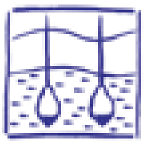

2009-2012 Triennium Work Report

June 2012

WORKING COMMITTEE 2: UNDERGROUNG GAS STORAGE

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Table of Contents

1 Abstract 4
2 Executive summary 6
2.1 Study group SG2.1: Updating and improving the IGU UGS data-base and promoting it as a reference 6
2.2 Study group SG2.2: Definition of some best practices in UGS operation and design. 7
2.3 Study group SG2.3 : Skills and Competencies for UGS activities 9
3 Report of Study Group 1 10
3.1 Introduction, Objectives and Recommendations 10
3.2 Underground Gas Storage in the World 12
3.2.1 UGS World Data Bank 12
3.2.2 UGS World Map 20
3.3 UGS Glossary 22
3.4 Trends in the UGS Business 23
3.4.1 Storage Demand General Trends - based on received replies 23
3.4.2 Storage Demand Forecasts - based on analysis carried out 25
3.4.3 General and technological issues 31
3.4.4 Database analysis 38
3.5 Trends in the UGS business from a national perspective 42
4 Report of SG 2.2: Best Practices 42
4.1 Introduction, objectives and Recommendation 42
4.2 Part 1: Methane emission reduction efforts in UGS operation 42
4.2.1 Background 42
4.2.2 Results of a focussed questionnaire 43
4.2.3 Other sources of data 43
4.2.4 Conclusion of the part 1 44
4.3 Part 2: Well Integrity Management for UGS. 44
4.3.1 Underground Gas Storage wells 44
4.3.2 Integrity Management 46
4.3.3 Work-flow of well integrity management 46
Step 1 : Review the geological, drilling and completion Wells data-base 48
Step 2 : Perform a regular monitoring 48
Step 3 : Assess criticality of failures 49
Step 4 : Perform a detailed diagnostic and specific measurements 49
Step 5: Repair 50
4.3.4 Conclusion of part 2 50
4.4 Part 3: CO2 sequestration 50

4.4.1 Introduction ... 51
4.4.2 Geological Storage ... 51
4.4.3 Trapping Mechanisms ... 51
4.4.4 Storage Site Capacity Estimates ... 52
4.4.5 Monitoring ... 53
4.4.6 Economics ... 54
4.4.7 Conclusions of part 3 ... 54
5 Report of SG 2.3: Skills and competencies for UGS activities ... 55
5.1 Introduction, Objectives and Recommendations ... 55
5.2 General Conditions ... 57
5.3 Solution ... 58
5.3.1 PART A Skills and Competencies Model ... 58
5.3.2 Part B: Young Employees Exchange Programme (YEEP) ... 70
5.3.3 Conclusions ... 70
6 Appendixes ... 71
6.1 List of figures ... 71
6.2 List of Tables ... 73
6.3 List of abbreviations ... 73
6.4 Units and conversion factor ... 74
6.5 List of WOC2 members ... 75
6.6 Appendix SG2.1_1 Summary by countries ... 77
6.7 Appendix SG2.1_2 Summary by regions ... 78
6.8 Appendix SG2.1_3 The UGS Glossary ... 79
6.9 Appendix SG2.1_ 4 Germany ... 83
6.10 Appendix SG2.1_5 Spain ... 88
6.11 Appendix SG2.1_6 Denmark ... 91
6.12 Appendix SG2.1_7 France ... 92
6.13 Appendix SG2.1_8 The USA ... 97
6.14 Appendix SG2.1_9 Russia ... 106
6.15 Appendix SG2.1_10 Austria ... 108
6.16 Appendix SG2.1_11 The Netherlands ... 111
6.17 Appendix SG2.1_12 Slovakia ... 116
6.18 References SG 2.2 ... 118
6.19 References SG 2 .3 ... 118
6.20 YEEP partners (SG 2.3) ... 118
6.21 YEEP students ... 123
6.22 YEEP entry test ... 123
6.23 YEEP time schedule ... 130
6.24 YEEP Programme ... 130

1 Abstract

Objectives of the study

The WOC 2 final report gives a great overview of the work programme followed by the Working Group during the Triennium 2009-2012.

The report is structured around the individual reports of the three study-groups:

- SG 2.1 : Basic Activity :Update and improvement of the underground gas storage database
- SG 2.2 : Definition of some best practices in UGS operation and design
- SG 2.3 : Skills and competencies for UGS activities

The objectives of SG2.1 were:

- Statistical survey of existing/planned UGS in the world
- Update of the database of underground gas storage facilities in the different regions of the world
- Extension of data content by new storage facilities and by new attributes
- Update of the UGS World Map
- Analysis of developed database
- Summary of general trends in the storage business
- Extension of the UGS Glossary by additional terms and languages

The main objective of the SG 2.2 was to present common practices used in the UGS community even if operations and design can be different from one region to another. Requirements from citizens and public authorities regarding safety and environmental issues are growing as well as demands from gas customers for flexibility and reliability, which leads to the development of interesting best practices.

SG 2.3 work was based on the fact that in recent years, human resources have become critically important in UGS activity such as in gas business in general. This new concern is in line with the strategic guidelines of the triennium and TF1 activity. In its first part SG 2.3 report gives elements of analysis used in human resources management policies in UGS business and provides a skills and competencies model. In addition, the SG 2.3 overcomes the theoretical approach and concretely answered the issue of education. It developed an intensive advanced six-weeks training programme dedicated to young professional working in UGS business, called Young employees exchange programme (YEEP).

Topics

The underground gas storage database covers the following types of storage facilities:

Porous storage

- 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

The report presents data from almost 693 UGS facilities worldwide.

The SG 2.2 selected three topics of study:

- Methane emissions
- Well integrity assessment
- CO2 sequestration
-

The elaboration of the skills and competencies model was based on the results of a questionnaire which main topics were:

- Description of skills, know-how and profiles requested for UGS professionals
- Assessment of the level of professional needed in a near future
- Selection of main relevant educational programmes and degrees
- Identification of ways to provided skilled professional and promote the attractiveness of the storage industry.

The YEEP mainly focused on the following themes:

- Geosciences
- Reservoir engineering
- Treatment of natural gas

Approach

The UGS database report has been developed mainly upon the direct feedback of a questionnaire which was distributed to gas storage companies.

The questionnaire was divided in two 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 received, from 117 companies have been processed and analysed.

SG 2.2 had different approaches according to the topics. The methane emissions report was elaborated on the basis of a short questionnaire sent to all the WOC 2 members. Others publications were also used. An article was published in the IGU magazine on this topic and it is the basis of the report.

. For the part on well integrity management, the authors used relevant data indicated in the UGS database and elements provided by the members during the workshop organized during one of the WOC 2 meeting on the specific topic of well integrity management.

The third part “CO2 sequestration” benefit from the close cooperation between WOC2 and PGCA. They analysed the current status of carbon capture and sequestration and described the results in a common report lead by PGCA. WOC2 contribution focused on the issue of geological storage. The final WOC2 report only contains a summary.

The skills and competencies model was elaborated by SG2.3 on a questionnaire send to WOC 2 members. This work gave also the opportunity to SG2.3 to contribute to Task Force 1: “Building Strategic Human Capacity”.

The YEEP needed the support of sponsors. The sponsorships were provided by Gazprom, RWE Gas Storage and the Czech Gas Association. Courses were provided by: Gubkin State University of Oil and Gas and Gazprom Vniigaz, Moscow (Russia), Technical University of Liberec (Czech Republic) and Institute of Chemical Technology Prague (Czech Republic).

2 Executive summary

Working Committee 2 (WOC2) dedicated to Underground Storage gathered70 nominated members from Europe, CIS and Asia. Among them around 35 members were active and contributed to the Triennium Work Program. To achieve this programme, WOC2 was organised in three Study Groups (SG) and the WOC2 report is divided in three parts, according to this organization.

2.1 Study group SG2.1: Updating and improving the IGU UGS data-base and promoting it as a reference

An updated and unique reference

WOC2 built a worldwide data-base of Underground Gas Storage facilities (UGS) several trienniums ago and regularly updates it as part of its basic activity. During this triennium, this world wide database, including data about individual storage facilities in the world, as well as graphical presentation of these data, has been improved further in number of UGS facilities and extent of data.

A comprehensive update with 2010-2011 data has been achieved using different means : direct or indirect (via AGA data, for North America) answers from operators of facilities, cross checking with others data-base and sources (Gas Storage Europe, part of Gas Infrastructures Europe, United Nations Economic Commission for Europe) and collection of public data.

The database covers UGS in operation and as well planned and potential storage projects. The main information available for every **693 UGS in 37 countries** refers to name, country, localisation, operatorship, type of storage, working gas volume. Extra technical information on capacities (rates of injection and withdrawal, total gas volume), on sub-surface (depth, pressure, geology) and surface facilities (type of equipment, power of compression, etc..) are also available for several facilities. Two sets of data are available in metric and English units.

UGS facilities key data are geo-referenced in the **UGS World Map** via links on the start page of the report, by clicking on the world map and zooming in to the area of interest. Further explanations are provided in the special GIS software which is enclosed to the World Gas Conference (WGC) proceedings.

The global figures are the following: **359.10^9 $m(n)^3$ of working gas** (without 45. 10^9 $m(n)^3$ of long term strategic reserves of Russia) is supplied by about 693 storage facilities all over the world. 23.007 storage wells deliver an average withdrawal rate of 235.10^6 $m(n)^3$/hour.

This data base is a unique tool to understand UGS in the world draw trends and calculate regional statistics and significant ratios. Some of them are presented in the report.

A multi-languages glossary

A glossary of 32 terms commonly used in UGS industry is included in different languages; English, Russian, Italian, Ukrainian, French, German, Japanese, Danish, Serbian, Portuguese, Slovak, Czech and Croatian.

Trends in the UGS Business

A global prognosis of storage demand in 2020 and 2030 is presented, which is consistent with the data-set of PGCB report on 2030 gas industry outlook.
This prognosis is based on several ratios between consumption and storage and it is compared to capacities of UGS projects.
With regards to the current 359.10^9 $m(n)^3$ of working gas volume, 503.10^9 $m(n)^3$ are forecast worldwide in 2030 representing around +**10. 10^9 $m(n)^3$ by year**. This is an average figure, a low case and an high case are also presented. Different figures are presented and commented for Europe, CIS and North America. These figures have been revised since 2009 report because of the American and European financial crisis as well as the shale gas development in North America. However an increasing demand for storage capacities is still forecast. The **183 planned and potential development projects** of operators would be able to bring this capacity if investment decisions can be made.

A synthesis of the general and technological trends is presented with national overviews of UGS activities in some countries such as: Austria, Denmark, France, Germany, the Netherlands, Russia, Slovakia, Spain, USA is included.

2.2 Study group SG2.2: Definition of some best practices in UGS operation and design.

Methane emission reduction efforts in UGS operation

Gas storage operation is not a major contributor to methane emission. Methane emissions resulting from **UGS operation represents around 5% of the total emission of the gas industry** (ratio calculated without Exploration and Production emissions).

Without considering the diffuse emissions and the emergency venting, the ranking of main sources of methane is the following:

1. compressor,
2. venting part of facilities for servicing,
3. well servicing including testing (for porous media storage)

From environmental reports (from Europe and CIS) published by major companies an average ratio of methane emission compared to working gas volume: approx. **500 m^3(n) per million m^3(n) of working gas, i.e. 0.05 % (assuming 1 working gas volume cycled in a year)** has been calculated.
This figure shows **a trend to reduction** from the previous years. In the IGU-Woc8 report published for the WGC 2000, the average emission factor was estimated to 0.1% of the working gas volume (0,05% at the lowest and 0,7% at the maximum).
Even if UGS is a very low methane emitting activity, UGS operators are involved in methane emission reduction programs.

- Emerging technology in the last decade, driven by environmental regulations, such as electrical driven encapsulated compressor , will help to achieve zero emission for some UGS activities,
- Reduction of natural gas venting during maintenance operation is developing quickly among UGS operators.

This has been mainly realised thanks to voluntary efforts by the operators, since regulations in the field of methane emission are not yet broadly implemented.

Well Integrity Management for UGS

One characteristic of UGS wells is that they could be in operation for decades and many of them are around 30 years old or more especially in Europe and CIS. This situation gives a very special interest to monitor the integrity of UGS wells. The age is a key factor but the initial quality of the well and the conditions of operation (that is another characteristic of UGS wells, submitted to pressure and temperature cycles) have also a huge influence on well integrity.

Wells are key assets for storage operators and their integrity has to be controlled not only during their aging phase but starting from their drilling or building phase.

A general work-flow is proposed, with different steps and decisions to manage the well integrity management of the wells of an UGS site.

- **Review the geological, drilling and completion Wells data-base.** This initial information is very valuable and should be easily accessible and safely preserved. **Perform a regular monitoring** of different parameters on regular basis, adapted to each situation and regulation. On a regular basis, data collected by the monitoring should be interpreted and linked to a probability of failures or integrity problems
- **Assess criticality of failures**. These failures could be more or less negative in their consequences according to the specific environment (on surface and in the subsurface) of the well. The result of this step is to identify wells having critical integrity problems. That means that a more detailed diagnostic has to be performed on them.
- **Perform a detailed diagnostic and specific measurements.** The well operator would prefer methods with low cost or a cost in proportion with the value of the information. With all the information coming from the initial data, the regular monitoring and the extra-measurements, a diagnostic could be made on the well. Either the current situation of the well could last, till the next assessment, or it cannot. In this last case a repair job is needed.

- **Repair.** As for special measurements, the preferred methods to repair are methods which could be performed without work-over. Once the repair job completed according to its design, the initial data of the well are updated and the well will be processed according to the general work-flow.

CO2 sequestration

WOC2 in close cooperation with PGCA have analysed the current status of carbon capture and sequestration and have described the results within a common report. As far as the geological storage of CO_2 is concerned the key messages are the following:

- To be included in a project able to store several years or decades of emission from a source of CO2, the target reservoirs are at least an order of magnitude larger than usual Underground Gas Storage sites.
- It turns out that, unfortunately, the least expensive storage reservoirs contribute the least to the total available capacity.
- Technologies to sequestrate CO2 are available but have to be improved or adapted to the large scale of target and the long-term of projects. UGS operators are key players for these types of projects because of their knowledge, experience and long term feed-back of underground storage operation.
- CO2 injection will be surely implemented for production purpose. These projects of injection either in the reservoir field or in another reservoir, will provide valuable experiments and improve knowledge and technology

2.3 Study group SG2.3 : Skills and Competencies for UGS activities

Since 2005, the storage sector has been noticing the beginning of a shortage of technical skills. It is a critical issue for companies either to operate and run maintenance on existing underground gas storage (UGS) facilities or to develop new projects. The UGS activity is strongly impacted as the needed skills are not only specific but also rather similar to the ones used in the Exploration and Production sector, which tends to receive more focus from companies than UGS activities.

