental impact. In accordance with the Energy Act, an operator of storage services needs a license.

The access to storage services is negotiated between operator and gas market participants in compliance with Gas market rules. The part of storage capacity is dedicated solely for the distribution system operator for the purpose of a network balancing.

In line with energy legislation, storage operators were obliged to publish their Rules of Operation, which lay down business conditions for access and use of storages and Technical conditions for access and connections to storages specifying minimum technical requirements, parameters and operation of storages.

Environmental

The increase of environmental efficiency is the main focus of all the involved parties. The main reason is to ensure an efficient utilization of energy and prevent it from being wasted. At the moment, there are limited environmental constraints which prevents construction or operation of UGS provided that an operator follows the conditions determined by environmental authorities. Under some circumstances environment impact assessment is required. In line with the Greenhouse gas emission trading Act, UGS operators are obliged to monitor and reduce the amount of produced CO_2 to meet assigned emission quotas. In line with the Air Protection Act, equipment with a prescribed installed power as gas turbines or burners of heaters, re-boilers have to be regularly certified by an authorized company to ensure meeting emission targets. Moreover, the Water Protection Act imposes to revamp storage facilities in order to guarantee a minimal risk of poisonous or hazardous liquids leakage. Pursuant to the Water Protection Act, UGS facilities are equipped with filling platforms to ensure capture of potential leakages during loading and off-loading of hazardous liquids from/to a truck. Hazardous liquids as methanol, glycols or reservoir water are stored either in double shell tanks or single shell tanks placed within leakage sump.

Technical trends

Concerning subsurface, 3D seismics, new methodologies and software tools are applied to depict as precisely as possible a geological reality i.e. geological structure, its extension and tightness of reservoir trap. Deliverability tests are involved to characterize production parameters of a particular storage well and reservoir properties and parameters of drainage area. Moreover, complex reservoir models are applied to provide a tool to optimize storage processes and forecast different scenarios of its development.

There is a strong tendency towards reduction of storage wells number and a preference of wells with higher deliverability whereby a special attention is given to the safety of UGS operation. Safety valve systems, including subsurface valves, are deployed in the completion of the storage wells. Surface facilities of UGS are revamped ensuring their compliance with the latest environmental and safety standards and regulations.

Spain

General Trends:

Spain is an energy importing country with a negligible domestic production. About 22 % of the total primary energy is provided by natural gas.
In 2004 27,5 10^9 m³ of natural gas was consumed, in 2005 the demand increases to about 33,5 10^9 m³ with a contribution of the electric generation of 9,55 10^9 m³ mainly by the 32 combined cycle units, in the year 2010 a total of 90 C.C.-units are planned to be in operation with a gas consumption of about 25 10^9 m³ over a total demand of 43,5 10^9 m³ .

Around 40% of this gas comes through the two pipelines from Algeria and France and the rest is imported as LNG from different countries (Algeria, Nigeria, Qatar, Trinidad & Tobago, Egypt, Abu-Dhabi, etc.) and re-gasified in the existing 4 re-gasification plants.
Two new pipelines from Algeria and France and three more re-gasification plants are planned or under construction.

Because around 82% of the gas is delivered to industrial users and to power plants and there is a peak demand of electricity in summer due to the air conditioning and the increase of population, the fluctuation in gas demand is much lower than in the rest of Western Europe.

In the next years the storage business is to be regulated by the government. The tariff will be fixed and there will be obligation to provide strategic reserves. As gas demand is increasing the storage business is a growing activity for both strategic and modulation purposes. More companies are expected to enter the Spanish gas market.

In 2005 Spain has 2 underground gas storage facilities in operation with a total maximum allowable working gas volume of 2,12 10^9 m³ and a total max. withdrawal rate of around 12,6 10^6 m³/day.

Gaviota is a depleted offshore gas field and is operated by Repsol-YPF on behalf of Enagas and Serrablo is a depleted onhore gas field owned and operated by Enagas who is the only UGS operator today.

Other structures are planned to be developed or adapted for UGS:

- Yela deep aquifer structure in development phase by Enagas
- Reus deep aquifer structure in appraisal phase by Enagas
- Poseidon depleted offshore gas field by Repsol-YPF
- Castor offshore oil field by Petroleum Oil Co.

Is also ongoing a feasibility study to increase capacity in Gaviota.

Environmental Aspects:

Exploration and operation activities in UGS are subject to environmental impact assessments ("Estudio de Impacto Ambiental") and to public inquiry.
The holders of an exploration permit do not implicitly have the right in Spain to obtain a permit to develop storage facilities. The applications for storage permission are required independent of existing development permits. This application and the operation of UGS are subject to regulations according to hydrocarbons act of 1998 (“Ley de Hidrocarburos”), in accordance with this law, the acquired subsurface geological data are submitted to the Ministry of Industry.

Ukraine

Ukraine is operation the third biggest UGS system in the world behind the USA and Russia. 13 storage facilities can provide an installed working gas volume in the order of 32 10^9 m³.

The basic functions of Ukrainian underground gas storages are:

- Regulation of seasonal irregularity in gas consumption
- Additional gas submission to consumers at extreme decreases in temperature, both in separate days, and during abnormally cold winters
- Creation of long-term reserves of gas at occurrence of unforeseen extreme situations, such as the long-term termination of gas supply as a result of the big failures, acts of God, etc.
- Reservation of gas on a case of occurrence of short-term emergencies in a gas supply system
- Reliability control of export gas transit through the territory.

The United Kingdom

THE CASE FOR UNDERGROUND GAS STORAGE (UGS)

Memorandum by British Geological Survey
Dr David Evans, Dr Sam Holloway, Dr Nick Riley, 25 March 2004
Published by The UK Parliament

BACKGROUND

1. In Western Europe, gas penetration in the residential and commercial sectors has now reached about 44 per cent. In line with this trend, United Kingdom gas consumption has more than doubled over the past 10 years, and gas now holds a key position as an energy source, both as a primary fuel (for heating and cooking) and for electricity generation.

2. The gas supply industry has to adjust to very wide seasonal variations in consumption due to rapidly changing electricity, heating and air conditioning requirements.

3. Thanks to its huge reserves of North Sea gas and oil, Britain is the only G7 country other than Canada still largely self-sufficient in energy. The United Kingdom continues to enjoy a high level of diversity and security of supply, but this is changing rapidly.

4. Although the United Kingdom is still a net exporter of natural gas, there are times during peak demand when it has to import foreign gas to meet its needs. In the course of 2000, the United Kingdom imported about 2 per cent of its gas demand of about 97 bcm (billion cubic metres) per year. The Department of Trade and Industry's (DTI) projections are of United Kingdom gas import dependency rising to more than 58 per cent of demand by 2010, and 90 per cent of demand by 2020. National Grid Transco predicts that net imports of gas will exceed domestic production in 2008-09 and will reach 70 per cent by 2014.

5. Our coming reliance on "less secure" external supply sources makes it necessary to be on guard against any risk of supply shortages or major disruption, be it technical as in an accident (such as the explosion at the Esso Longford gas plant in 1998 in Victoria, Australia, which disrupted supplies across the State for nearly two weeks), or political such as following a terrorist attack.

UNITED KINGDOM GAS DEMAND AND LIKELY TRENDS

6. 50 years ago Britain's coal mines supplied almost 90 per cent of our energy needs, with crude oil providing the rest. This changed rapidly with the advent of nuclear power plants in the mid-1950s, and the subsequent discovery of North Sea gas. The "dash for gas" occurred in the power generation sector in the 1980s, when coal-fired power stations were replaced with gas-fired equivalents. There was a continued shift in the balance between gas and coal in the period 1996-2001, due to the abundance of gas supplies from the North Sea combined with low gas prices on international markets.

7. The recent rise in gas prices has led to some generating companies considering the option of mothballing gas-fired plants, and at least one United Kingdom coal-fired power station has been brought back into service. Despite this, gas is, and will remain, an increasingly important fuel for electricity generation. The DTI predict that gas could form the energy source for 70-80 per cent of the United Kingdom's electricity generation needs by 2020. This is not only because it has been cheap and easy to obtain, but also because it is not clear that alternative fuels will be available. Nuclear energy production is predicted to decline over the next 15 to 20 years unless circumstances, including Government policy towards that energy source, change. At present, the significant contribution to energy needs from coal-fired electricity generation will become increasingly difficult to reconcile with the Government's environmental targets for the reduction of carbon dioxide emissions, as well as more stringent European Union Directives which will affect other emissions, such as particulates, sulphur oxides and nitrous/nitrogen oxides, in addition to carbon dioxide.

8. The DTI expects demand for gas, both for electricity generation and for direct (domestic and commercial) use, to rise gradually, from about 108 bcm (90 Mtoe [million tonnes of oil equivalent]) in 1999 to more than 144.6 bcm (120 Mtoe) by 2020, although demand will depend on changes in the cost of alternatives on international markets. On this basis, annual United Kingdom demand is predicted to exceed production capacity on the UKCS by 2005 (two years earlier than National Grid Transco predict), with imports concentrated in the winter months. As indicated above, the DTI projections are of United

Kingdom gas import dependency rising to more than 76 bcm (63 Mtoe), or 58 per cent of demand by 2010, and to 133 bcm (110 Mtoe) or 90 per cent of demand by 2020.

THE NEED FOR MORE UNDERGROUND GAS STORAGE FACILITIES

9. These projections, if realized, will require the creation of an infrastructure capable of dealing with the problem of fluctuating demand and guaranteeing security of supply. France, Germany and Italy each have gas storage capacity in excess of 20 per cent of annual consumption. Compared to these countries, the United Kingdom has very limited purpose-built natural gas storage facilities, providing for less than 4 per cent of annual consumption. What is more, more than 450 surface gas holders ("gasometers"), with a total storage capacity of 24 million cubic metres of gas at low pressure for delivery to domestic and industrial consumers, are scheduled to be phased out over the next 10 years or so, reducing total gas storage capacity.

10. There is currently no statutory requirement for the provision of strategic gas reserves, unlike in the coal and oil sectors. In the past, ready accessibility to United Kingdom gas reserves in our offshore gas fields may have justified the relatively low priority that has been attached to the development of strategic gas storage in the United Kingdom. However, given that the United Kingdom will become a major net gas importer in the near future and to guard against the unforeseen disruption of external supplies, Government, together with the industry, may wish to give serious consideration to the development of strategic storage capability. Among the solutions that might be considered, subsurface geological storage best fits the bill as the most reliable long-term storage option. Underground gas storage is safe, secure and reliable. Some countries, eg Hungary, which has to import all its gas, relies solely on underground natural gas storage to maintain grid supplies and hold strategic reserves. In comparison to liquefied natural gas (LNG) storage, there is little surface expression from the facility, lower fire and explosion risk, and less energy is expended in storage. Underground storage sites are already located within and around cities (eg Berlin and Paris).

UNDERGROUND GAS STORAGE FACILITIES

11. Natural gas is stored at surface in liquefied natural gas (LNG) receiving terminals, and underground gas storage facilities. The latter form strategic reserves and peak-shaving units, which can supply gas at a high rate in the cold season and over a short interval. In 1996-97, there were 580 underground storage sites worldwide, with a working capacity of 262 109 m3. Storage in porous and permeable formations (hydrocarbon reservoirs and aquifers) represents 98 per cent of the working capacity of all the storage facilities in the world.

12. The goal of underground gas storage is to balance gas consumption and resources at all times (seasonal, daily and hourly fluctuations) chiefly in the residential and commercial sectors, where demand is especially sensitive to changes in temperature. In addition, storage makes it possible to meet peak winter demand. The relative peak demand on the coldest day of the year is a very important parameter for the gas industry, because it conditions the size of the gas distribution network. In the United Kingdom the need to meet peak electricity demand accentuates peak gas demand because so much of the United Kingdom's electricity is now generated from gas rather than coal.

UNITED KINGDOM POTENTIAL FOR THE DEVELOPMENT OF FURTHER NATURAL GAS STORAGE FACILITIES

13. There are three types of large-scale underground natural gas storage facilities: salt caverns, depleted/depleting gas or oil fields, and aquifers:

14. Salt caverns. Salt cavities have been used to store liquid petroleum gas (LPG) for many years, but the technique (with respect to salt caverns) is relatively recent for pressurized natural gas. It was first introduced in the United States in 1961. Today, there are 54 storage facilities of this type worldwide, 26 of which are in the United States. This type of storage is developing rapidly and is particularly well suited to shallow underground storage where the need is to meet daily swing demand and intra-day peaks in demand. Caverns are created in the salt by solution mining (pumping fresh or sea water down a well drilled into the salt, dissolving it, and then recovering the produced brine via the well). These caverns can then be filled with pressurised natural gas. Thick natural deposits of salt are found underground in certain parts of the United Kingdom. United Kingdom storage facilities of this type include the caverns operated by Scottish and Southern Energy at Atwick, near Hornsea on the east coast. In the near term there are

potential opportunities for further facilities of this type in salt deposits in the Hornsea area, Cheshire, West Lancashire (Preesall and Walney Island areas), Northern Ireland, Teesside, Dorset and possibly North Somerset. The future potential of hydrogen storage in salt caverns is shown by the construction of a cluster of hydrogen production storage and distribution facilities, operated by Huntsman Petrochemicals at Teesside.

15. Depleting or depleted gas or oil fields. Gas storage in depleted fields is the most widespread method in the world and often the least expensive. Along with aquifer storage (see below) they are capable of storing very large volumes of gas and are particularly suitable for strategic storage and storage to meet seasonal demand swings. An advantage of using depleted natural gas, or oil fields, for underground storage is that they are known to be capable of storing natural gas or oil for geological time-scales—in many cases millions of years, and they can require less "cushion gas" (see below) than other underground storage scenarios. Furthermore, they have commonly been well characterized as a result of the gas or oil extraction programme. Today, there are 448 storage facilities located in depleted reservoirs worldwide. United Kingdom storage facilities of this type include Hatfield Moors gas field (Edinburgh Oil & Gas plc), which stores gas 1,800 metres below ground onshore to the East of Sheffield and the Rough gas field off the East Coast (Centrica Storage Ltd) that has been developed to store natural gas 3,000 metres underground. There are plans to develop some of the United Kingdom's onshore oil fields as natural gas storage facilities, eg Star Energy's Humbly Grove oil field, near Basingstoke and the Welton oil field, near Lincoln. These locations will also have the advantage of stimulating further oil production through restoring the oilfield pressure. Further opportunities are likely to exist amongst Britain's onshore oil and gas fields and offshore in the Southern North Sea.

16. Aquifers. Aquifers are porous and permeable sedimentary rocks, the pore spaces of which are filled with water rather than oil or gas. The principle of aquifer storage is to create an artificial gas field by injecting gas into the voids of an aquifer formation. Many deeper aquifers contain saline water that cannot be used for potable water supply or agriculture. Where they are confined beneath cap rocks (impermeable rocks which prevent escape of gas), they have the potential to store natural gas if a trap for buoyant substances, such as gas (such as a dome) is present. Injection and retrieval of the gas would be similar to a facility in a depleted natural gas field. More testing and development may be required than for depleted oil or gas fields. However, aquifers are more widely distributed than oil and gas fields or thick salt deposits, so they may provide opportunities where there is no potential for the other types of storage. There are 76 storage facilities in aquifers in the world today, most of them in the United States, the former Soviet Union and France.

RESEARCH NEEDS

17. The main research needs for developing gas storage in the United Kingdom salt caverns are to more closely locate and characterize thick salt deposits in order to better define areas of potential.

18. The main research needs for gas storage in oil and gas fields are to determine their geological suitability, eg some fields may not have sufficient permeability to allow gas to be recovered at appropriate rates, others may be too large, too small, or too deep to develop economically for gas storage purposes.

19. The main research needs for aquifers are to identify the location of suitable traps for buoyant gases within aquifers, which otherwise have the correct characteristics for gas storage.

20. A further research need is to create a Geographic Information System (GIS) for United Kingdom natural gas storage, which will locate and characterize potentially suitable sites in relation to other elements of the United Kingdom gas infrastructure. This could form an important national decision support tool for use by policymakers, regulators, planners and operators.

BARRIERS TO DEPLOYING UGS IN THE UNITED KINGDOM

21. Public perception is an issue with underground natural gas storage—see for example the web sites: http://www.overwyrefocus.co.uk/gas—storage/gas—articles.htm and http://www.nogasplant.co.uk/. Opposition is likely to be at the local level, given that the main perceived risks are local (eg risk of fire or explosion from a leaking facility, risk of ground movement). It is hard to see why security of energy supply and seasonal peak shaving (the main drivers for underground natural gas storage) could be perceived negatively. However, from a local perspective these benefits may be outweighed, or ignored, especially by property owners, as they are concerned that a new storage facility could impact on the value of house prices (a significant factor in other infrastructure planning such as onshore windfarms). There is no

obvious upside to living above, or near, an underground gas storage facility, but neither is there any significant downside, as surface facilities are very unobtrusive, quiet and easily hidden by careful landscaping and/or tree planting. Research into public perception could be commissioned if it is felt that the United Kingdom underground natural gas storage facilities should be expanded.

22. When asked in March 2004 about the development of gas storage facilities in underground caverns formed within deep rock salt deposits, the Secretary of State for Trade and Industry replied that "as Great Britain becomes increasingly dependent on imported gas it will be important that the market continues to provide sufficient flexibility to meet demand. Gas storage projects help do this. The Government therefore welcomes proposals for new projects. They must, of course, obtain necessary planning and other regulatory consents."

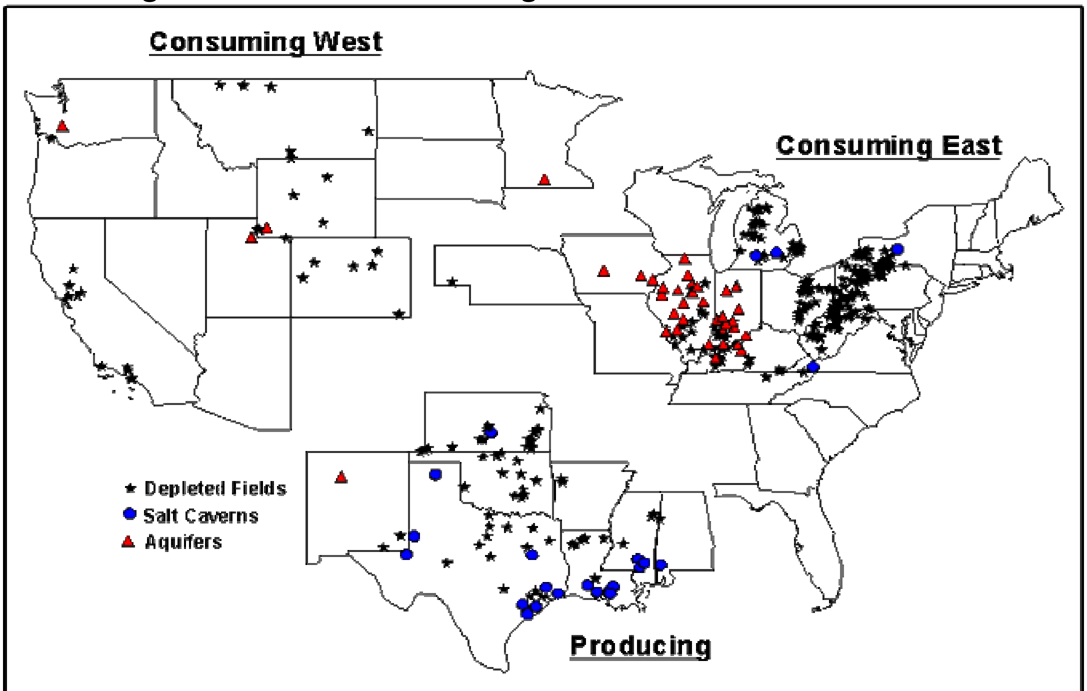
North America

by Fred Metzger using information from the American Gas Association (AGA) and the United States Energy Information Administration (EIA)

There are over 115 natural gas storage operators in the United States, with over 385 active underground storage facilities in 30 states. These facilities have a working storage capacity of nearly 3,500 Bcf of natural gas, and the capability of maximum daily deliverability of 80 Bcf per day. US storage operators manage about 15,000 injection/withdrawal wells of which about 120 are horizontal. The industry also operates about 3,000 pressure control or observation wells.