The work of SG2.3 on this topic provided two deliverables: a qualitative analysis of the situation and a concrete program of training of young professionals.

Skills and Competencies Model

A questionnaire was sent to UGS operators companies about Human Resources items and the answers are analysed and commented by a panel of expositors in order to obtain concrete views from different countries, companies, and universities.

According to the survey, in two thirds of the cases certification are asked by mining authorities and has to be periodically renewed. It shows the importance of competencies in UGS industry.

The results show a clear difficulty for UGS operators to fill position of engineers, geoscientists and drilling specialists, especially with an adequate degree of competences. This situation is not expected to be better in a near future.

But some examples of positive initiatives (close relationship with universities, knowledge management, etc...) are presented and could be developed as best practices.

Young Employees Exchange Programme

SG2.3 has organised three two-week intensive advanced courses for 15 young UGS professionals from WOC2 member companies aged under 30, called **Young Employees Exchange Programme (YEEP)**.

The young professionals were coming from Europe, CIS and Asia selected by their company. Their level of knowledge has been checked.

This programme took place during summer 2011. It included:

- a course on Geology, supported by Gazprom and Gubkin State University in Moscow (Russia)
- a course on Reservoir Engineering – supported by RWE Gas Storage and Technical University in Liberec (the Czech Republic)
  - a course on Gas Treatment supported by the Czech Gas Association and the Institute of Chemical Technology in Prague (the Czech Republic)

All the details of the programme (tests before and after the programme, content of the lectures) are provided in the report.

3 Report of Study Group 1

3.1 Introduction, Objectives and Recommendations

The Basic Activity Study has been established for the first time as part of the International Gas Union (IGU) Triennium work programme 2000 – 2003 and since that time it provides valuable summary of storage activities worldwide. The study has been constantly improved during previous trienniums and is complemented by unique storage database updated each triennium. The results are to be presented during the World Gas Conference 2012 (WGC) in Kuala Lumpur.

The Study Group Members are listed in the Appendix 4 detailing the members of the WOC2.

The Study Group leader was Ladislav Goryl (Slovakia).

The main contributors:
Fred Metzger (the US), Joachim Wallbrecht (Germany), Remy Champavere (France), Fabien Favret (France), Emmanuelle Wicquart (France), Jacques Grappe (France), Dmitry Pavlenkov (Russia), Leif Hansen (Denmark), Ana Maria Garcia (Spain), Michael Kreuz (Austria), Eddy Kuperus (Netherlands)

IT support (database programming, data handling): Vladimir Lorenc (Slovakia)
Geo-referenced visualisation: Igor Olejnik (Slovakia)

As described in the abstract, the objectives of the Basic Underground Gas Storage (UGS) Activities Study have been:

- Statistical survey of existing/planned UGS in the world
- Update of the database of underground gas storage facilities in the different regions of the world
- Extension of data content by new storage facilities and by new attributes
- Update of the UGS World Map
- Analysis of developed database
- Summary of general trends in the storage business
- Extension of the UGS Glossary by additional terms and languages

The study covers the following types of storage facilities storing natural gas worldwide:

Porous storage
- 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.

The structure of the Basic activity study contains the following elements:

I. **UGS World Data Bank** — UGS in operation, planned and abandoned (status: 2010/11)
- Metric units
- English units

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. Appendices, incl. relevant terms, units and definitions

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

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

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

The countries of interest for UGS were grouped into the following regions respecting IGU classification: North America, Latin America & Caribbean, Europe, Commonwealth of Independent States (CIS), Middle East, Asia, Asia Pacific and Africa.

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 the **Chyba! Nenašiel sa žiaden zdroj odkazov.**. As the Basic Activity will ontinue in the next trienniums, the existing database will be broadened and updated successively.

Trends in the UGS business are discussed in the report according to regions and from the perspective of countries. Regional distribution is based on IGU classification.

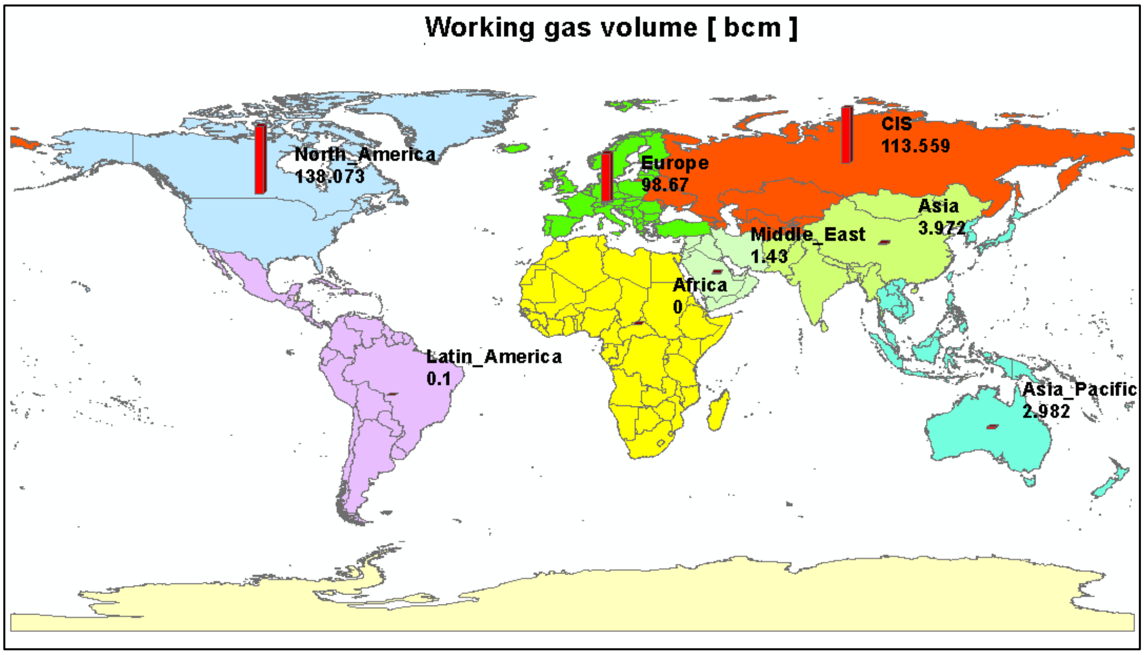


Figure 1 WGV distribution by regions

3.2 Underground Gas Storage in the World

3.2.1 UGS World Data Bank

Storage facility data were received from companies in reply to the data request/questionnaire. At first 271 questionnaires were distributed to respective companies and 117 were return back filled with storage data.

The direct feedback from storage operators was very good for major storage regions as Europe, CIS (direct replies only from Russia). Progress was made also in Asia (China) thanks to our Chinese Study Group 2.1 (SG 2.1) member. Direct replies from Latin America (Argentina) and Asia Pacific (Japan) were also received; however, the size of their storage facilities is limited.

Taking into account a huge number of storage operators in North America, different approach was applied. Those data were gathered and delivered by our correspondent member, resulting in excellent coverage of American UGS industry.

Missing data from other regions were complemented mainly from public domain. The same applied also for the data on planned storages which were added from other sources (e.g. Gas Storage Europe (GSE) investment database for Europe). Even though co-operation with United Nations Economic Commission for Europe (UNECE) UGS Working Group (aimed at defining the current status and prospects of underground gas storage industry in Europe and Central Asia) has started; however, no input from this body has been obtained due to different time schedule of both the studies.

Based on the data received directly, the data received in previous triennium and available data from public domain, in total an excellent database with the status and actuality of year 2010/2011 has been developed. The database covers UGS in operation and as well planned and potential storage projects. The UGS World Data Bank is well accepted and has developed into knowledge data base for technical reference.

Thanks to the extensive company information received directly and from public domain, the IGU Working Committee 2 (WOC 2) Survey 2012 of the Basic UGS Activities Study covers an installed working gas volume (WGV) of some 359 bcm (without 45 bcm of long term strategic reserves of Russia), operated in about 693 storage facilities all over the world. The withdrawal rate of some 235 mcm/h is delivered by 23.007 storage wells.

The WGV capacity of 37 countries with known underground gas storage facilities in operation is summarized in the Table 1.

Country	No. of UGS Facilities (current triennium)	Total Installed Working Gas Volume of UGS Facilities (current triennium)	Total installed Working Gas Volume of UGS Facilities (previous triennium)
		bcm	bcm
USA	419	121.40	110.67
Russia *	22	65.62	65.56
Ukraine	13	32.78	31.88
Germany	46	20.33	20.32

Country	No. of UGS Facilities (current triennium)	Total Installed Working Gas Volume of UGS Facilities (current triennium)	Total installed Working Gas Volume of UGS Facilities (previous triennium)
Italy	12	17.44	16.76
Canada	56	16.68	16.41
France	16	12.60	11.91
Austria	10	7.45	4.18
Hungary	6	6.28	3.72
Uzbekistan	3	5.40	4.60
Netherlands	4	5.20	5.00
United Kingdom	9	4.82	3.70
Kazakhstan	3	4.20	4.20
Azerbaijan	3	4.20	1.35
China	9	3.97	1.14
Czech Republic	8	3.71	3.07
Romania	8	3.51	2.76
Spain	6	3.38	1.46
Slovakia	3	2.97	2.72
Poland	8	2.70	1.66
Latvia	1	2.30	2.30
Turkey	2	1.90	1.60
Bulgaria	2	1.65	0.50
Australia	4	1.61	1.13
Iran	2	1.43	0.00
Belarus	3	1.16	0.75
Japan	4	1.10	0.55
Denmark	2	1.02	0.82
Belgium	1	0.73	0.55
Croatia	1	0.56	0.56
New Zealand	1	0.27	0.00
Ireland	1	0.21	0.21
Portugal	1	0.14	0.15
Armenia	1	0.14	0.11
Argentina	1	0.10	0.10
Kyrgyzstan	1	0.06	0.06
Sweden	1	0.01	0.01
Total	**693**	**358.79**	**322.48**

Table 1 WGV capacity by countries

Note:

* Without 30 bcm of long-term strategic reserves in the previous triennium and 45 bcm of long-term strategic reserves in current triennium.

This WGV capacity by countries is visualized in the Figure 1

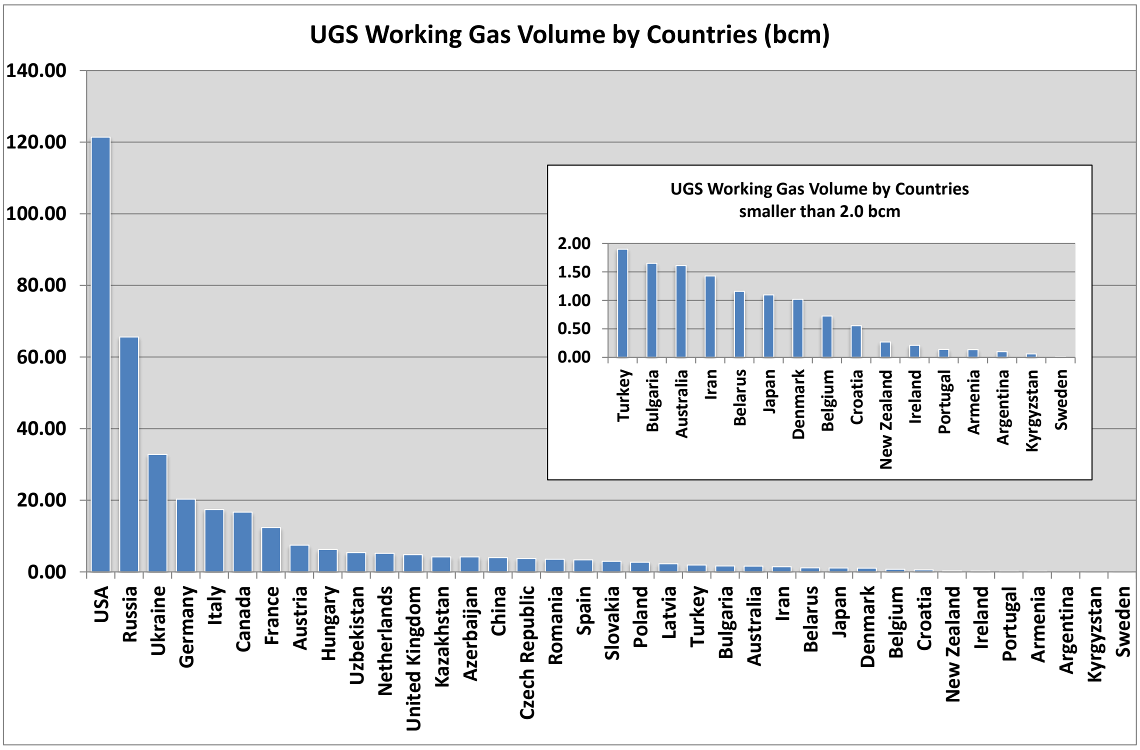


Figure 2 WGV by countries

It is obvious, that the USA are operating the highest WGV, followed by Russia, Ukraine and Germany. The threshold of 10 bcm WGV exceeds also Italy, Canada and France. However, it must be stressed that those data represent declared maximal WGV which does not have to correspond with real storage utilizations from whatever reasons e.g. Ukrainian storages are usually used for two thirds of its maximally declared WGV. Contrary to the previous report, it has to be noted, that the Russian WGV does not include currently declared 45 bcm of long-term strategic reserves.

Compared to the previous IGU WOC 2 Survey 2009, the installed WGV <u>increased significantly by 36 bcm.</u> This is mainly due to storage developments in USA and other countries as depicted in Figure 3.