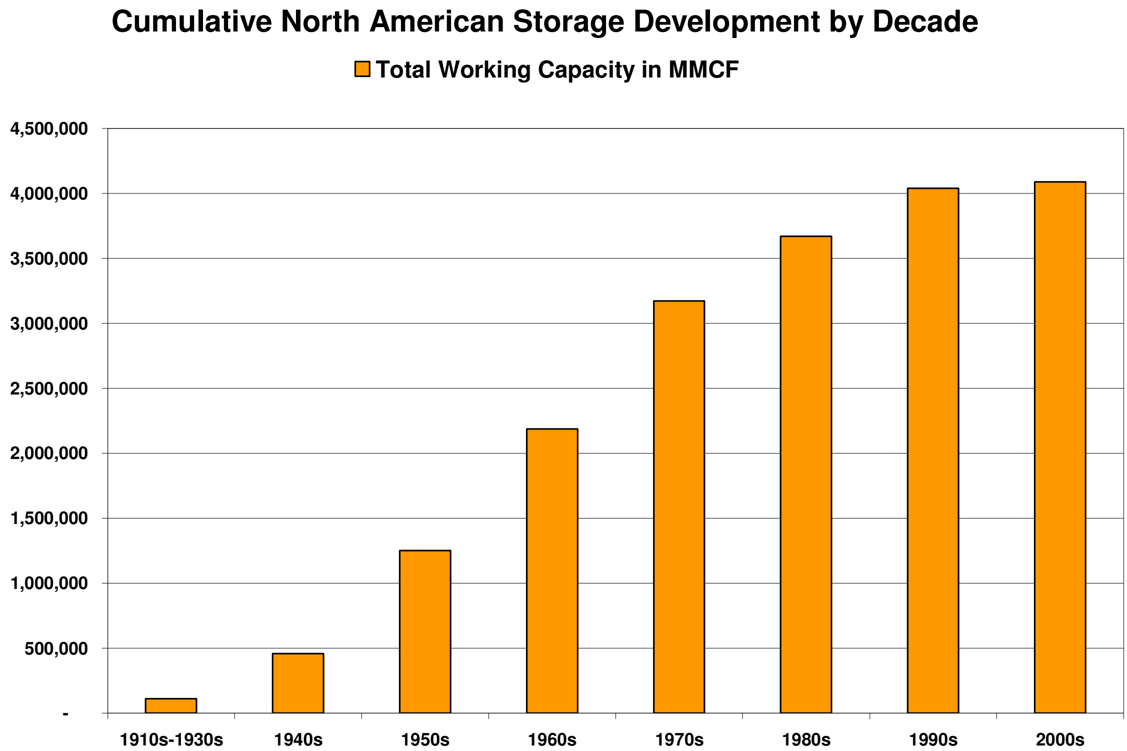
The 2004 AGA Storage report indicates that there are 7 natural gas operators in Canada, with over 50 underground storage facilities in 5 provinces. These facilities have a working storage capacity of over 530 Bcf of natural gas, and the capability of maximum daily deliverability of close to 5 Bcf per day. Canadian storage operators manage nearly 500 injection/withdrawal wells of which about 30 are horizontal. The industry also operates about 150 pressure control or observation wells.

Underground Natural Gas Storage Facilities in the Lower 48 States



Source: Energy Information Administration (EIA), EIA GasTran Geographic Information System Underground Storage Data Base.

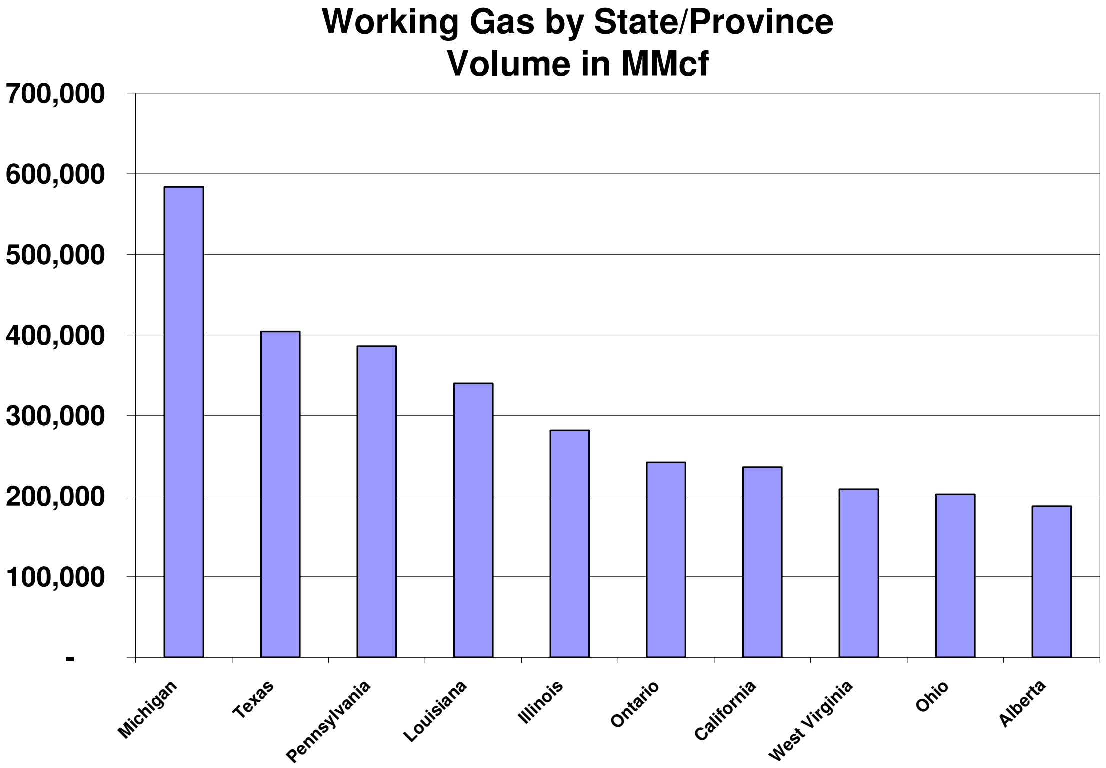
The first instance in North America of successfully storing natural gas underground occurred in Weland County, Ontario, Canada, in 1915. This storage facility used a depleted natural gas well that had been reconditioned into a storage field. In the United States, the first storage facility was developed just south of Buffalo, New York. The Zoar field was discovered in 1888 and converted to natural gas storage in 1916. It is the oldest continuously operated storage field in North America. By 1930, there were nine storage facilities in six different states.



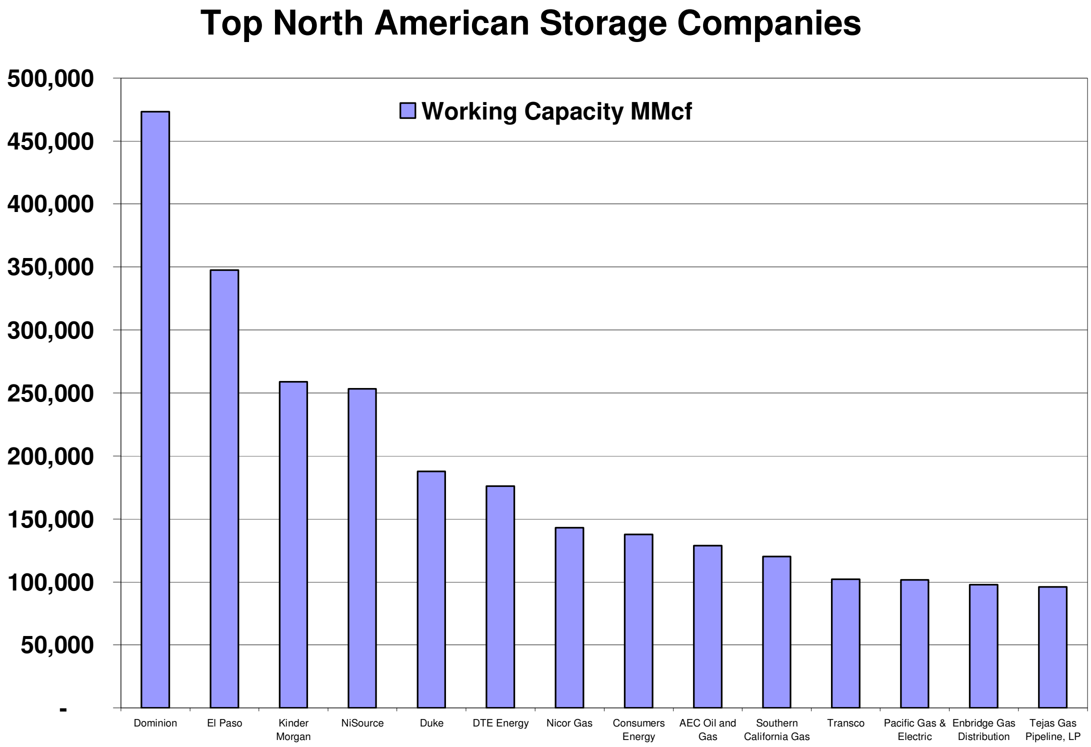
The development of underground natural gas storage fields grew rapidly after World War II. (See chart above). At the time, the natural gas industry realized that seasonal demand increases could not feasibly be met by pipeline delivery alone. In order to meet seasonal demand increases, the size and deliverability of pipelines, would have to increase dramatically. However, the technology required to construct such large pipelines to consuming regions was, at the time, unattainable and unfeasible. In order to be able to meet seasonal demand increases, underground storage fields were the only option.

The slowdown in the growth of storage field development in the 1990's is a direct result of changes in market requirements and the implementation of Federal Energy Regulatory Committee (FERC) Order 636. Prior to 1994, interstate pipeline companies, which are subject to the jurisdiction of the FERC, owned all of the gas flowing through their systems, including gas held in storage, and had exclusive control over the capacity and utilization of their storage facilities. Following FERC Order 636, jurisdictional pipeline companies were required to operate their storage facilities on an open-access basis. That is, the major portion of working gas capacity at each site must be made available for lease to third parties on a nondiscriminatory basis. Pipeline operators are still able to reserve gas volumes required to maintain system integrity and for load balancing.

Today, in addition to interstate pipeline storage, many storage facilities owned and operated by large local distribution companies (LDCs), intrastate pipelines, and independent operators also operate on an open-access basis, especially those sites affiliated with natural gas market centers. Open access has allowed storage to be used other than simply as backup inventory or a supplemental seasonal supply source. For example, marketers and other third parties may move gas into and out of storage (subject to the operational capabilities of the site or the tariff limitations) as changes in price levels present arbitrage opportunities. Additionally, storage is used in conjunction with various financial instruments such as futures and options contracts, swaps, etc. in ever more creative and complex ways in an attempt to profit from market conditions. Reflecting this change in focus within the natural gas storage industry during recent years, the largest growth in daily withdrawal capability has been from high deliverability storage sites, which include salt cavern storage reservoirs as well as some depleted oil or gas reservoirs. These facilities can cycle their inventories or completely withdraw and refill working gas (or vice versa)-more rapidly than can other types of storage, a feature more suitable to the flexible operational needs of today's storage users. Since 1993, daily withdrawal capability from high deliverability salt cavern storage facilities has grown significantly. Nevertheless, conventional storage facilities continue to be very important to the industry as well.



The State of Michigan has the largest volume of working capacity in the United States. The reason is primarily based on geology, but can also be attributed to the fact that it is in the industrial heartland of the United States and its industry spurred the early development of storage fields after World War II. University of Michigan professor Dr. Donald L. Katz was a pioneer in development of storage field technology, and provided significant consulting to the Michigan natural gas utility and pipeline companies during the rapid growth period of the 1950s to the 1970s.



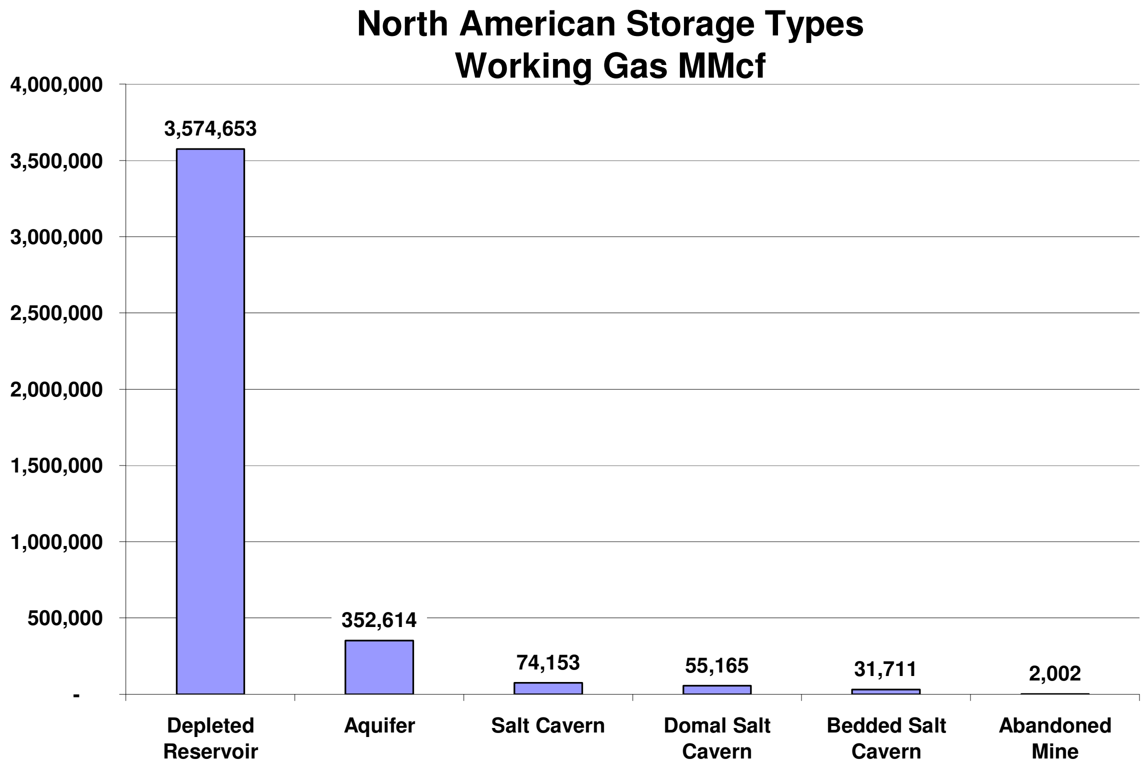
The principal owners/operators of underground storage facilities are (1) interstate pipeline companies, (2) intrastate pipeline companies, (3) local distribution companies (LDCs), and (4) independent storage service providers. If a storage facility serves interstate commerce, it is subject to the jurisdiction of the Federal Energy Regulatory Commission (FERC); otherwise, it is state-regulated.

Owners/operators of storage facilities are not necessarily the owners of the gas held in storage. Indeed, most working gas held in storage facilities is held under lease with shippers, LDCs, or end users who own the gas. On the other hand, the type of entity that owns/operates the facility will determine to some extent how that facility's storage capacity is utilized.

For example, interstate pipeline companies rely heavily on underground storage to facilitate load balancing and system supply management on their long haul transmission lines. 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 also use storage capacity and inventories for similar purposes, in addition to serving end-user customers.

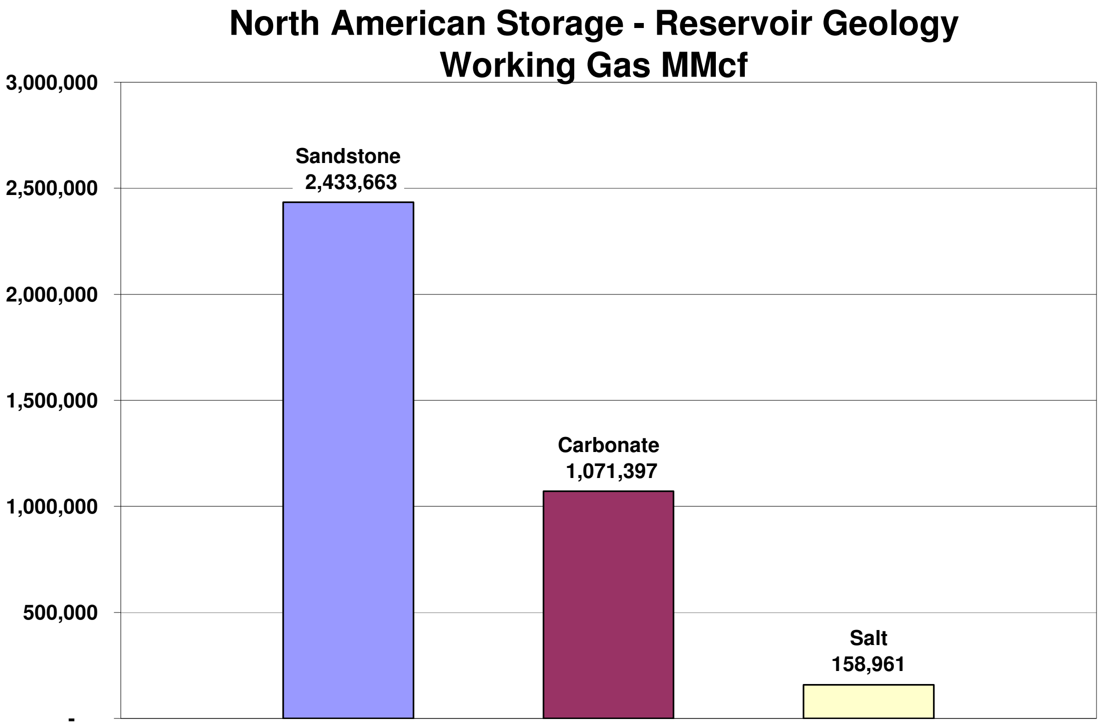
In the past, LDCs have generally used underground storage exclusively to serve customer needs directly. However, some LDCs have both recognized and been able to pursue the opportunities for additional revenues available with the deregulation of underground storage. These LDCs, which tend to be the ones with large distribution systems and a number of storage facilities, have been able to manage their facilities such that they can lease a portion of their storage capacity to third parties while still fully meeting their obligations to serve core customers. These arrangements are subject to approval by the LDCs' respective state-level regulators.

The deregulation of underground storage has combined with other factors such as the growth in the number of gas-fired electricity generating plants to place a premium on high-deliverability storage facilities. Many salt formation and other high deliverability sites, both existing and under development, have been initiated by independent storage service providers, often smaller, more nimble and focused companies started by entrepreneurs who recognized the potential profitability for these specialized facilities. They are utilized almost exclusively to serve third-party customers who can most benefit from the characteristics of these facilities, such as marketers and electricity generators.



Most existing gas storage in the United States is in depleted natural gas or oil fields that are close to consumption centers. Conversion of a field from production to storage duty takes advantage of existing wells, gathering systems, and pipeline connections. Depleted oil and gas reservoirs are the most commonly used underground storage sites because of their wide availability and lower cost to operate.

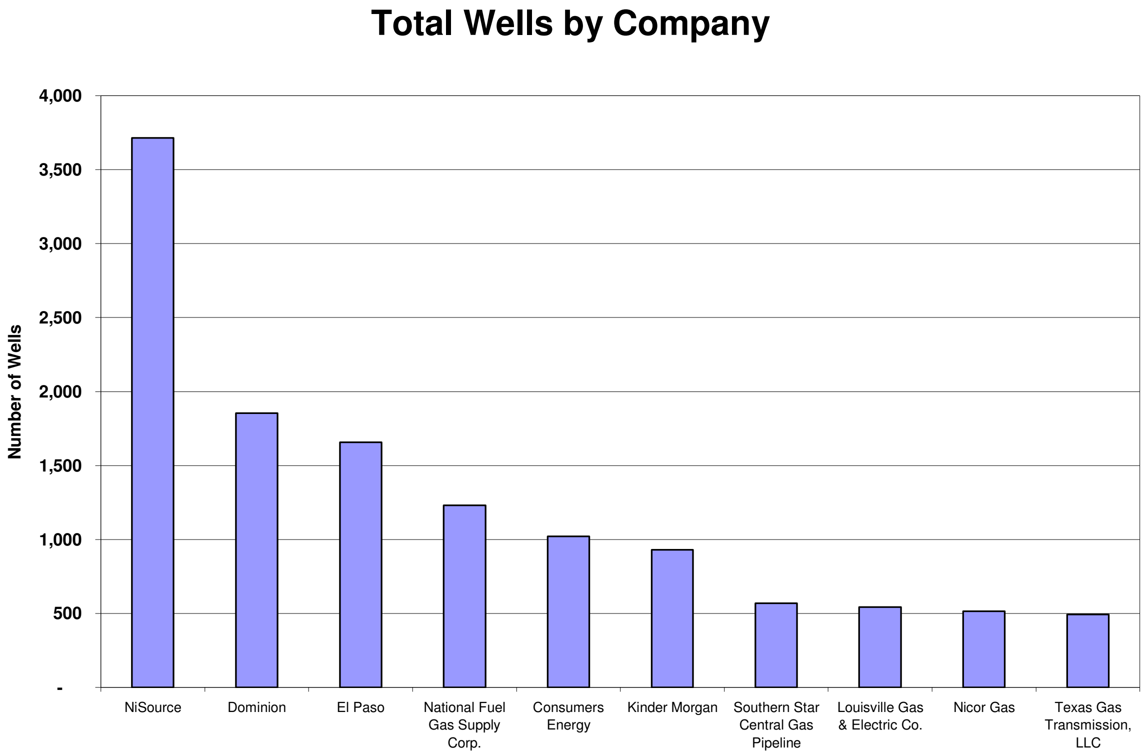
In some areas, most notably the Midwestern United States, natural aquifers have been converted to gas storage reservoirs. An aquifer is suitable for gas storage if the water bearing sedimentary rock formation is overlaid with an impermeable cap rock. While the geology of aquifers is similar to depleted production fields, their use in gas storage usually requires more base or cushion gas and greater monitoring of withdrawal and injection performance. Deliverability rates may be enhanced by the presence of an active water drive.