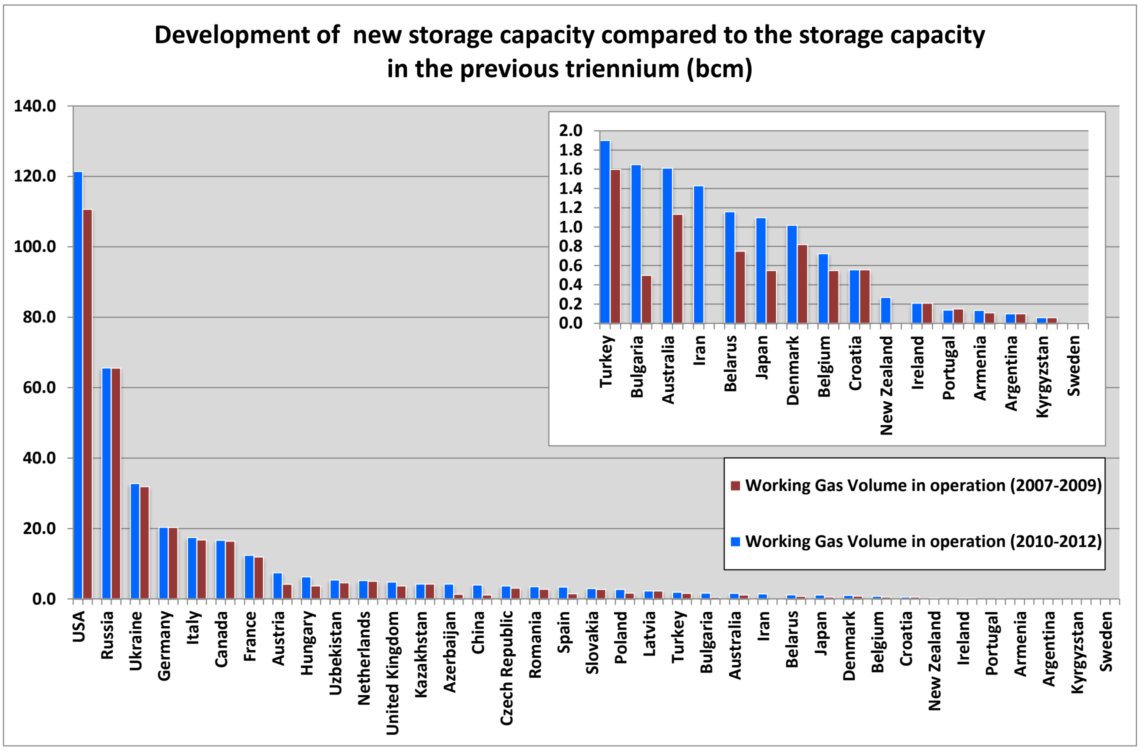


Figure 3 Development of new storage capacity over trienniums

Summary of installed and planned capacities with further details is given by regions in the Appendix SG2.1_2.

The regional distribution WGV of UGS facilities in operation 359 bcm is presented in the Figure 4.

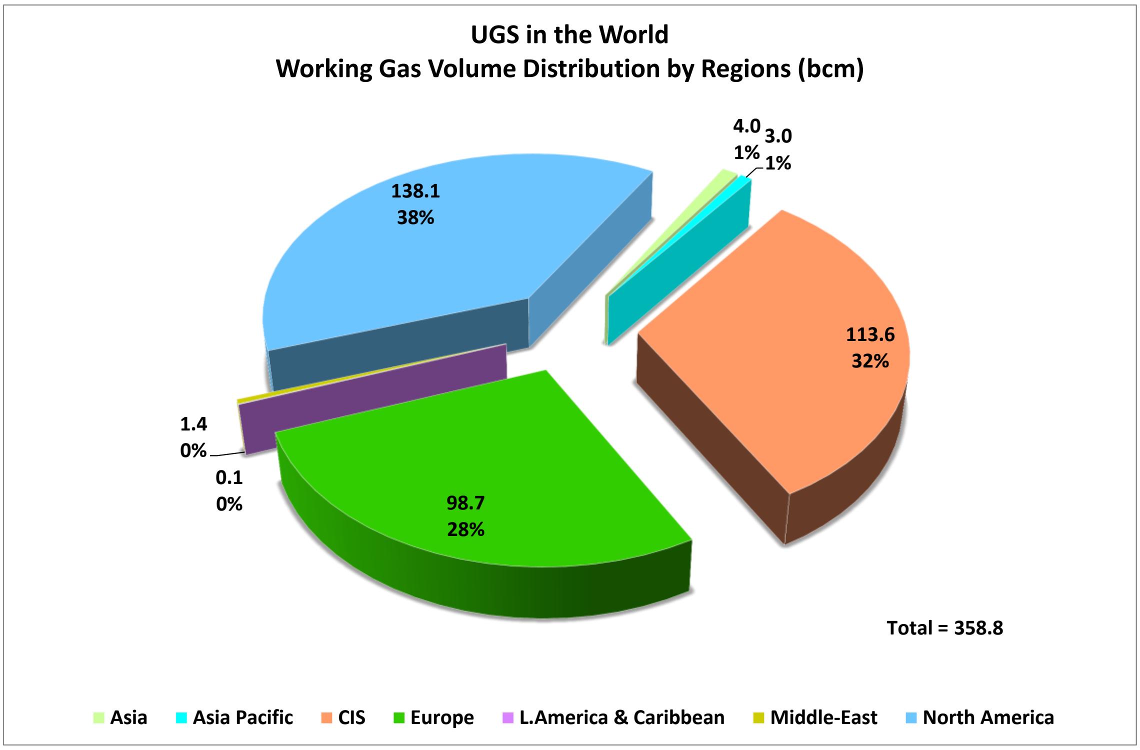


Figure 4 WGV distribution by regions

The major part of the WGV is installed in the CIS, North America and Europe.
It is evident from the following chart that the majority of the WGV in the world is installed in UGS facilities in former gas fields (76%), followed by storage facilities in aquifer structures (13%), salt caverns (6%) and former oil fields (5%).

This distribution of storage types differs from region to region. World distribution of storage types is depicted in Figure 5.

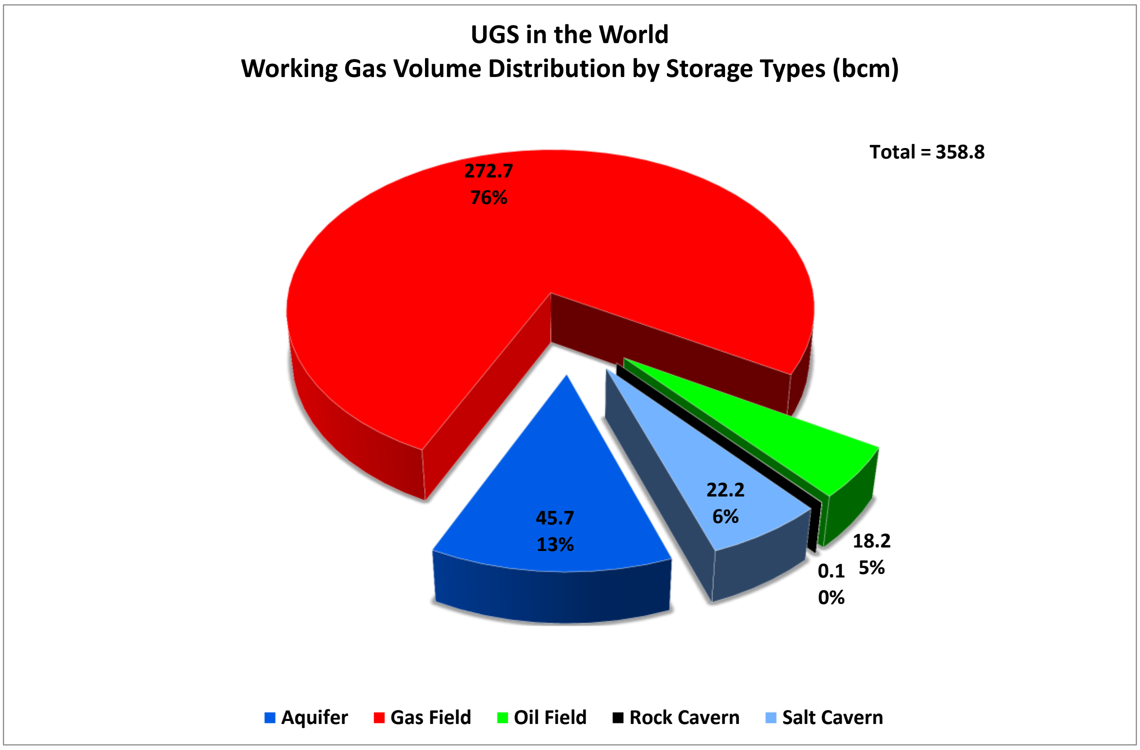


Figure 5 WGV distribution by storage types

The ratio of national WGV vs. No of UGS facilities has been analysed. As an average, about 0.518 bcm of WGV/UGS facility can be derived just based on the real installed WGV. The specific WGV by countries (WGV/No. of UGS) and No. of UGS by countries are presented in Figure 6. Russia offers specifically the highest ratio, resulting from the fact that large reservoir are used for storage.

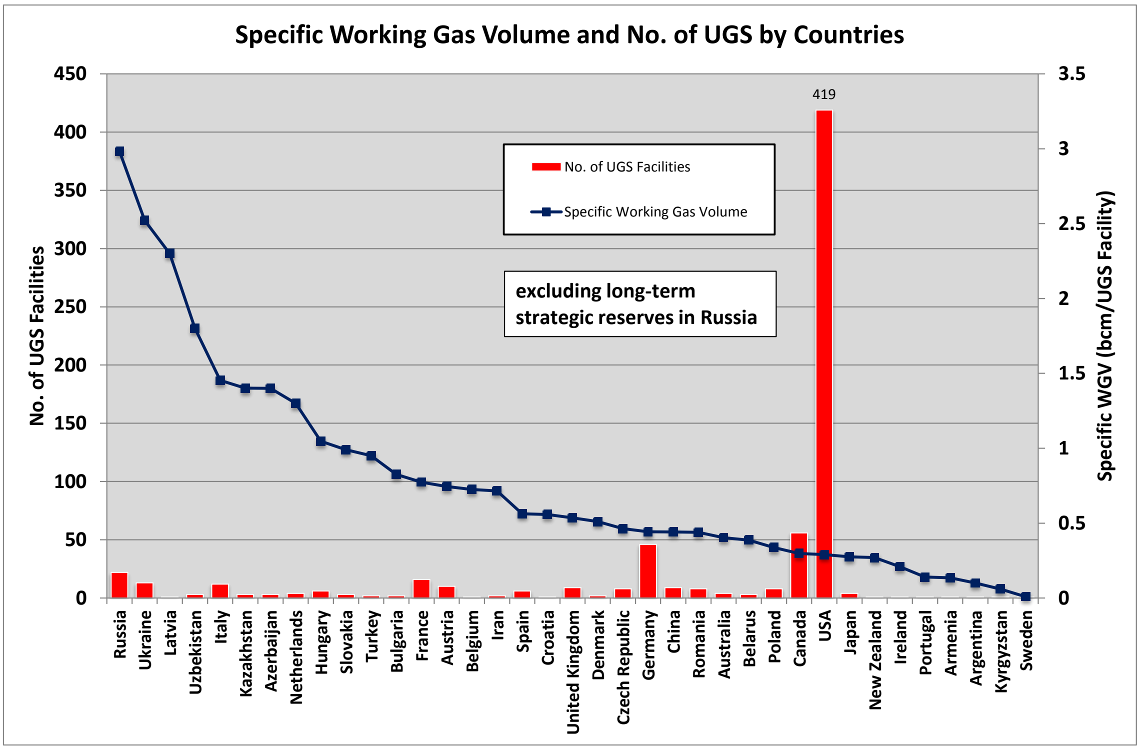


Figure 6 Specific WGV and No. of UGS by countries

The database includes, in addition to the UGS in operation, reported planned and potential UGS facilities. The overall summary is given in Table 2 for the world and in Table 3 for Europe respectively.

World	No. of UGS Facilities	Working Gas Volume (bcm)
UGS in operation	**693**	**358.8**
Planned developments in existing UGS	32	16.1
Planned new (Greenfield) UGS	120	102.5
Potential	31	22.0
Planned and potential developments	**183**	**140.6**
Total - UGS in operation and planned	**844**	**499.4**

Table 2 The overall summary for the world

The detailed focus on Europe in some parts of this study is due to comprehensive data available from this region as a result of large participation of European members within the group.

Europe	No. of UGS Facilities	Working Gas Volume (bcm)
UGS in operation	**148**	**98.7**
Planned developments in existing UGS	26	10.6
Planned new (Greenfield) UGS	58	54.1
Potential	16	8.1
Planned and potential developments	**100**	**72.7**
Total - UGS in operation and planned	**222**	**171.4**

Table 3 The overall summary for Europe

For other regions, please refer to the Appendix SG2.1_2.

The reported planned storage projects distributed according to regions and types are depicted in Figure 7 and Figure 8 respectively.