Salt caverns provide very high withdrawal and injection rates relative to their working gas capacity. Base gas requirements are relatively low. The large majority of salt cavern storage facilities have been developed in salt dome formations located in the Gulf Coast states. Salt caverns have also been leached from bedded salt formations in Northeastern, Midwestern, and Southwestern states. Cavern construction is more costly than depleted field conversions when measured on the basis of dollars per thousand cubic feet of working gas capacity, but the ability to perform several withdrawal and injection cycles each year reduces the per-unit cost of each thousand cubic feet of gas injected and withdrawn.

Many of the carbonate reservoirs are ancient coral reefs. These reefs make excellent storage reservoirs. They have very good porosity and permeability resulting in very high deliverability. Additionally they usually are capped by evaporate deposits such as salt or anhydrite which provide excellent seals and containment.

There have been efforts to use abandoned mines to store natural gas, with at least one such facility having been in use in the United States in the past. Additionally, the potential for commercial use of hard-rock cavern storage is currently undergoing testing. None are commercially operational as natural gas storage sites at the present time.



There are over 19,000 storage facility wells in North America, and many of them are 80 to 100 years old. These wells require continual maintenance and remediation to maintain storage field integrity and deliverability requirements. Throughout the 1990's and up until 2004 the major source of natural gas research and development (R&D) funding was provided by a mechanism imposed by the Federal Energy Regulatory Committee (FERC), but that funding was phased out entirely by 2004. At its peak, the FERC funding program raised approximately $212 million per year. A very small percentage of those funds were used for underground gas storage research. Most of that research was directed by an industry steering committee co-coordinated by the Gas Research Institute (GRI). It was determined by that committee that the primary focus for underground storage research should be on maintaining storage field integrity, storage field deliverability, and on the design and operation of storage caverns.

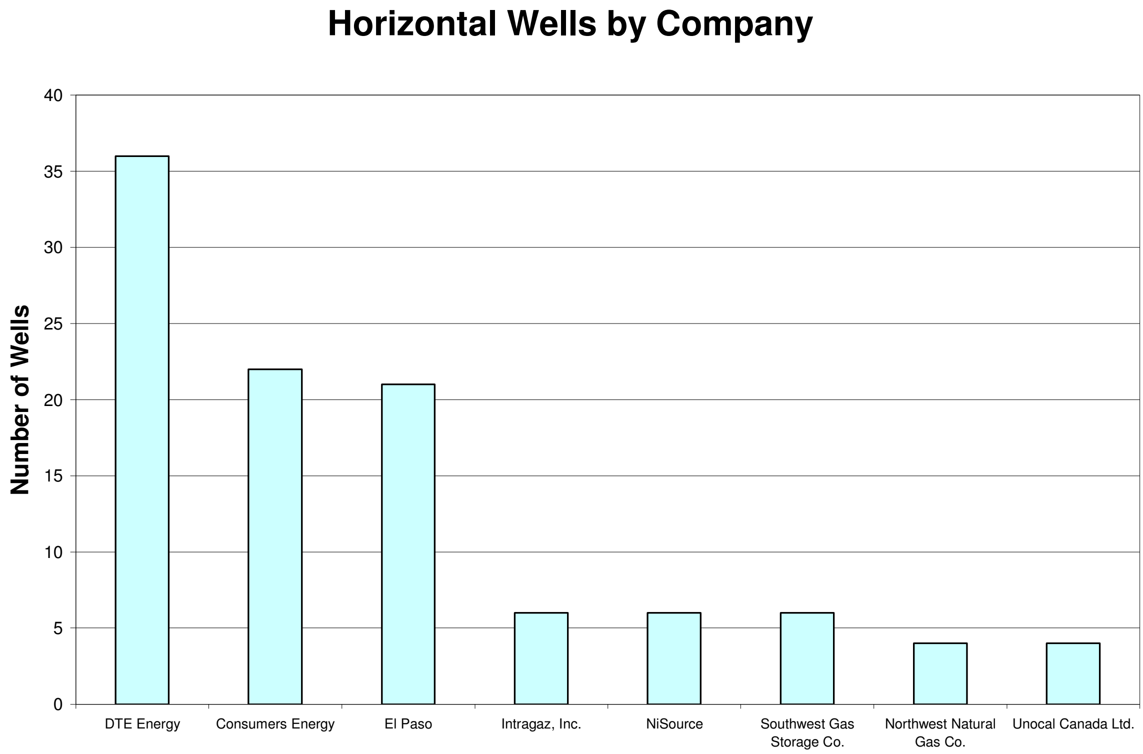
Important work was completed using the FERC R&D funding mechanism. Studies documented that deliverability decline is a consistent and inherent problem in all types of storage fields. Declines average between 2% and 8% per year depending of the geology and use of the storage formations. Causes of this deliverability decline were identified and remediation technologies studied and demonstrated in the field. Many storage operators have incorporated this important research in their operations and have increased capacity and deliverability of existing storage fields and at the same time abandoned poorer performing high cost fields.

Methods employed presently for deliverability enhancement and maintenance include, but are not limited to:

- Horizontal Drilling
- Acid Stimulations
- Fresh Water Washes
- Delta Pressuring
- Down Hole Remediation

- Coiled Tubing Clean-outs
- Fracture Treatments
- Well bore Enhancement (re-perforating, deepening, under reaming)
- Surface Facility Improvements (compression, processing, gathering lines, safety equipment)

The applicability of deliverability enhancement methods is dependent upon storage facility type and geology. Natural gas storage operators are estimated to have invested at least $1 billion over the past few years for storage facility deliverability maintenance and enhancements.



The storage industry began applying horizontal drilling technology in the early 1990's. This technology has proven very successful in improving both capacity and deliverability. DTE Energy has used this technology in a 50 year old storage field and replaced hundreds of old vertical wells with about 30 horizontal wells. This specific project has improved deliverability, improved storage field integrity and reduced O&M costs.
Current gas storage research activities are coordinated through the Gas Storage Technology Consortium (GSTC). The mission of the GSTC is to assist in the development, demonstration, and commercialization of technologies to improve the integrity, flexibility, deliverability, and cost-effectiveness of the United States' underground gas storage facilities. Its projects are primarily funded by the US Department of Energy (DOE) with co-funding provided by the storage industry, universities and service companies.

The economics of supply and demand dictate business decisions associated with the development of new storage capacity. New underground storage development requires viable subsurface geologic conditions, incremental market demand, pipeline infrastructure for gas transportation and a corresponding volume of upstream gas supply. As intended in the Federal Energy Regulatory Commission's (FERC) restructuring of the pipeline system, the market has been and continues to be the driving force for such investments.
New underground storage projects will effectively be built to the extent that committed long-term markets support such investments. According to the Energy Information Administration's (EIA), September 2004

report, U.S. Natural Gas Pipeline and Underground Storage Expansions in 2003, more than 73 underground natural gas storage projects have been proposed for the period between 2004 and 2008. Twenty-six are new facilities, and 47 are expansions to existing facilities. These projects have the potential to add as much as 346 Bcf to existing working gas capacity and 17 Bcf/d to daily withdrawal capability.

10. Lessons learned, further improvement and proposals for the next triennium

The Basic UGS Activity Study of Study Group 2.1 should be carried on as well in the following trienniums. Because of work load respectively availability of contributors, support of the study is insufficient. Other ways of working should be considered in the following Triennium, e.g. by cooperation with consultants. Further improvements are proposed for the oncoming Triennium:

- Continuous completion of database, especially incorporating ”new“ storage countries and planned projects
- Incorporation of additional data: split between oil-/gas fields, company shares in individual storage facilities
- Participation of additional countries and active participants in the study work for data collection and derivation of trends
- Development of a standard data bank platform on the IGU website
- Incorporation of the pipeline system in the geo-referenced visualisation
- Extended incorporation of status and trends of the storage industry on a country basis
- Development of a more detailed prognosis on storage demand in corporation with institutes/consulting companies incorporating all relevant elements related to gas demand and gas supply variables (LNG-supplies, load, sources of supply and flexibility)
- Demonstration of best practice operation by examples.

11. Contact Address

In case of any additional questions and for support please contact:

Joachim Wallbrecht
BEB Transport und Speicher Service GmbH
Riethorst 12
D-30659 Hannover
Germany
☎: +49-(0)511 - 641-2294
Fax: +49-(0)511 - 641-2554
e-mail: Joachim.Wallbrecht@BEB.de

Attachments

Attachment 1 -	Study Group members
Attachment 2 -	Summary - UGS in the world
Attachment 3 -	Summary - UGS in the world by nations
Attachment 4 -	Glossary of relevant technical Underground Gas Storage Terminology
Attachment 5 -	Relevant terms used in the Basic Activity Study - Units and definitions -

Attachment 1

Study Group Members

Czech Republic		Grigelova, Petra
Crotia		Tancer, Davorka
France		Wicquart, Emmanuelle
Austria		Kreuz, Michael
Czech Republic		Blazej, Radim
		Luner, Karel
		Onderka, Vladimir
Japan		Tanazawa, Satoshi
The Netherlands		Ketting, Joost
Romania		Stancu, Lucian
Russia		Dr. Khan, Sergeij
Slovakia		Goryl, Ladislav
Spain		Pinilla, Francisco
USA		Metzger, Frederick
Germany		Dr. Brauner, Hans-Jürgen
Germany	- Study Leader -	Wallbrecht, Joachim *

Attachment 2

UGS IN THE WORLD
SUMMARY 2004

Region	UGS in operation Nations	Storage Type	UGS in operation									New Greenfield UGS Projects		Total	
			Installed Capacities					Planned Projects in existing UGS		Undeveloped Capacities in existing UGS					
			No. of UGS	Working Gas Volume [10^6 m³]	Cushion Gas Volume [10^6 m³]	Peak Withdrawal Capacity [10^3 m³/h]	Injection Capacity [10^3 m³/h]	Working Gas Volume [10^6 m³]	Peak Withdrawal Capacity [10^3 m³/h]	Working Gas Volume [10^6 m³]	Peak Withdrawal Capacity [10^3 m³/h]	Working Gas Volume [10^6 m³]	Peak Withdrawal Capacity [10^3 m³/h]	Working Gas Volume [10^6 m³]	Peak Withdrawal Capacity [10^3 m³/h]
America		Oil-/gasfield	348	101.331	100.785	75.555	87			120	80	0	0	101.451	75.635
		Aquifers	51	9.960	26.847	10.309	0				0	1.700	0	11.660	10.309
		Salt Cavern	36	4.518	2.107	15.112	0				0	0	0	4.518	15.112
		Rock Cavern	0	0	0	0	0				0	0	0	0	0
		Abandoned Mi	1	57	22	218	0				0	0	0	57	218
	3	**Total**	**436**	**115.866**	**129.761**	**101.194**	**87**	**0**	**0**	**120**	**80**	**1.700**	**0**	**117.686**	**101.274**
Asia		Oil-/gasfield	10	5.626	1.400	1.661	105			1.000	0		0	6.626	1.661
		Aquifers	2	653	550	271	0			550	312	0	0	1.203	583
		Salt Cavern	0	0	0	0	0			0	0	1.500	0	1.500	0
		Rock Cavern	0	0	0	0	0			0	0	0	0	0	0
		Abandan. Mine	0	0	0	0	0			0	0	0	0	0	0
	3	**Total**	**12**	**6.279**	**1.950**	**1.932**	**105**	**0**	**0**	**1.550**	**312**	**1.500**	**0**	**9.329**	**2.244**
East Europe *		Oil-/gasfield	52	117.584	128.821	37.042	26.650	4.503	1.606	21.941	11.499	4.447	2.798	148.475	52.945
		Aquifers	12	24.095	22.332	7.313	5.187	0	0	2.300	2.055	7.400	2.920	33.795	12.288
		Salt Cavern	1	337	116	880	422	440	880	0	0	4.334	7.354	5.111	9.114
		Rock Cavern	1	60	13	250	250	0	0	0	0	0	0	60	250
		Abandan. Mine	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	**Total**	**66**	**142.076**	**151.282**	**45.485**	**32.509**	**4.943**	**2.486**	**24.241**	**13.554**	**16.181**	**13.072**	**187.441**	**74.597**
Middle East		Oil-/gasfield	6	6.010	1.700	1.895	1.561	0	0	1.950	476	3.100	1.233	11.060	3.604
		Aquifers	0	0	0	0	0	0	0	0	0	550	0	550	0
		Salt Cavern	1	110	25	167	50	0	0	0	0	1.275	1.492	1.385	1.659
	4	**Total**	**7**	**6.120**	**1.725**	**2.062**	**1.611**	**0**	**0**	**1.950**	**476**	**4.925**	**2.725**	**12.995**	**5.263**
West Europe		Oil-/gasfield	37	41.279	72.647	30.690	14.628	20	15	4.788	3.846	5.837	1.964	51.924	36.515
		Aquifers	21	13.580	16.429	9.614	5.635			1.080	1.125	2.105	1.065	16.765	11.804
		Salt Cavern	25	8.023	3.473	14.739	4.886	421	314	714	1.000	3.350	8.287	12.508	24.340
		Rock Cavern	1	9	1	40	18			0	0		0	9	40
		Abandan. Mine	1	3	2	40	100			0	0	0	0	3	40
	12	**Total**	**85**	**62.894**	**92.552**	**55.123**	**25.267**	**441**	**329**	**6.582**	**5.971**	**11.292**	**11.316**	**81.209**	**72.739**
World		Oil-/gasfield	453	271.830	305.353	146.843	43.031	4.523	1.621	29.799	15.901	13.384	5.995	319.536	170.360
		Aquifers	86	48.288	66.158	27.507	10.822	0	0	3.930	3.492	11.755	3.985	63.973	34.984
		Salt Cavern	63	12.988	5.721	30.898	5.358	861	1.194	714	1.000	10.459	17.133	25.022	50.225
		Rock Cavern	2	69	14	290	268	0	0	0	0	0	0	69	290
		Abandan. Mine	2	60	24	258	100	0	0	0	0	0	0	60	258
	33	**World Total**	**606**	**333.235**	**377.270**	**205.796**	**59.579**	**5.384**	**2.815**	**34.443**	**20.393**	**35.598**	**27.113**	**408.660**	**256.117**

*** Russia incl. some $30x10^9$ m³ of strategic reserves**

Attachment 3

UGS in the World
Summary 2004/5 by nations

Region	Nation	Storage Type	No of UGS	Installed Cushion Gas Volume	Installed Working Gas Volume	Installed Peak Withdrawal Capacity	Installed Injection Capacity	Storage Wells	Observation Wells	Disposal Wells	Planned Working Gas Volume	Planned Peak Withdrawal Capacity	Undeveloped Working Gas Volume	Undeveloped Peak Withdrawal Capacity	No of UGS	Green Working Gas Volume	Field Peak Withdrawal Capacity	No of UGS	Total Working Gas Volume	Total Peak Withdrawal Capacity
Asia		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	1		600	210		12					1.000					1	1.600	210
		Rock Caver																0	0	0
		Salt Cavern													1	1.500		1	1.500	0
	China	Total	*1*		*600*	*210*		*12*					*1.000*		*1*	*1.500*		*2*	*3.100*	*210*
Asia		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield																0	0	0
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	India	Total																*0*	*0*	*0*
Asia		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	4	874	542	90	34	12	10	1								4	542	90
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Japan	Total	*4*	*874*	*542*	*90*	*34*	*12*	*10*	*1*								*4*	*542*	*90*
Asia		Abandoned																0	0	0
		Aquifer	2	550	653	271		89					550	312				2	1.203	583
		Oil/Gasfield	1		3.550	925		266					0	0				1	3.550	925
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Kazakhstan	Total	*3*	*550*	*4.203*	*1.196*		*355*					*550*	*312*				*3*	*4.753*	*1.508*
		Asia Total	*8*	*1.424*	*5.345*	*1.496*	*34*	*379*	*10*	*1*			*1.550*	*312*	*1*	*1.500*		*9*	*8.395*	*1.808*

Region	Nation	Storage Type	No of UGS	Installed Cushion Gas Volume	Installed Working Gas Volume	Installed Peak Withdrawal Capacity	Installed Injection Capacity	Storage Wells	Observation Wells	Disposal Wells	Planned Working Gas Volume	Planned Peak Withdrawal Capacity	Undeveloped Working Gas Volume	Undeveloped Peak Withdrawal Capacity	No of UGS	Green Working Gas Volume	Field Peak Withdrawal Capacity	No of UGS	Total Working Gas Volume	Total Peak Withdrawal Capacity
Australia		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	4	526	934	436	71	5	2				0	0				4	934	436
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Australia	Total	*4*	*526*	*934*	*436*	*71*	*5*	*2*				*0*	*0*				*4*	*934*	*436*
	Australia Total		*4*	*526*	*934*	*436*	*71*	*5*	*2*				*0*	*0*				*4*	*934*	*436*
East Europe		Abandoned																0	0	0
		Aquifer	1	300	400	167		40					0	0				1	400	167
		Oil/Gasfield	1	300	350	200	100						950	300				1	1.300	500
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Belarus	Total	*2*	*600*	*750*	*367*	*100*	*40*					*950*	*300*				*2*	*1.700*	*667*
East Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	1	500	500	167		17					0	0				1	500	167
		Rock Caver																0	0	0
		Salt Cavern													1	400	42	1	400	42
	Bulgaria	Total	*1*	*500*	*500*	*167*		*17*					*0*	*0*	*1*	*400*	*42*	*2*	*900*	*209*
East Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	1	374	558	240	180	22	7				0	0				1	558	240
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Croatia	Total	*1*	*374*	*558*	*240*	*180*	*22*	*7*				*0*	*0*				*1*	*558*	*240*

Region	Nation	Storage Type	No of UGS	Installed Cushion Gas Volume	Installed Working Gas Volume	Installed Peak Withdrawal Capacity	Installed Injection Capacity	Sto rage Wells	Observ ation Wells	Dis posal Wells	Planned Working Gas Volume	Planned Peak Withdrawal Capacity	Unde Working Gas Volume	veloped Peak Withdrawal Capacity	No of UGS	Green Working Gas Volume	Field Peak Withdrawal Capacity	No of UGS	Total Working Gas Volume	Total Peak Withdrawal Capacity
East Europe		Abandoned																0	0	0
		Aquifer	1	158	165	137	62	21	35				0	0				1	165	137
		Oil/Gasfield	6	2.216	2.666	2.009	1.284	194	47	3			0	0				6	2.666	2.009
		Rock Caver	1	13	60	250	250	5		2			0	0				1	60	250
		Salt Cavern																0	0	0
	Czech Republic	Total	*8*	*2.387*	*2.891*	*2.396*	*1.596*	*220*	*82*	*5*			*0*	*0*				*8*	*2.891*	*2.396*
East Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	5	3.868	3.610	1.939	1.290	146	10				700	542				5	4.310	2.481
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Hungary	Total	*5*	*3.868*	*3.610*	*1.939*	*1.290*	*146*	*10*				*700*	*542*				*5*	*4.310*	*2.481*
East Europe		Abandoned																0	0	0
		Aquifer	1	2.145	2.300	896	542	180	58	3			750	0				1	3.050	896
		Oil/Gasfield																0	0	0
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Latvia	Total	*1*	*2.145*	*2.300*	*896*	*542*	*180*	*58*	*3*			*750*	*0*				*1*	*3.050*	*896*
East Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	5	6.658	1.219	578	394	99	27		1.266	633	2.434	1.058	2	297	171	7	5.216	2.440
		Rock Caver																0	0	0
		Salt Cavern	1	116	337	880	422	8			440	880	0	0	4	1.934	3.142	5	2.711	4.902
	Poland	Total	*6*	*6.774*	*1.556*	*1.458*	*816*	*107*	*27*		*1.706*	*1.513*	*2.434*	*1.058*	*6*	*2.231*	*3.313*	*12*	*7.927*	*7.342*
East Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	5	4.184	2.300	1.010	549	170	9				2.120	629	4	3.150	957	9	7.570	2.596
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Romania	Total	*5*	*4.184*	*2.300*	*1.010*	*549*	*170*	*9*				*2.120*	*629*	*4*	*3.150*	*957*	*9*	*7.570*	*2.596*