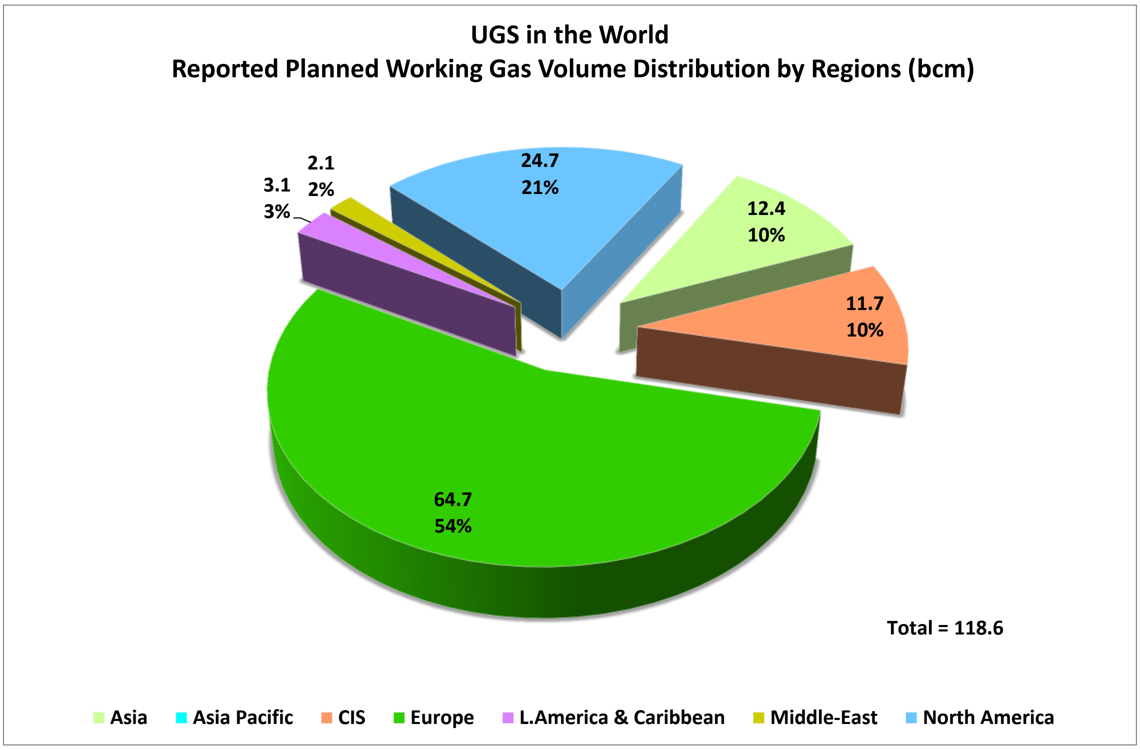


Figure 7 Reported planned WGV distribution by regions

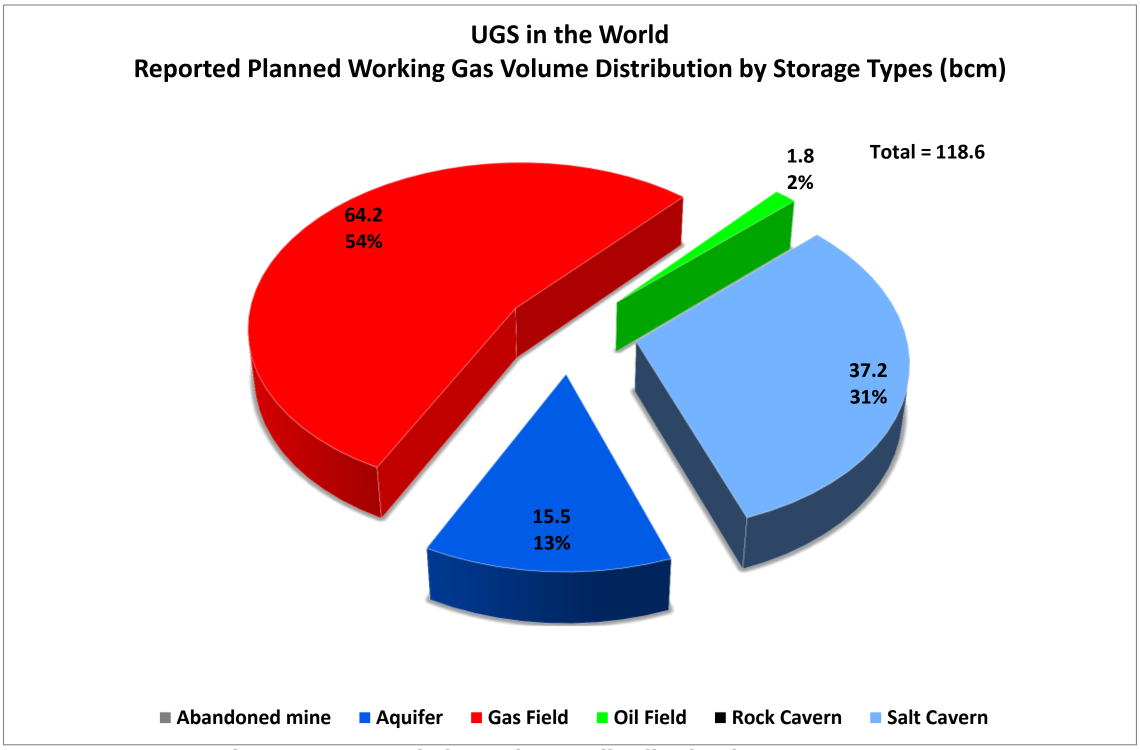


Figure 8 Reported planned WGV distribution by storage types

More than 86% of reported planned WGV is coming from green field projects and 14% from expansions of existing UGS as depicted in Figure 9.

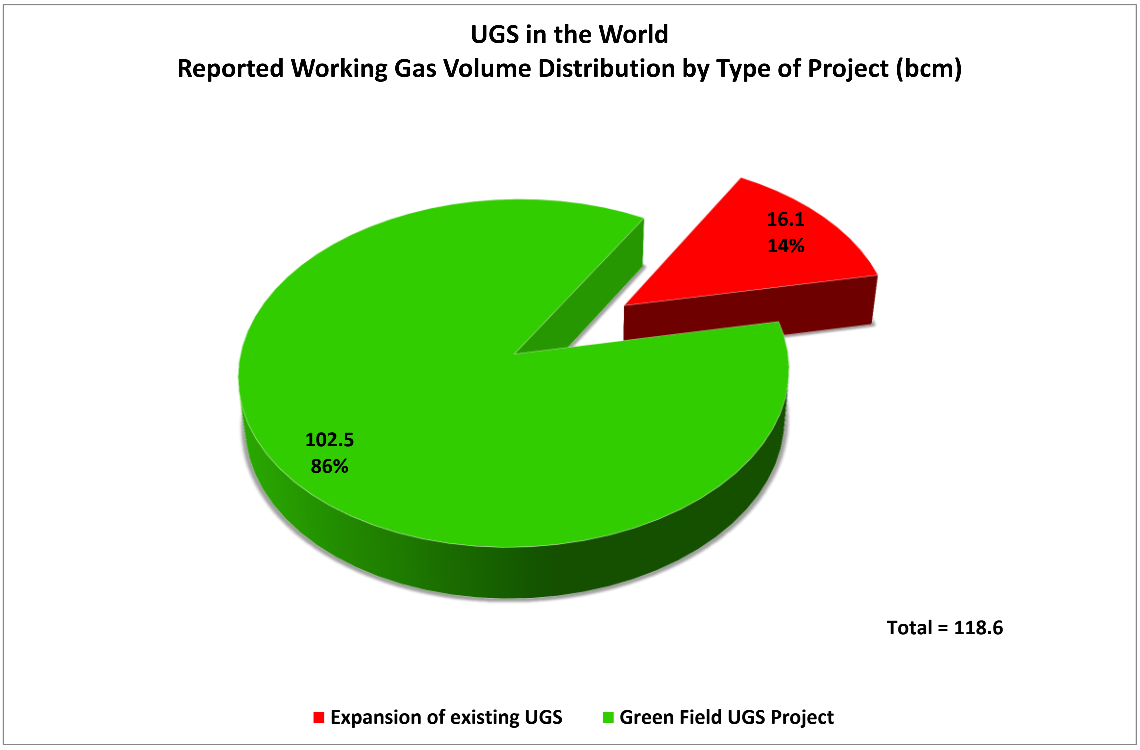


Figure 9 Reported WGV distribution by type of project

The detailed breakdown of reported development status of planned storage projects is depicted in Figure 10 underlining the fact that so far only 28% of planned storage projects is to be realized.

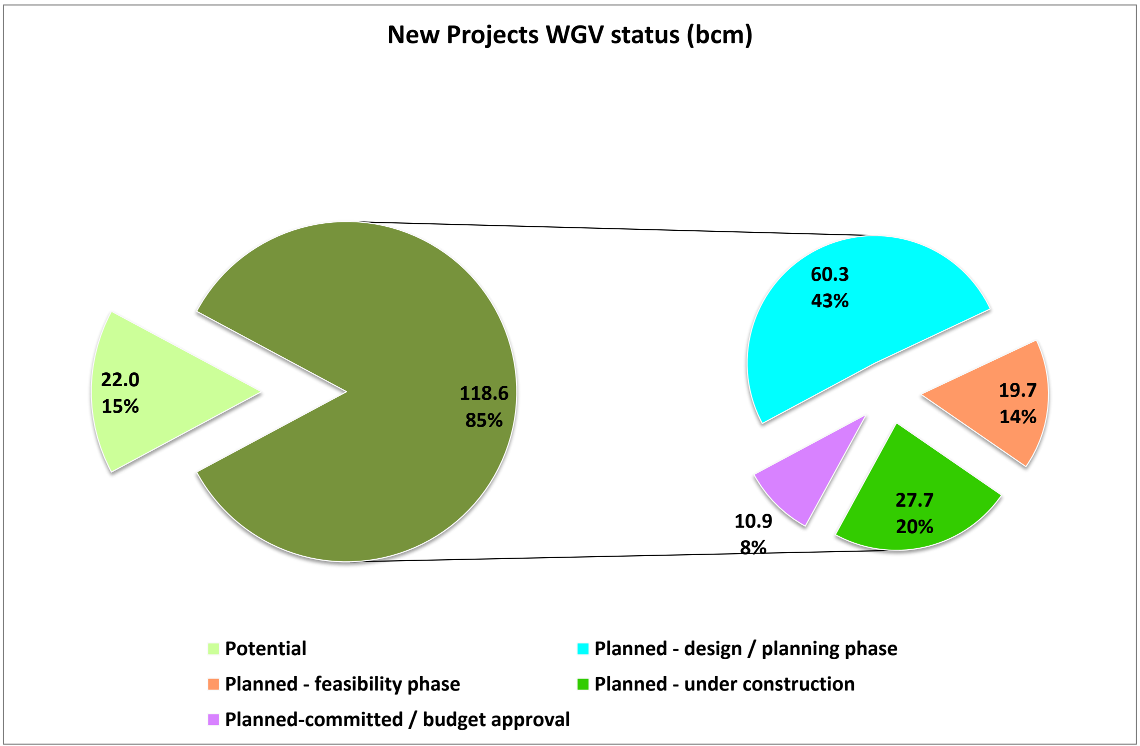


Figure 10 New projects WGV status

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

The detailed information, incl. technical details', concerning reference year 2010/11, is available in the **UGS World Data Bank**, which is Access based; however, via links on the front page of the report they are accessible in EXCEL form. The data are made available for information purposes and for any further detailed analysis in metric and in English units.

3.2.2 UGS World Map

Key data of UGS facilities in the world are available geo-referenced in the **UGS World Map** via links on the start page of the report, by clicking on the world map and zooming in to the area of interest. Further explanations are provided in the special GIS software which is enclosed to the World Gas Conference (WGC) proceedings.

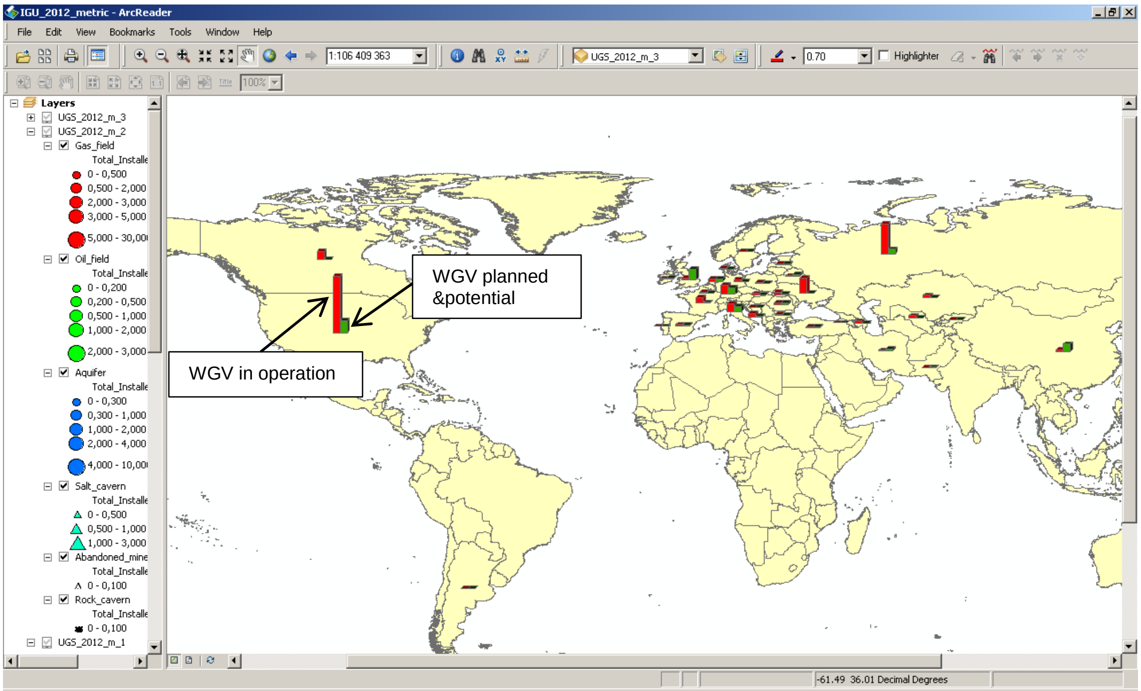


Figure 11 Layer visualisation of WGV by countries

By opening the world map Figure 1, appears and depicts the regional WGV distribution in the form of bar chart.

By zooming in the map UGS key data can be accessed by applying the identify-mode ( ) on the UGS location of interest. Figure 11 depicts WGV by countries split into WGV in operation and planned&potential. Further zooming provides information of WGV split according to storage type by countries as depicted in Figure 12.