Region	Nation	Storage Type	No of UGS	Installed Cushion Gas Volume	Installed Working Gas Volume	Installed Peak Withdrawal Capacity	Installed Injection Capacity	Storage Wells	Observation Wells	Disposal Wells	Planned Working Gas Volume	Planned Peak Withdrawal Capacity	Undeveloped Working Gas Volume	Undeveloped Peak Withdrawal Capacity	No of UGS	Green Working Gas Volume	Field Peak Withdrawal Capacity	No of UGS	Total Working Gas Volume	Total Peak Withdrawal Capacity
East Europe		Abandoned																0	0	0
		Aquifer	7	17.879	12.970	5.448	4.125	660	659	27			1.550	2.055	2	7.400	2.920	9	21.920	10.423
		Oil/Gasfield	15	78.160	50.563	17.667	13.993	1.888	566	22			15.610	8.905	1	1.000	1.670	16	67.173	28.242
		Rock Caver																0	0	0
		Salt Cavern													3	2.000	4.170	3	2.000	4.170
	Russia	Total	*22*	*96.039*	*63.533*	*23.115*	*18.118*	*2.548*	*1.225*	*49*			*17.160*	*10.960*	*6*	*10.400*	*8.760*	*28*	*91.093*	*42.835*
East Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	2	3.114	2.198	1.362	1.125	230	119	5	587	63	127	65				2	2.912	1.490
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Slovakia	Total	*2*	*3.114*	*2.198*	*1.362*	*1.125*	*230*	*119*	*5*	*587*	*63*	*127*	*65*				*2*	*2.912*	*1.490*
East Europe		Abandoned																0	0	0
		Aquifer	2	1.850	1.810	665	458	107	86	171			0	0				2	1.810	665
		Oil/Gasfield	11	29.447	30.070	11.870	7.735	1.689	242	1.331	2.650	910	0	0				11	32.720	12.780
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Ukraine	Total	*13*	*31.297*	*31.880*	*12.535*	*8.193*	*1.796*	*328*	*1.502*	*2.650*	*910*	*0*	*0*				*13*	*34.530*	*13.445*
	East Europe Total		*66*	*151.282*	*112.076*	*45.484*	*32.509*	*5.476*	*1.865*	*1.564*	*4.943*	*2.486*	*24.241*	*13.554*	*17*	*16.181*	*13.072*	*83*	*157.441*	*74.596*
Middle East		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield																0	0	0
		Rock Caver																0	0	0
		Salt Cavern	1	25	110	167	50	18										1	110	167
	Armenia	Total	*1*	*25*	*110*	*167*	*50*	*18*										*1*	*110*	*167*

Region	Nation	Storage Type	No of UGS	Installed Cushion Gas Volume	Installed Working Gas Volume	Installed Peak Withdrawal Capacity	Installed Injection Capacity	Storage Wells	Observation Wells	Disposal Wells	Planned Working Gas Volume	Planned Peak Withdrawal Capacity	Undeveloped Working Gas Volume	Undeveloped Peak Withdrawal Capacity	No of UGS	Green Working Gas Volume	Field Peak Withdrawal Capacity	No of UGS	Total Working Gas Volume	Total Peak Withdrawal Capacity
Middle East		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	2	1.700	1.350	604	354	125	4				1.950	476				2	3.300	1.080
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Azerbaijan	Total	*2*	*1.700*	*1.350*	*604*	*354*	*125*	*4*				*1.950*	*476*				*2*	*3.300*	*1.080*
Middle East		Abandoned																0	0	0
		Aquifer													1	550		1	550	0
		Oil/Gasfield													1	1.500	750	1	1.500	750
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Iran	Total													*2*	*2.050*	*750*	*2*	*2.050*	*750*
Middle East		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	1		60			10					0	0				1	60	0
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Kyrgyzstan	Total	*1*		*60*			*10*					*0*	*0*				*1*	*60*	*0*
Middle East		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield													2	1.600	483	2	1.600	483
		Rock Caver																0	0	0
		Salt Cavern													2	1.275	1.492	2	1.275	1.492
	Turkey	Total													*4*	*2.875*	*1.975*	*4*	*2.875*	*1.975*
Middle East		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	3		4.600	1.291	1.207	353	37				0	0				3	4.600	1.291
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Uzbekistan	Total	*3*		*4.600*	*1.291*	*1.207*	*353*	*37*				*0*	*0*				*3*	*4.600*	*1.291*

Region	*Nation*	*Storage Type*	*No of UGS*	*Installed Cushion Gas Volume*	*Installed Working Gas Volume*	*Installed Peak Withdrawal Capacity*	*Installed Injection Capacity*	*Storage Wells*	*Observation Wells*	*Disposal Wells*	*Planned Working Gas Volume*	*Planned Peak Withdrawal Capacity*	*Undeveloped Working Gas Volume*	*Undeveloped Peak Withdrawal Capacity*	*No of UGS*	*Green Field Working Gas Volume*	*Green Field Peak Withdrawal Capacity*	*No of UGS*	*Total Working Gas Volume*	*Total Peak Withdrawal Capacity*
Middle East Total			*7*	*1.725*	*6.120*	*2.062*	*1.611*	*506*	*41*				*1.950*	*476*	*6*	*4.925*	*2.725*	*13*	*12.995*	*5.263*
North Americ		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	41	7.210	14.310	4.474		433	135									41	14.310	4.474
		Rock Caver																0	0	0
		Salt Cavern	8	162	508	1.286		28	0									8	508	1.286
	Canada	Total	*49*	*7.372*	*14.818*	*5.760*		*461*	*135*									*49*	*14.818*	*5.760*
North Americ		Abandoned	1	22	57	218		16	16									1	57	218
		Aquifer	51	26.847	9.960	10.309		1.705	892									51	9.960	10.309
		Oil/Gasfield	305	93.455	86.821	70.959		12.425	1.895									305	86.821	70.959
		Rock Caver																0	0	0
		Salt Cavern	28	1.945	4.010	13.826		136	36									28	4.010	13.826
	USA	Total	*385*	*122.270*	*100.847*	*95.311*		*14.282*	*2.839*									*385*	*100.847*	*95.311*
North America Total			*434*	*129.641*	*115.665*	*101.071*		*14.743*	*2.974*									*434*	*115.665*	*101.071*
South Americ		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	2	120	200	122	87	7	12				120	80				2	320	202
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Argentina	Total	*2*	*120*	*200*	*122*	*87*	*7*	*12*				*120*	*80*				*2*	*320*	*202*
South Americ		Abandoned																0	0	0
		Aquifer													1	1.700		1	1.700	0
		Oil/Gasfield																0	0	0
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Uruguay	Total													*1*	*1.700*		*1*	*1.700*	*0*

Region	Nation	Storage Type	No of UGS	Installed Cushion Gas Volume	Installed Working Gas Volume	Installed Peak Withdrawal Capacity	Installed Injection Capacity	Storage Wells	Observation Wells	Disposal Wells	Planned Working Gas Volume	Planned Peak Withdrawal Capacity	Undeveloped Working Gas Volume	Undeveloped Peak Withdrawal Capacity	No of UGS	Green Field Working Gas Volume	Green Field Peak Withdrawal Capacity	No of UGS	Total Working Gas Volume	Total Peak Withdrawal Capacity
South America Total			*2*	*120*	*200*	*122*	*87*	*7*	*12*				*120*	*80*	*1*	*1.700*		*3*	*2.020*	*202*
West Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	4	3.355	2.820	1.445	1.279	180	29	1			509	0	1	2.637	1.300	5	5.966	2.745
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Austria	Total	*4*	*3.355*	*2.820*	*1.445*	*1.279*	*180*	*29*	*1*			*509*	*0*	*1*	*2.637*	*1.300*	*5*	*5.966*	*2.745*
West Europe		Abandoned																0	0	0
		Aquifer	1	550	550	525	250	11	25				80	125				1	630	650
		Oil/Gasfield																0	0	0
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Belgium	Total	*1*	*550*	*550*	*525*	*250*	*11*	*25*				*80*	*125*				*1*	*630*	*650*
West Europe		Abandoned																0	0	0
		Aquifer	1	760	400	450	100	12	6	1			800	900				1	1.200	1.350
		Oil/Gasfield																0	0	0
		Rock Caver																0	0	0
		Salt Cavern	1	300	420	600	165	7					400	600				1	820	1.200
	Denmark	Total	*2*	*1.060*	*820*	*1.050*	*265*	*19*	*6*	*1*			*1.200*	*1.500*				*2*	*2.020*	*2.550*
West Europe		Abandoned																0	0	0
		Aquifer	12	13.890	10.775	7.202	4.688	391	182				0	0				12	10.775	7.202
		Oil/Gasfield													1	82	20	1	82	20
		Rock Caver																0	0	0
		Salt Cavern	3	598	868	1.721	953	36					0	0				3	868	1.721
	France	Total	*15*	*14.488*	*11.643*	*8.923*	*5.641*	*427*	*182*				*0*	*0*	*1*	*82*	*20*	*16*	*11.725*	*8.943*

Region	Nation	Storage Type	No of UGS	Installed Cushion Gas Volume	Installed Working Gas Volume	Installed Peak Withdrawal Capacity	Installed Injection Capacity	Storage Wells	Observation Wells	Disposal Wells	Planned Working Gas Volume	Planned Peak Withdrawal Capacity	Undeveloped Working Gas Volume	Undeveloped Peak Withdrawal Capacity	No of UGS	Green Working Gas Volume	Field Peak Withdrawal Capacity	No of UGS	Total Working Gas Volume	Total Peak Withdrawal Capacity
West Europe		Abandoned	1	2	3	40	100	1	1				0	0				1	3	40
		Aquifer	7	1.229	1.858	1.437	597	78	42	9			200	100				7	2.058	1.537
		Oil/Gasfield	15	9.786	10.975	7.090	4.226	221	64	12	20	15	384	185	1	600		16	11.979	7.290
		Rock Caver																0	0	0
		Salt Cavern	19	2.350	6.343	11.595	3.688	152	1	3	421	314	314	400	5	1.850	2.275	24	8.928	14.584
	Germany	Total	*42*	*13.366*	*19.179*	*20.162*	*8.611*	*452*	*108*	*24*	*441*	*329*	*898*	*685*	*6*	*2.450*	*2.275*	*48*	*22.968*	*23.451*
West Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	1		210	118	42	3					0	0				1	210	118
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Ireland	Total	*1*		*210*	*118*	*42*	*3*					*0*	*0*				*1*	*210*	*118*
West Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	10	11.871	17.415	13.696	6.614	276	42	7			2.450	0	2	1.810	15	12	21.675	13.711
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Italy	Total	*10*	*11.871*	*17.415*	*13.696*	*6.614*	*276*	*42*	*7*			*2.450*	*0*	*2*	*1.810*	*15*	*12*	*21.675*	*13.711*
West Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	3	39.135	5.000	5.875	1.500	15	5	1			0	3.017				3	5.000	8.892
		Rock Caver																0	0	0
		Salt Cavern													1	180	1.600	1	180	1.600
	Netherlands	Total	*3*	*39.135*	*5.000*	*5.875*	*1.500*	*15*	*5*	*1*			*0*	*3.017*	*1*	*180*	*1.600*	*4*	*5.180*	*10.492*
West Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield																0	0	0
		Rock Caver																0	0	0
		Salt Cavern													1	200	600	1	200	600
	Portugal	Total													*1*	*200*	*600*	*1*	*200*	*600*

Region	Nation	Storage Type	No of UGS	Installed Cushion Gas Volume	Installed Working Gas Volume	Installed Peak Withdrawal Capacity	Installed Injection Capacity	Storage Wells	Observation Wells	Disposal Wells	Planned Working Gas Volume	Planned Peak Withdrawal Capacity	Undeveloped Working Gas Volume	Undeveloped Peak Withdrawal Capacity	No of UGS	Green Field Working Gas Volume	Field Peak Withdrawal Capacity	No of UGS	Total Working Gas Volume	Total Peak Withdrawal Capacity
West Europe		Abandoned																0	0	0
		Aquifer													2	2.105	1.065	2	2.105	1.065
		Oil/Gasfield	2	1.555	1.981	529	354	10	3	0			1.445	644				2	3.426	1.173
		Rock Caver																0	0	0
		Salt Cavern																0	0	0
	Spain	Total	*2*	*1.555*	*1.981*	*529*	*354*	*10*	*3*	*0*			*1.445*	*644*	*2*	*2.105*	*1.065*	*4*	*5.531*	*2.238*
West Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield																0	0	0
		Rock Caver	1	1	9	40	18	1										1	9	40
		Salt Cavern																0	0	0
	Sweden	Total	*1*	*1*	*9*	*40*	*18*	*1*										*1*	*9*	*40*
West Europe		Abandoned																0	0	0
		Aquifer																0	0	0
		Oil/Gasfield	2	6.945	2.875	1.937	613	30					0	0	3	708	629	5	3.583	2.566
		Rock Caver																0	0	0
		Salt Cavern	2	225	392	823	80	11					0	0	3	1.120	3.812	5	1.512	4.635
	United Kingdom	Total	*4*	*7.170*	*3.267*	*2.760*	*693*	*41*					*0*	*0*	*6*	*1.828*	*4.441*	*10*	*5.095*	*7.201*
West Europe Total			*85*	*92.551*	*62.894*	*55.123*	*25.267*	*1.435*	*400*	*34*	*441*	*329*	*6.582*	*5.971*	*20*	*11.292*	*11.316*	*105*	*81.209*	*72.739*
World		Abandoned	*2*	*24*	*60*	*258*	*100*	*17*	*17*				*0*	*0*				*2*	*60*	*258*
		Aquifer	*86*	*66.158*	*41.841*	*27.506*	*10.822*	*3.294*	*1.985*	*211*			*3.930*	*3.492*	*6*	*11.755*	*3.985*	*92*	*57.526*	*34.983*
		Oil/Gasfield	*453*	*305.353*	*248.276*	*146.842*	*43.031*	*18.838*	*3.265*	*1.383*	*4.523*	*1.621*	*29.799*	*15.901*	*18*	*13.384*	*5.995*	*471*	*295.982*	*170.359*
		Rock Caver	*2*	*14*	*69*	*290*	*268*	*6*		*2*			*0*	*0*				*2*	*69*	*290*
		Salt Cavern	*63*	*5.720*	*12.988*	*30.898*	*5.358*	*396*	*37*	*3*	*861*	*1.194*	*714*	*1.000*	*21*	*10.459*	*17.133*	*84*	*25.022*	*50.225*
UGS Countries 38		Total	*606*	*377.270*	*303.234*	*205.795*	*59.579*	*22.551*	*5.304*	*1.599*	*5.384*	*2.815*	*34.443*	*20.393*	*45*	*35.598*	*27.113*	*651*	*378.659*	*256.116*

Attachment 4

Glossary of relevant technical Underground Gas Storage Terminology

Scope of Glossary
The glossary covers the relevant technical terminology related to the storage of natural gas in underground gas storage facilities. As the technology is similar, the terminology can be applied for the storage of hydrogen, CO_2, O_2 and other gases.

Term	Definition
Underground Gas Storage (UGS)	All subsurface and surface facilities required for the storage and for the withdrawal and injection of natural gas. Naturally or artificially developed containments in subsurface geological strata are used for the storage of natural gas. Several subsurface storage horizons or caverns may be connected to one common surface facility, which is referred to as the underground gas storage location
Type of Storage	There are several types of underground gas storage facilities, which differ by storage formation and storage mechanism: **Porous rocks** - Storage in aquifers - Storage in former gas fields - Storage in former oil fields **Caverns** - Storage in salt caverns - Storage in rock caverns (including lined rock caverns) - Storage in abandoned mines
UGS in Operation	Storage facility capable to inject and withdraw gas
Greenfield Storage Project	New underground storage development project, not based on any existing storage facilities
Storage Capacity	Total ability of a storage facility to provide working gas volume, withdrawal rate and injection rate
Inventory	Total of working and cushion gas volumes stored in UGS

Cushion Gas Volume (CGV) or Base Gas	Gas volume required in a storage field for reservoir management purpose and to maintain an adequate minimum storage pressure for meeting working gas volume delivery with the required withdrawal profile. In caverns, the cushion gas volume is also required for stability reasons. The cushion gas volume may consist of recoverable and non-recoverable in-situ gas volumes and injected gas volumes
Working Gas Volume (WGV)	Volume of gas in the storage above the designed level of cushion gas volume, which can be withdrawn/injected with installed subsurface and surface facilities (wells, flow lines, etc.) subject to legal and technical limitations (pressures, velocities, etc.). Depending on local site conditions (injection/withdrawal rates, utilization hours, etc.) the working gas volume may be cycled more than once a year (see annual cycling capability).
Withdrawal Rate	Flow rate at which gas can be withdrawn from storage fields and caverns, based on the installed subsurface and surface facilities and technical limitations.
Withdrawal Profile	Dependency between the withdrawal rate and the withdrawn working gas volume. The withdrawal profile and the time (utilization hours) required for withdrawal are indicative of the layout of an underground gas storage facility. The withdrawal profile usually consists of a constant rate (plateau) period (see 'Nominal Withdrawal Rate') followed by a period of declining rates.
Peak Withdrawal Rate	Maximum flow rate which can be delivered based on the installed subsurface and surface facilities and technical limitations. This flow rate is normally reached when the storage is at its maximum working gas volume, i.e. maximum allowable storage pressure. Also known as 'maximum design deliverability'
Nominal Withdrawal Rate	Withdrawal rate representing the deliverability of the subsurface and surface facilities available over an extended period of withdrawal (plateau period). This rate corresponds to the constant rate period of the withdrawal profile
Last Day Withdrawal Rate	Withdrawal rate which can be delivered based on the installed subsurface and surface facilities and technical limitations when the storage reservoir or cavern is at or close to its cushion gas volume
Injection Rate	Flow rate at which gas can be injected into a storage field and cavern, based on the installed subsurface and surface facilities and technical limitations

Injection Profile	Dependency between the injection rate and the injected working gas volume. The injection profile and the time (utilization hours) required for injection are indicative of the layout of an underground gas storage facility. The injection profile may include a period of declining rates close to maximum storage pressure
Annual Cycling Capability	Number of times the working gas volume can be withdrawn and injected on an annual basis
Undeveloped Storage Capacities	Additional storage capacities which could be developed in an existing underground gas storage, e.g.: by additional gas injection, increase of the maximum storage pressure, decrease of the minimum storage pressure, additional facilities (wells, re-compression) etc.
Storage Well	Well completed for gas withdrawal and/or injection
Observation Well	Well completed for the purpose of monitoring the storage horizon and/or the overlying or underlying horizons for pressures, temperatures, saturations, fluid levels, etc.
Auxiliary Well	Well completed for other purposes, e.g. water disposal
Abandoned Well	Well permanently out of operation and plugged
Initial Reservoir Pressure	Initial pressure conditions encountered in a porous formation before any change due to operation of the reservoir, for example: start of production or injection. The initial pressure is related to a reference depth/datum level. Also known as ‘discovery pressure’
Maximum Allowable Storage Pressure	Maximum pressure of the storage horizon or cavern, normally at maximum inventory of gas in storage. This pressure has to be engineered in order to ensure the integrity of the storage field. The maximum allowable pressure is related to a reference/datum depth and normally has to be approved by authorities
Minimum Storage Pressure	Minimum pressure of the storage horizon or cavern, normally reached at the end of the decline phase of the withdrawal profile. The minimum pressure is related to a reference/datum depth. The minimum pressure of caverns has to be engineered and approved in order to ensure stability
Pressure Datum Level	Reference depth at the porous storage level, normally related to the sea level, used for pressure normalisation and correlation throughout the reservoir. In caverns the depth below surface of the last cemented casing shoe is normally used as the reference level for pressures

Depth Top of Structure/Cavern Roof Depth	Minimum true vertical depth from the surface down to the top of the storage formation/cavern roof
Caprock of a Porous Storage	Sealing formation for gas overlying the porous storage horizon. Caprock prevents the migration of oil and gas out of the storage horizon
Containment	Ability of the storage reservoir or cavern and the storage well completion to resist leakage or migration of the fluids contained therein. Also known as the integrity of a storage facility
Closure	Vertical distance between the top of the structure and the spill point
Spill Point	Structural point within a reservoir, where hydrocarbons could leak and migrate out of the storage structure
Areal Extent of the Storage Structure	Subsurface area of the storage formation at its maximum gas water contact extent
Cavern Convergence	Reduction in geometrical cavern volume caused by e.g. salt creeping. The annual reduction of the geometrical cavern volume is expressed by the convergence rate

Gas volumes are related to temperatures and pressures at normal conditions: 273,15 K (0°C) and 1,01325 bar

Relevant terms used in the Basic Activity Study - Units and definitions - **Attachment 5**

Data Bank Data/Units

Main Attributes	Metric Units	English Units
Installed max/planned/undeveloped Working Gas Volume	(10^6 m³(Vn))	(MMcf)
Cushion Gas Volume incl. inj. + indig.	(10^6 m³(Vn))	(MMcf)
Peak Withdrawal Rate	(10^3 m³(Vn)/h)	(Mcf/d)
Nominal Withdrawal Rate	(10^3 m³(Vn)/h)	(Mcf/d)
Last Day Withdrawal Rate	(10^3 m³(Vn)/h)	(Mcf/d)
Injection Rate	(10^3 m³(Vn)/h)	(Mcf/d)
Installed Compressor Power	(MW)	(Horsepower)
Areal Extent Storage Reservoir	(km²)	(acres)
Minimum Storage Pressure @ Datum Level	(bar)	(Psig)
Maximum Allowable Storage Pressure @ Datum Level	(bar)	(Psig)
Initial Reservoir Pressure @ Datum Level	(bar)	(Psig)
Pressure Datum Level below Surface	(metre)	(feet)
Depth Top Structure/Cavern Roof	(metre)	(feet)
Maximum Depth of Storage Structure	(metre)	(feet)
Net Thickness (metre)	(metre)	(feet)
Porosity (average)	(%)	
Permeability (average)	(mD)	
Reservoir Temperature	(°C)	
Cavern Height average	(metre)	
Cavern Diameter average	(metre)	
Distance between Caverns average	(metre)	
Convergence Rate of Caverns	(%/year)	
Total Convergence of Caverns	(%)	
Remaining GIP before UGS Operation in Gasfield	(10^6 m³(Vn))	
Gasquality H_{sup}	(kWh/m³)	