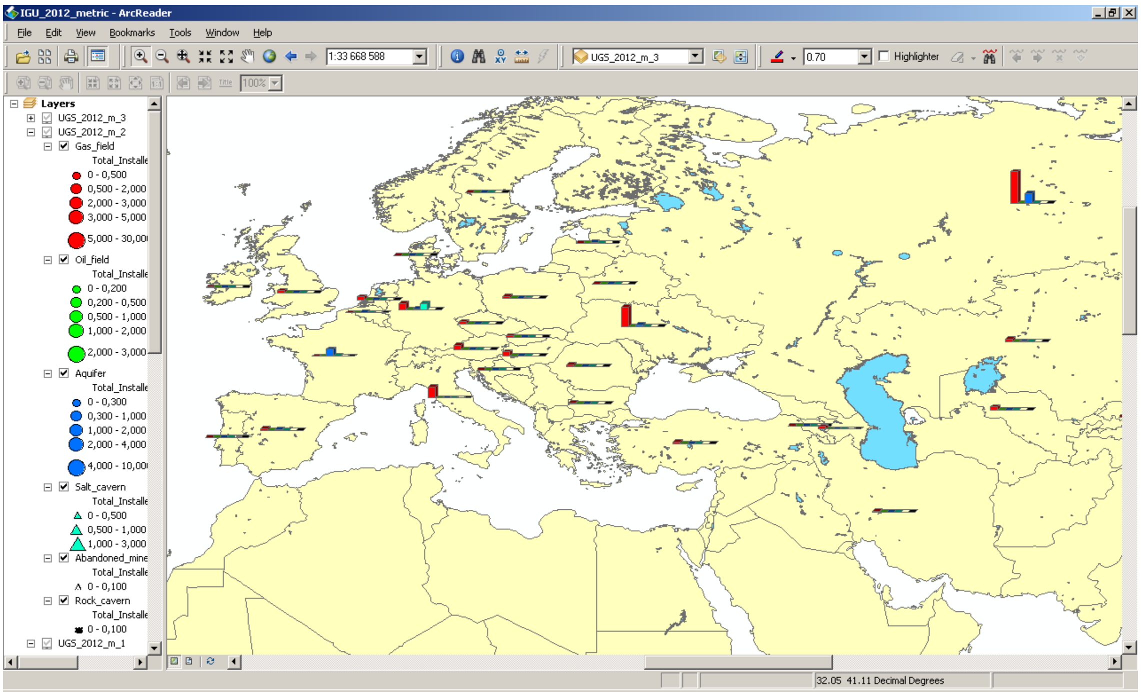


Figure 12 Layer visualisation of WGV by storage types

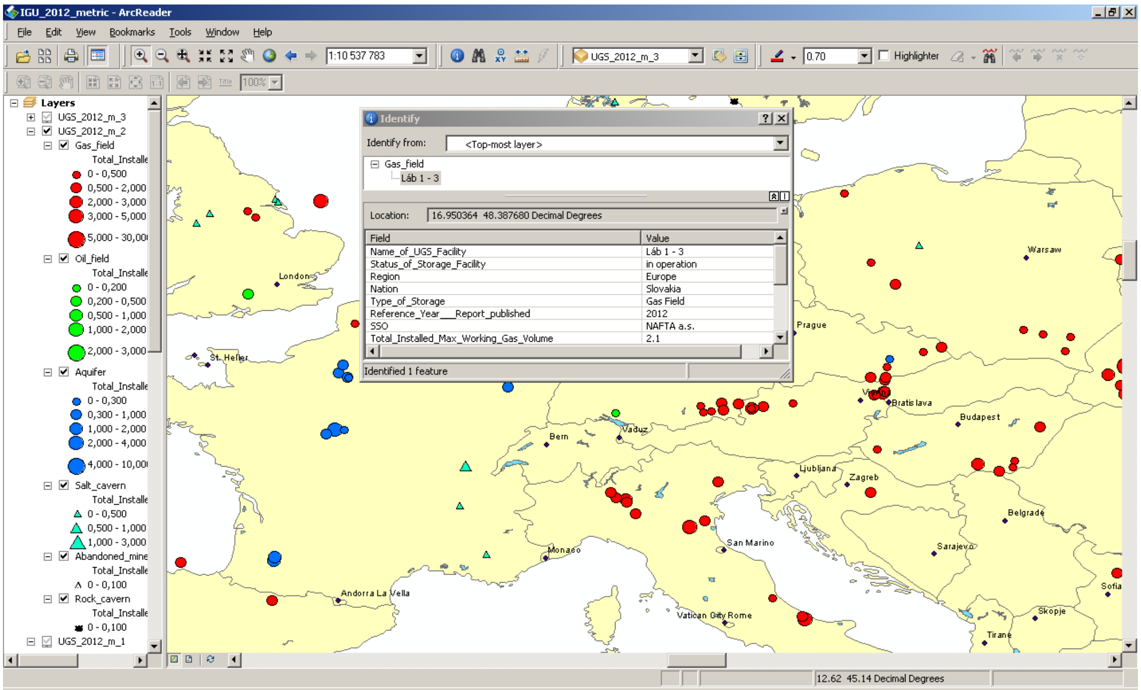


Figure 13 Layer visualisation of UGS by storage types

Further zooming provides location of individual storage facilities (storage type and size of the storage are marked by different symbols) with basic technical data as depicted in Figure 13.

The data of the numerous North American UGS are as well available in this geo-referenced way in the **UGS World Map**. Data can be accessed as well just by clicking on the locations on the map.

3.3 UGS Glossary

As there are too many different storage related definitions available, mainly exploration and production (E&P) and marketing related consolidated glossary of the relevant technical 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 (H_2), Carbon Dioxide (CO_2), Air and other gases. The glossary covers the following terms depicted in Figure 14:

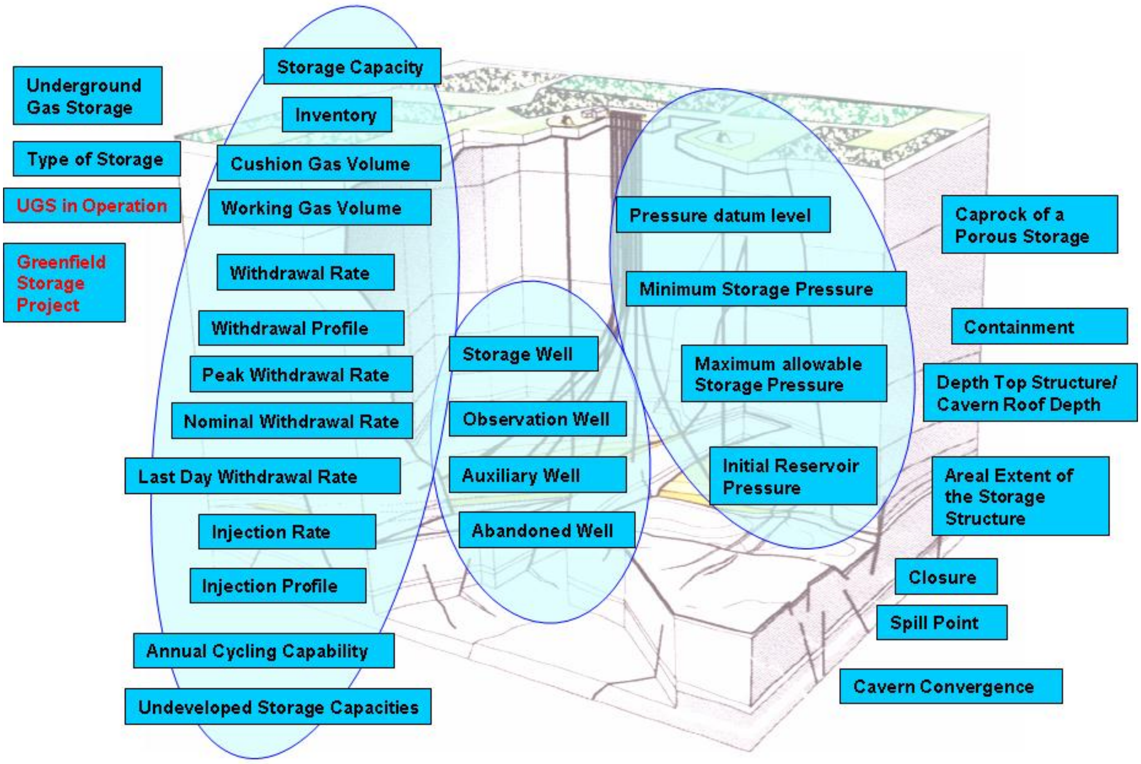


Figure 14 The Glossary

The English glossary is included in Appendix SG2.1_3. The enclosed glossary was translated in other languages (Russian, Italian, Ukrainian, French, German, Japanese, Danish, Serbian, Portuguese, Slovak, Czech and Croatian) available via links.

3.4 Trends in the UGS Business

The derivation of trends in the storage industry business is based on replies from 12 countries (Europe (9), from CIS (1), Asia Pacific (1) and Latin America (1)) received as a feedback to the general questionnaire. It has to be stated that the feedback was not sufficient and even lots of questions were not answered thus inputs from other IGU working groups and additional sources from public domain were used.

3.4.1 Storage Demand General Trends - based on received replies

Mainly European countries and Russia addressed storage demand prognoses. Due to source of the replies, the trends are mainly related to Europe.

Underground gas storage is increasingly understood as a key asset in the energy supply chain. As gas represents energy, energy storage is an interesting opportunity for storage operators to store energy in form of gas which may come from different sources.

Based on demand at the moment, there is sufficient storage capacity in Europe as a whole. Due to previous and recent significant gas storage developments, some countries have more storage capacity than they need so those countries may also provide storage capacity to others provided that there is sufficient interconnection capacity e.g. in Germany, Austria, Hungary, Slovakia, etc.

However, some companies indicated that once oversupply of gas in Europe and transitory decreasing demand of gas due to financial crisis ends up, currently installed storage capacity will not be sufficient. Assuming that gas balance situation will recover, an additional storage capacity will be needed. Moreover, this is supported also by declining indigenous production (the UK, the Netherlands, and Denmark) which means also decrease of production swing for balancing seasonal gas demand and supply variations. Although part of this flexibility will be covered by other types of infrastructures (LNG regas terminals, new pipelines) storage will play significant role in the future, especially if we consider security of supply, phase out of nuclear plants in Germany, growing share of renewables, etc.

On the other hand it must be stressed that regional demand for storage capacity exists even today especially in countries where gas market is growing and gas infrastructure development is lagging e.g. South-eastern Europe. However, the required WGV does not represent substantial figure compared to overall volume.

Storage has developed from matching tool for physical imbalances to trading tool enhancing value of gas. Gas market liberalization is supported by development of trading hubs across Europe with growing numbers of trading transactions. As further gas market liberalization is impossible without sufficient storage capacity we consider this as an additional impetus for storage development.

Storage fulfils several roles for gas market. Taking into account physical nature of gas business it is very efficient tool for supplying gas market with flexibility needed for:

- Seasonal balancing
- Weekly balancing
- Peak balancing (daily, even intra-day)
- Security of supply

On top of that, gas storage provides an excellent instrument supporting trading activities enabling to play seasonal or quarterly, monthly, daily gas price arbitrage based on different gas prices at time and trading hubs. Moreover, it is an excellent tool protecting consumers against volatile gas prices arising from the fact that gas prices are more and more linked to gas indexes. We can even say that without sufficient storage capacities gas liberalization might be hardly possible.

Seasonal balancing is determined mostly by gas demand in domestic and commercial sector where gas is used mostly for space heating. As heating requirements depend on outside temperature gas demand is substantially volatile reaching in Europe a ratio 2 – 4.5 between January and July average gas demand. Industrial sector shows more stable gas demand pattern; however, further volatility is generated by power sector where most gas power plant are used for peak generation. This tendency will be even stronger in the future as renewables (intermittent energy producer depending on weather conditions) increase their percentage in energy mix covering base load. However, in case of changed weather conditions immediate back up is needed from gas plant thus creating significant gas demand at short notice challenging capacity of gas infrastructure. There is no doubt that in such a case gas withdrawal from deliverable storages will be required.

Increasing import dependency in regions with declining indigenous production needs special attention. Furthermore, special attention needs. It is not only issue of security of supply in case of accident at gas supplying infrastructure or if political tensions occur but also declining production swing which especially in some regions e.g. Europe was an important flexibility tool in the past.

Mainly Europe exhibits very high import dependency followed by Asia. North America due to massive shale gas development might become gas exporter from overall point of view. This demonstrates that ensuring security of supply is crucial for gas keeping its position as fuel of choice for power generation. A good example is the very cold winter 2011-2012 all over Europe and CIS when gas demand was provided mostly by withdrawals from storages. It is much cheaper commercially store gas than facing damages from gas supply disruptions. Of course, security of supply may be secured also by other tools than gas storage but it is essential to understand that gas stored in the territory of its consumption may be extremely quickly mobilized and delivered to gas grid without any risk of disruptions or long lead times. This role of the storage was successfully demonstrated several times during last five years in Europe when gas supplies from outside European territory were cut.

3.4.2 Storage Demand Forecasts - based on analysis carried out

The detailed prognosis requires elaborating of overall supply/demand study, complemented with analysis of all sources of flexibility. However, such detailed study was outside the scope of Study Group therefore modified way had to be used.

The prognosis analysis was carried out by the SG 2.1 on a regional basis as derivation of trends by regions is more reliable. Moreover, not every country has suitable geological conditions for storage construction which does not mean that there is no demand for flexibility which needs to be met either by storages outside the countries' territory or other sources of flexibility.

In order to derive more global storage demand trends, the gas demand prognosis up to 2030 elaborated by Programme Committee B (PGC B) was used. Taking into account limited scope of available data for developing gas regions this prognosis was carried out mostly for mature gas regions (Europe, North America, CIS). The data of remaining regions were aggregated and analysed in one group as others.

Prognosis methodology

Gas storage prognosis was determined in the following steps:

1. As the first step ratio of WGV vs gas demand for actual data representing years 2005 and 2010 were calculated. Based on those ratios WGV demand was projected for next 20 years knowing gas demand in particular region and in particular year. This ratio is between 17% and 20% for developed gas countries and regions.

2. In the second step the extrapolation of regional WGV data sets since 1995 was carried out so WGV demand for next 20 years was estimated.

3. In the third step the WGV demand figures were verified with IGU storage database for planned projects and other data from public domains. The most of those planned projects are to be commissioned before 2020 year.

4. Preparing prognosis is always uneasy task due to dynamic changes in the world economy so rather than providing exact figures we decided to define span of new capacity development represented by low demand case and high demand case which differed over regions.

5. Afterwards average WGV demand of both demand cases (low and high) was calculated and used as prognosis.

Results

Summary of WGV demand prognosis is given in Table 4 and Figure 15. In total an increase of storage capacity from current 359 bcm to 456 bcm in 2030 for low demand case and up to 549 bcm for high demand case represents incremental growth of storage capacity (ca 100 – 200 bcm) requiring significant investment and engineering capacities.

This demand might be triggered by different factors varying across particular regions but generally they are as follows:

- Short term volatility of gas demand caused by
  - Intermittent nature of renewables used for electricity generation and backups by gas plants
  - Trading activity
  - Grid balancing

- Seasonal modulation caused either by
  - Decreased production swing or
  - Limited flexibility of shale gas production

- Security of supply due to increased import dependency
- Gas market developments especially in gas developing countries (China, Iran)

	Working Gas Volume Demand (bcm)					
	2005 actual	2010 actual	2015	2020	2025	2030
Europe - low demand case	79	99	107	123	127	132
Europe - average demand case	79	99	111	128	138	149
Europe - high demand case	79	99	115	132	150	167
North America - low demand case	116	138	142	145	147	150
North America - average demand case	116	138	146	150	154	160
North America - high demand case	116	138	149	155	160	169
CIS - low demand case	106	114	115	125	132	140
CIS - average demand case	106	114	119	130	138	146
CIS - high demand case	106	114	123	136	144	151
Others - low demand case	2	8	9	14	22	35
Others - average demand case	2	8	12	20	36	48
Others - high demand case	2	8	14	26	50	62
World - low demand case	303	359	373	408	429	456
World - average demand case	303	359	388	428	466	503
World - high demand case	303	359	402	449	503	549

Table 4 Storage demand forecast

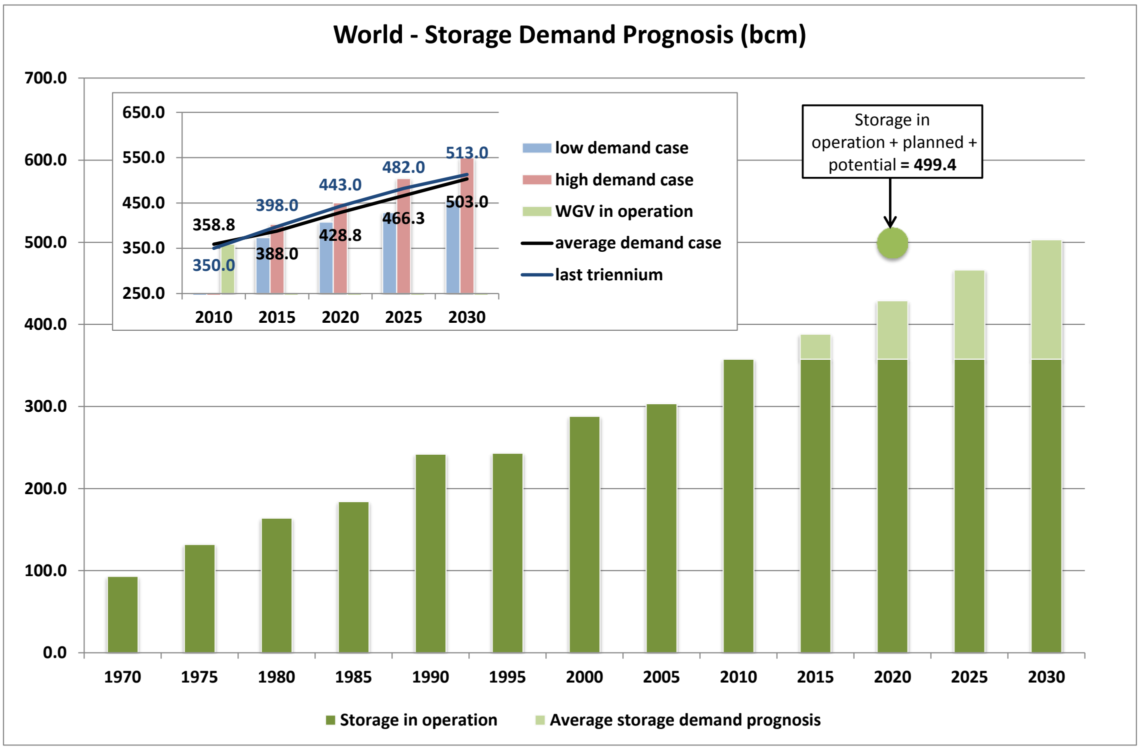


Figure 15 World – Storage demand forecast

Figure 15 depicts gradual growth of storage gas capacity over years plus prognosis for years 2015 – 2030 represented by averaged demand case. Furthermore, there is added detailed depiction of low and high demand cases appended with current and previous prognosis and potential/planned storage capacity just to demonstrate preparedness of storage industry to build new storage capacity if demanded by market. The same approach was applied also for particular regions.

Moreover, in line with increased WGV, the demand for withdrawal rates linked to increased flexibility will be also significant amounting to additional 165 mcm/h in 2030 under high demand case.

The development of such WGV will require cushion gas volume varying between 100 to 200 bcm which represents substantial investment costs. Innovative agreements between stakeholders (storage operators, storage users and gas producers) could reduce this drawback.

Underground gas storage is the most efficient way of energy storage with excellent safety record. However, it must be stressed that as storage development requires quite a long lead time coupled with substantial investment, development of those storage capacities especially for high demand case might happen only in case of stable regulatory environment incentivizing such a long term investment.

Planned and potential projects of new storage capacities demonstrate readiness of storage industry to take this challenge and contribute to cleaner environment and efficient economy by supporting secure and flexible gas supplies.

Europe

High case WGV demand is represented by assuming 36% WGV-import ratio to be observed also in the next years, underlining the Security of Supply issue. Moreover it is linked with modulation of seasonally varying gas demand in Figure 16. This IGU prognosis is more conservative that the ones from other prognosis especially due to our experience from the past that not all storage projects would get final investment decision and materialize in real storage capacity.

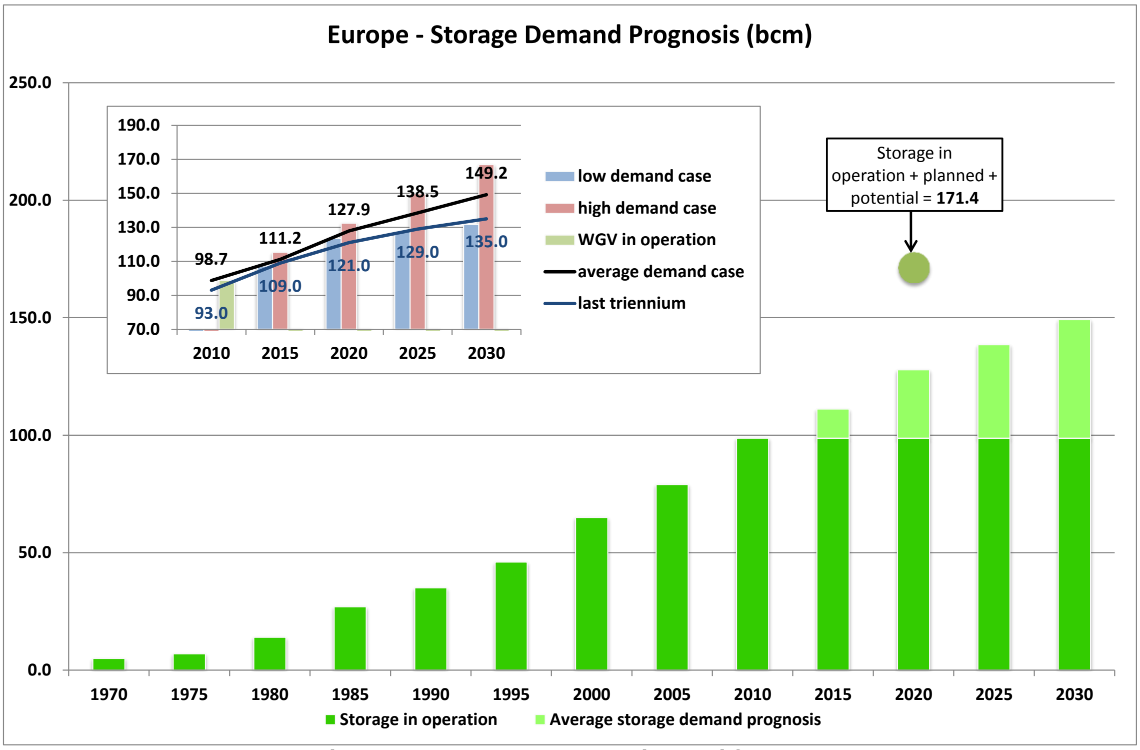


Figure 16 Europe – Storage demand forecast

Moreover, there is growing competition of other sources of flexibility coming with new pipelines and LNG regas terminals. Permitting process due to environmental and safety concerns in highly populated area of Europe brings another challenge for storage developers.

In contrary, Europe dependency on gas imports will be growing from 49% in 2010 up to nearly 70% in 2030. If security of supply gets higher in the agenda of policymakers than today the demand for storage capacity may soar and trigger substantial storage development. Just for illustration: Europe would need totally 163 bcm of WGV in 2020 if the current 36% WGV-import ratio should stay unchanged. Nevertheless, this scenario can be considered as a very high case, with regards to the capacity of investment in new projects. Low case demand assumes 20% WGV – gas demand ratio which fits with the value for developed gas markets.

Gas storage is an essential tool for gas market liberalization so this might create additional impetus for gas storage development. Growing share of renewables might also increase storage capacity demand if intermittency is to be covered by highly efficient gas plants.

CIS

High case WGV demand is represented by assuming 17.5% WGV – gas demand ratio matching with growing gas demand. Low case demand assumes modest grow backed by linear extrapolation of WGV development since 1995. New developments will be focused rather on withdrawal rates than WGV. Figure 17 illustrates this fact, CIS region exhibits very low unit peak withdrawal rate (PWR) 0.0083 mcm/d per WGV in mcm (in other words reciprocal value represents theoretical number of consecutive days needed to withdraw all WGV if PWR would be available across the entire withdrawal profile, i.e. 120 days) compared to other major storage regions Europe and the USA (0.0187 (53 days) or 0.02 (50 days)) respectively. This is addressed also in Gazprom policy to increase substantially PWR up to 1000 mcm/d till 2030 at WGV 100 bcm.

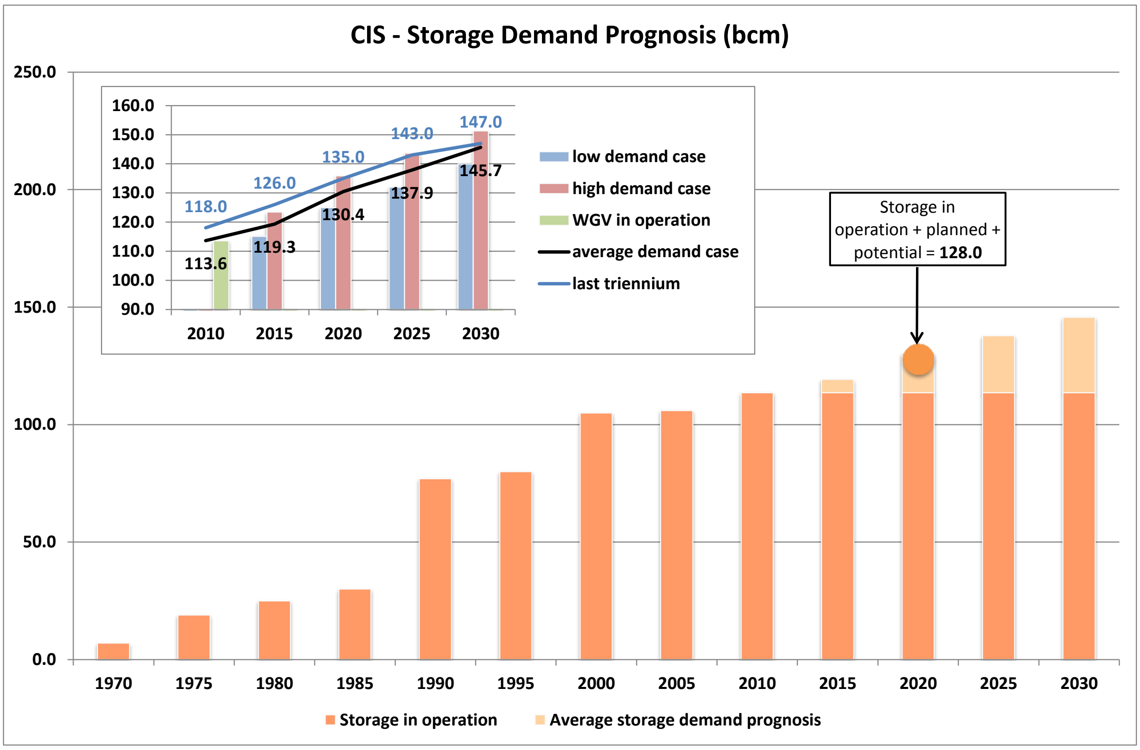


Figure 17 CIS – Storage demand forecast

Development of WGV demand is mostly linked to growth of gas consumption in domestic and commercial sector mostly for space heating which is extremely sensitive to outside temperature which was also the case in February 2012 when CIS region suffered from very low temperature.

North America

High case WGV demand is represented by assuming current 17.8% WGV – gas demand ratio also for other years matching with growing gas demand. Low case demand assumes modest grow of WGV due to significant increase of WGV over the last 10 years Figure 18.

After massive shale gas development, the risk of security of supply diminished and storages are now used for seasonal and peak balancing caused by power generation from gas. Trends towards greater use by marketers and less use by utilities resulted in less cycling of working capacity and higher focus on rates. Another significant change is that pricing is becoming a greater driver of storage use than the weather adding additional volatility on storage use.

The big difference towards previous triennium prognosis is caused shale gas revolution. To certain extend, limited production swing of shale gas might be attributed to needs of storages.

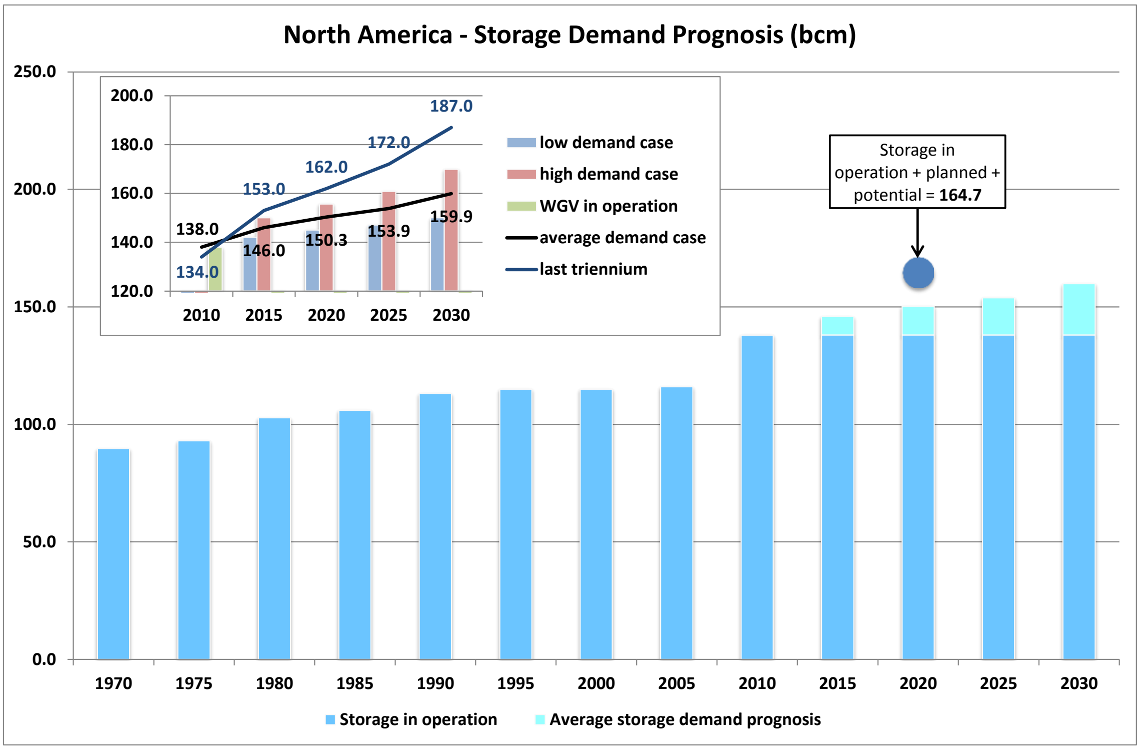


Figure 18 North America – Storage demand forecast

Current market situation with low spreads might even force some operators to challenge their decision to stay in the business or abandon storage activity and produce cushion gas which happened also in the past. Cheap gas also supports usage of gas plants for electricity generations which require flexible storage capacity especially coming from salt caverns. For detailed insight into North America storage activity please see part national perspective.

Others

Prognosis is based on information on planned storage capacity either from IGU members or public domain and is depicted in Figure 19. These regions include on one side countries like China and Iran with huge plans for storage development and on the other side countries like South Korea and Japan with high gas demand but limited geological possibilities for storage construction.

Demand of WGV is based on ambitious plans of China concerning increased gas utilization. At the moment, storage capacity development is lagging behind pipeline construction; however, China intends to reach 15 bcm by 2020.

In the Middle East development of storage capacity is connected with Iran's plans on storage projects. In year 2011 first storage was commissioned and there are further plans for storage development up to level of 19 bcm.

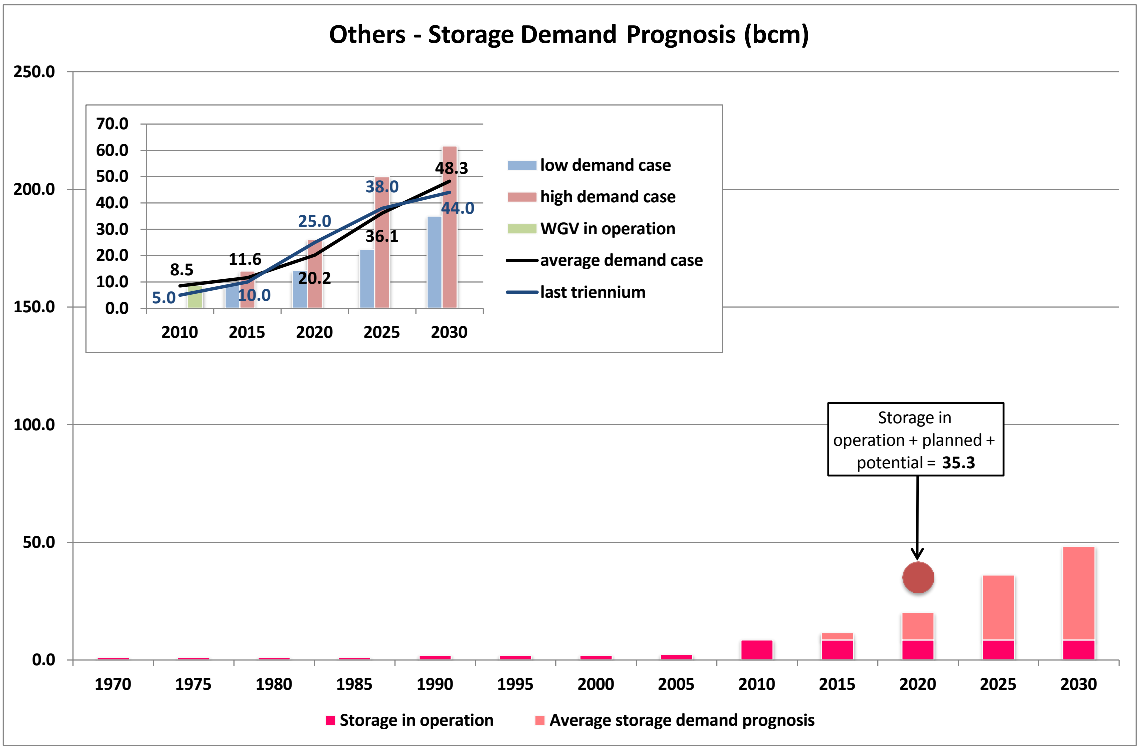


Figure 19 Others – Storage demand forecast

3.4.3 General and technological issues

Based on the replies which were received as a 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.

3.4.3.1 General issues

On-going gas liberalization drives demand on storage flexibility. Third party access enabled access to storages to all market players with different needs thus pushing storage operators to increase portfolio of storage products with increased flexibility. Improved interconnections between neighbouring countries have changed national to regional storage market and increased competition not only among storage operators but also among other flexibility providers. New storage products are developing rapidly enabling to use instruments of financial markets.

There is a strong tendency to expand role of renewables in energy mix; however due to their intermittency - gas power plants are needed to provide quick and responsive back up. Unpredictable usage of gas plants will require flexible gas infrastructure with adequate storage capacity able to start withdrawal at short notice. For this purpose salt caverns are required due to their high withdrawal rates but also pore storages might be to a certain extent competitive in addition to other sources of flexibility operated within portfolio of gas supplier.

Underground gas storage is the most efficient way of energy storages. WGV with reasonable withdrawal rates are needed for security of supply because Europe becomes more and more dependent on gas imports. Having available storage products close to the market represents a strong advantage in case of any gas supply disruptions. Commercial storages have proved their ability to provide sufficient and quick gas deliveries thus stabilizing gas industry in time of gas supply cuts as experienced during this winter.

Even there has already been competition in the storage industry, further increase of storage capacity and growing competition may be observed. So qualitative improvements of the storage product are even more important (e.g.: time to change the operational mode, unlimited intraday re-nominations, etc.) in order to attract customers.

The UGS business will require a significant amount of capital investment for the development of infrastructures and long lead times. In some countries, direct participation and/or financial assistance by the government is considered.

Essential concerns are still in place, whether the liberalisation process allows for sufficient incentives for new developments and whether the operation of existing UGS can be carried out economically in the future. As storage developments becomes more costly because of materials and services, etc. as well as the good locations have been developed and new storage developments are more complex and costly. Considering long lead items (up to 8 years for design, permitting, construction and build up) and demanding permitting process, not enough storage capacity might be available for market in few years' time. Moreover, in case of mandatory regulated TPA to UGS, linked to low uneconomic storage tariffs, 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.

Examples from the USA demonstrate that abandonment and conversion for gas production happens and is dictated by commercial attractiveness of “quick” production of gas rather than providing storage services which is a long run process with continuous social and environmental responsibility with volatile income depending on future market and regulatory situation.

3.4.3.2 Commercial issues

Storage plays an important role in structuring import capacities as well as seasonal demand fluctuations. Increasing trading volumes and product at the virtual trading points (gas hubs) have to be backed by storages.

Generally storage customers may choose from different product types with various performance attributes. The product range consists of bundled storage parameters (WGV, injection rate, withdrawal rate), unbundled and intra-year storage capacities. Products might be sold on long-term basis, several years or short-term less than one year even for days. In order to provide comfort to customers storage operators are offering trading platforms which enable customers to click and book day-ahead storage capacity or trade their storage capacity on secondary market. These storage capacities can be booked firm or interruptible if firm storage capacity is not available.

Storages are used for arbitrage reasons and protect customers from excessive short-term market price volatility. The storage providers discovered in their portfolios new types of customers. The new entrants, arbitrage seeking gas traders and even risk taking commercial banks joined traditional incumbents as customers in now unbundled storage companies. Classical summer injection and winter withdrawal cycles will still form the majority of activities performed by storage operators but they will be continually complemented with short-term flexible services.

Moreover, there is still potential for improvements in storage services ranging from increased flexibility to storage & transmission bundled products. Storage operators will have to update their products regularly in order to meet customers´ requirements.

3.4.3.3 Technological issues

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

Pore storages

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, automation, safety investments.

Development of capacities

Regarding the expansion of capacities, the trend is towards the development of huge UGS and small city gate UGS and concerning cavern facilities, as well towards 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 depending on detailed engineering studies and the authority approval.

Additional capacities are made available by recompletion of storage facilities with larger tubing diameters.

The replacement of cushion gas volume by low value gases is still of relevance as the CGV requires significant funds; however, so there is no evidence of operating such storage. But gas mixing/quality aspects are hindering the implementation.

Subsurface

Concerning subsurface aspects, 3D seismic, 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/fault tightness is of a great importance.

2D seismic measurement is replaced by 3D seismic with new methodologies of interpretation and better results with great benefit to geological model.

Log measurements help to find out petrophysical characterization of the reservoir and also specify geological structure of the reservoir, its overlying and underlying rocks.

Necessary data are received from cores in laboratory measurements. Data give important petrophysical information, elastic parameters for geomechanical analysis and parameters for finding out integrity of caprock.

Deliverability tests are recommended to characterize productivity parameters of storage well and reservoir behaviour. The 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 optimize storage processes and forecast different scenarios of its development. Goals of simulation models are to predict and guarantee capacities and performance in the future.

Very important information about wells behaviour and stability of reservoir in various dynamic states can be derived from geomechanical analysis.

Wells

There is a strong tendency towards reduction of the number of storage wells and their footprints. Well cluster concept is becoming popular. The horizontal or directional drilling well technology is applied when appropriate and possible.

Wells are re-completed to optimise pressure losses due to frictions and to install surface controlled subsurface safety valves. Improved well completions (e.g. expandable sand screens) are installed for sand control purpose in unconsolidated reservoirs and slightly cemented reservoirs. Geomechanic models are used for selecting suitable well completion to mitigate sand production.
The issue of well integrity management is raising (see SG2.2 report).

Salt caverns

Introduction

In recent years, progresses have been made, particularly in Europe, in the four following areas:

- Local acceptability of projects,
- Reduction of development duration and costs,
- Emergence of new innovative techniques,
- Extension of the operating range of cavities.

Local acceptability of projects

Due to the regulatory environment that increases the constraints, it is given greater consideration to urbanization and environmental concerns:

- To reduce the surface influence of storage, the cluster design of cavities with “S” shape deviated wells has become quite usual in Europe (e.g. Preesal in the UK, Etzel in Germany). Also noted is the attempt to develop a project with a very large deviation following American techniques (drilling at 75° and very large well diameter 20 " for Preesal in the UK),
- To look for other opportunities, other than the chemistry of chlorine and salt, to make the best use of the natural resources extracted from the caverns. As an example, there are R & D studies on the production of electricity by reverse osmosis. Another one is the development of local measures to support projects such as onshore sea fisheries or thalassotherapy,
- To limit the impact on freshwater resources through the use of sea water even for caverns located tens kilometres onshore (sea and brine lines of tens of km, e.g. King street in the UK, Salins-des-Landes project in France) or through the development of offshore leaching techniques using dedicated monopod structures (e.g. Gateway in the UK),
- Finally, for sites where several storage projects are being developed, the need arises of a mutual understanding and better collaboration between Owners and future operators to provide clear and consistent communication *vis-à-vis* neighbours and governmental bodies (e.g. Infobox on the Etzel website that includes all stakeholders in the area but also the global hazards study of including all of four storage sites)

Reduction of development duration and costs
Due to unfavourable economic conditions following the financial crisis of 2008 the different techniques have been implemented in Europe:

- Converting existing cavities not designed for gas (e.g. oil cavities at Etzel in Germany, extension of Hole House in the UK),
- Leaching at high flow rates up to more than 350 cm/h (eg Etzel in Germany),
- Leaching in parallel a large number of cavities (ex: Stublach (10 cavities) and Byley (8) in the UK, Etzel (>10) in Germany,
- Increasing the size of cavities beyond 0.5 mcm (Nutternoor > 1.0 mcm ,Preesal (0.7-0.8 mcm) in the UK, Etzel (>0.7 mcm) in Germany, Hauterives in France (> 0.6 mcm), ...),
- Using leaching techniques already implemented in the United States: a single leaching cycle at Preesal in the UK, where possible (homogeneous salt dome)
- Finally, as an illustration of the necessary technical cooperation between operators: the case of first-gas fill of Crystal cavities at Etzel, for which the construction of gas installations were not completed. Crystal benefited from the compressors of EGL storage facilities.

Emergence of new innovative techniques
Apart from the innovative techniques already mentioned on projects Preesal and Gateway, the concept of operations with use of the compensation technique with brine was studied for Portland in the UK. For this project, it is planned to operate very deep cavities (2 400 m) at a constant pressure of more than 400 bar by injection of brine during withdrawal, the brine being stored in a nearby aquifer (18 km). Also note that restricted access to new salt sites suitable for gas storage and the additional costs of greenfield projects gave the mining license holders the opportunity to propose their assets on the market for the development of gas salt caverns.

Extension of the operating range of the cavities
A key factor in the profitability of storage in salt caverns is the possibility of extending the operating conditions in volume and flow. It is then useful to increase the working volume by expanding the range p_{min} / p_{max} and flow (trading) by increasing the daily pressure gradient beyond the standard 8 bar/d. Models and geomechanical studies become longer, sharper and more sophisticated. The problem remains in the ability to convince the authorities of their validity. In many cases, the Administration turns to the third expertise, registered or not, to validate the results of the studies. Unfortunately, the models used are not always the same and it is often difficult to achieve completely identical results. To illustrate the case, three institutes in Germany are accredited by the Administration, each having developed its own models and concepts. At Etzel, for example, each new project has a different expert; every project, even if developed in the same salt, with the same drilling techniques and leaching and at similar depths, faces different constraints (e.g. concept of annual average minimum pressure vs obligation to stay above a certain healing pressure for a time that depends on the period at minimum pressure).

Conclusion
In the light of recent projects developed in Europe, we notice the hardening of regulatory and environmental constraints and thus lengthening of administrative procedures. There are also differences between the national and supranational (Europe) levels, both on the criteria of stability and usability of cavities as well as the administrative and environmental facilities areas that restrict or distort the competition between countries/projects globally and refrain the development of new projects.

3.4.3.4 New opportunities for storage

The energy used in the world today is mainly produced by using coal, oil, natural gas and renewable. Natural gas business has experienced great progress. Exploration for new sources, building new production facilities and infrastructure all over the world are increasing. The world´s growing population and climate change are very hot issues, the tsunami in Japan and the consequences afterwards relating the nuclear power production are unclear. Until now, Germany has decided to close down their nuclear power stations in 2022 and this production stands for 20% of the power supply in Germany.

In the future it is necessary to look at the new possibilities for the existing and new storage:

Compressed air energy storage (CAES)
It is not a new way to store energy. It is already used at existing plants in Germany (Huntorf) and one in USA (the McIntosh Project in Alabama) for peak shaving. Compressed air energy is to be used either for power generation or might be used in combustion chamber of gas turbine powering electrical generator thus eliminating air compression by the gas turbine.

The principle of current installations is that you use off peak electricity to run a compressor which compresses air to a cavern which is optimised for large injection and withdrawal rates. Consequently, during peak time compressed air enters into combustion chamber of gas turbine powering electricity generator. The CAES plant is at this moment very well tested, but it is still a challenge to get a better efficiency.

The project (ADELE) running in Germany aims at increase of energy efficiency of the entire process via adiabatic storage where heat generated during air compression is recovered, stored and later used to preheat air expanding from the cavern and entering into gas turbine powering generator. Moreover, other projects investigate interconnection of CAES and wind farms or utilization of pore reservoir for CAES.

Carbon capture storage (CCS)
Power stations and plants etc. using fossil fuels produce greenhouse gasses as, i.e. CO_2, which is affecting our climate in a negative way. That is why companies are testing demonstration plants to separate CO_2 from the gasses and want to store it, thus contributing to decrease of emissions.
On this topic see SG2.2 report and PGCA contribution.

Wind and solar to gas
The journey from using fossil fuel to using renewable goes over wind power and solar production. When the wind is blowing and the sun is shining, overproduction has to be stored for the days when the wind does not blow and the sun does not shine. At the moment, it is not possible to store electricity, without changing it to H_2 and again to methane before storing the gas in underground storage.

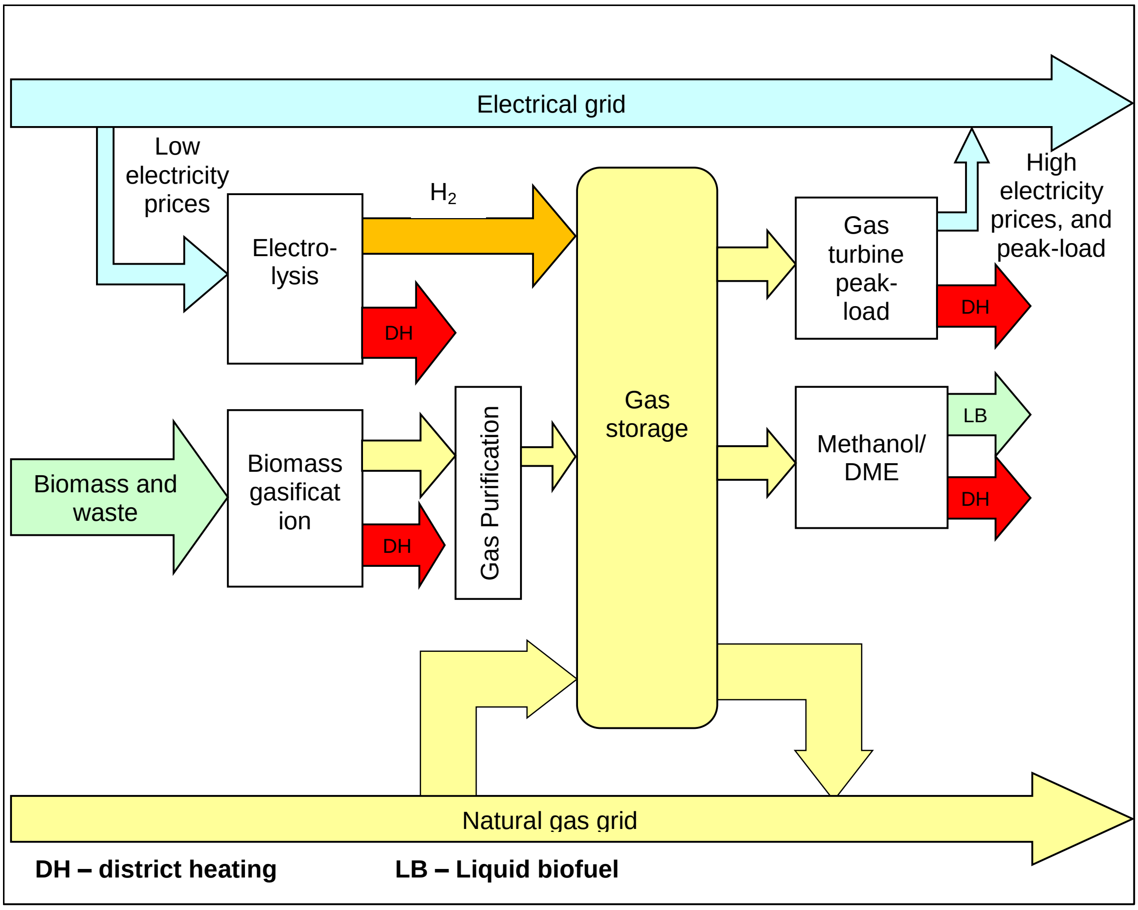


Figure 20 Perspectives for the integration of renewable into the gas system

Figure 20 shows various important elements of a possible future energy system. Renewable energy gas will be, for example, produced through electrolysis of wind power-generated electricity and through the gasification of biomass and waste. The gas produced is used in gas turbines (peak-load generation), liquid biofuel production (methanol, Dimethyl ether (DME) etc.) or upgraded in order to be fed into the main gas grid providing that it meets gas quality specification.

In the figure, gas includes not only methane but also other renewable energy gases (hydrogen and gasification gas). This type of gas can be produced from various types of fuels and would therefore be a stabilising factor in the energy system however it must be purified and upgraded to methane in order to meet gas quality specification of the gas grid. In hours of very large amounts of wind power and thus low electricity prices, using this electricity in the production of hydrogen or methane would be competitive.

The gas may be an important peak-load fuel and thus a significant factor in terms of security of supply. On the input side, not only electricity and biogas will play an important role in the future gas supply - waste and, in principle, coal gasification may also be important contributors.

The emerging scenario where gas will play a major role in the integration of renewable energy fuels into the energy system creates a need for additionally developed the gas system. The development is to ensure that the existing gas system is capable of handling various types of renewable energy gases, for example by methanising the gas. On the other hand renewable energy gases must comply with gas quality specification of the main gas grid.

Hydrogen storage (H_2)
Hydrogen storage has already been operated in the last years in the UK and the USA and the knowledge from this operation is studied very carefully to see how the H_2 influences not only salt cavern but also materials as steel for pipes etc.
In Germany they are currently testing how much H_2 can be added to natural gas and stored in caverns or depleted gas field. H_2 would be produced via electrolysis powered by electricity from renewables at off-peak time. Produced H_2 might be mixed with natural gas in gas grid and underground gas storages provided that storage performance is not affected due to potential chemical reactions.

3.4.4 Database analysis

Some analyses from UGS databank were carried out providing interesting comparison.

Frequency and size distributions
The storage facility were analysed and based on their numbers related to their size in working gas volume they were separated in the following categories further used for analysis:

- <0.1 bcm
- >0.1 bcm and < 0.5 bcm
- >0.5 bcm

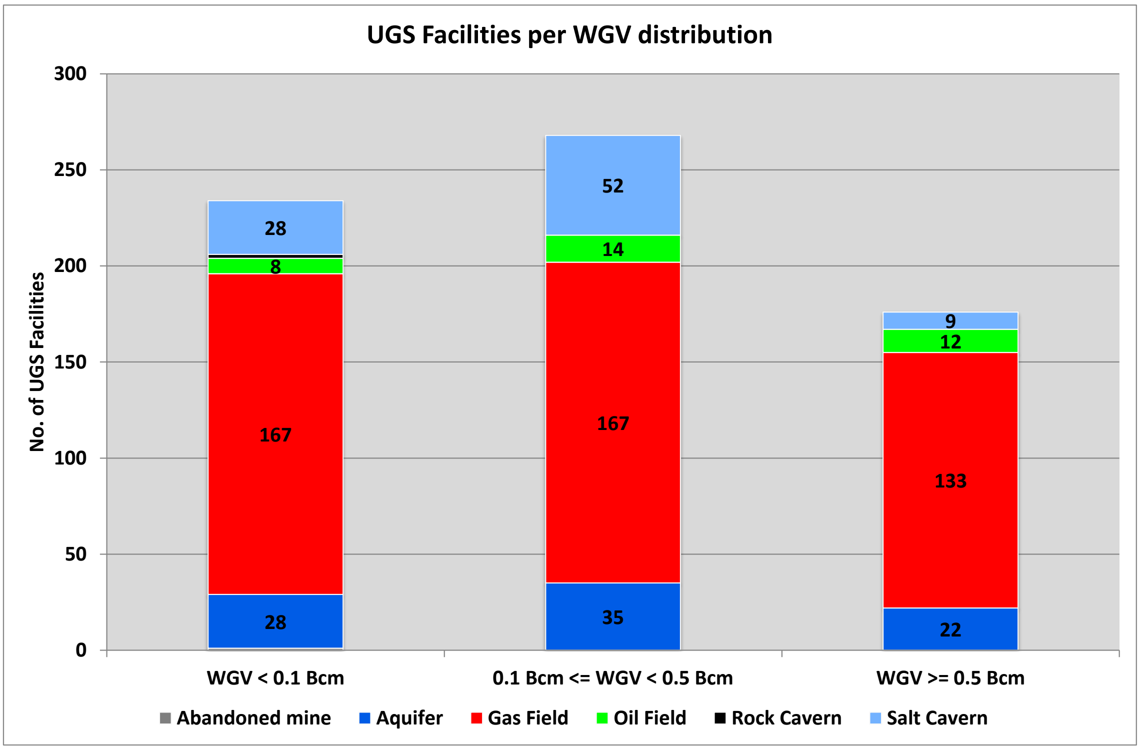


Figure 21 UGS facilities per WGV distribution

Original vs maximum allowable pressure gradient
The Figure 22 shows comparison of original pressure and maximum allowable pressure gradients for some storages in gas and oil fields illustrating that increase of original reservoir pressure is well established practise and the most efficient method of WGV increase. If properly applied this practise does not cause additional safety risk.

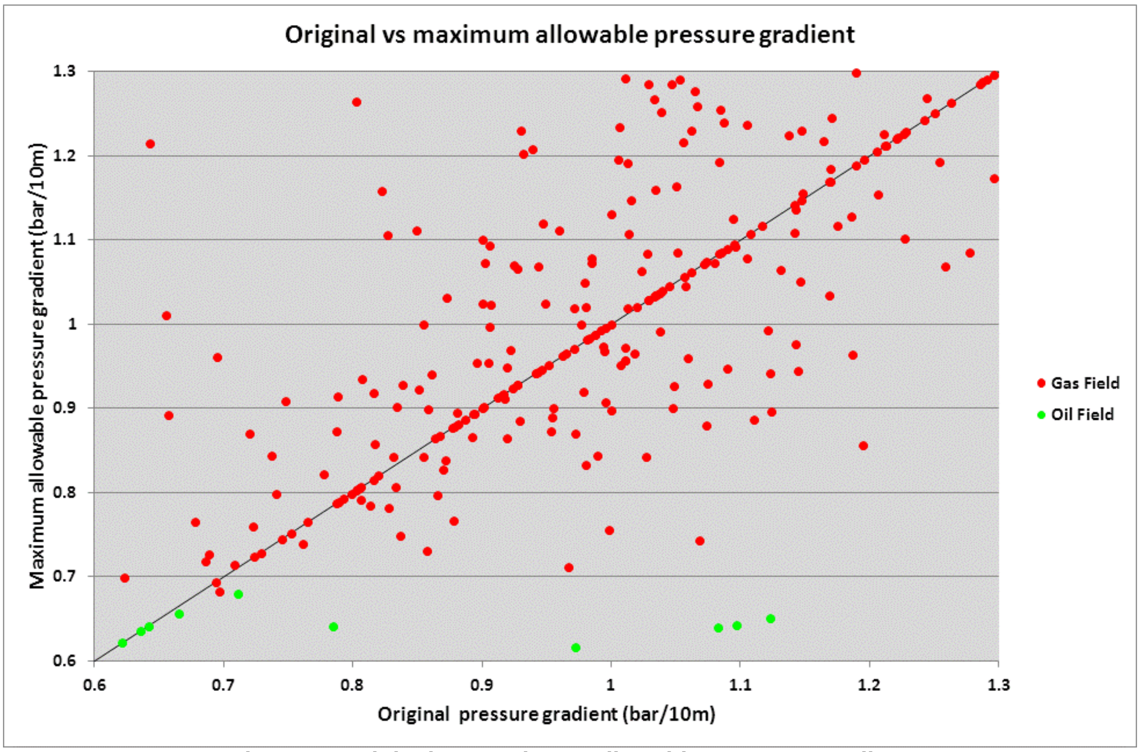


Figure 22 Original vs maximum allowable pressure gradient

Maximum allowable pressure gradients for salt caverns

Maximum allowable pressure gradients for salt caverns confirm that with a few exceptions the gradients are below 2 bar/10m.

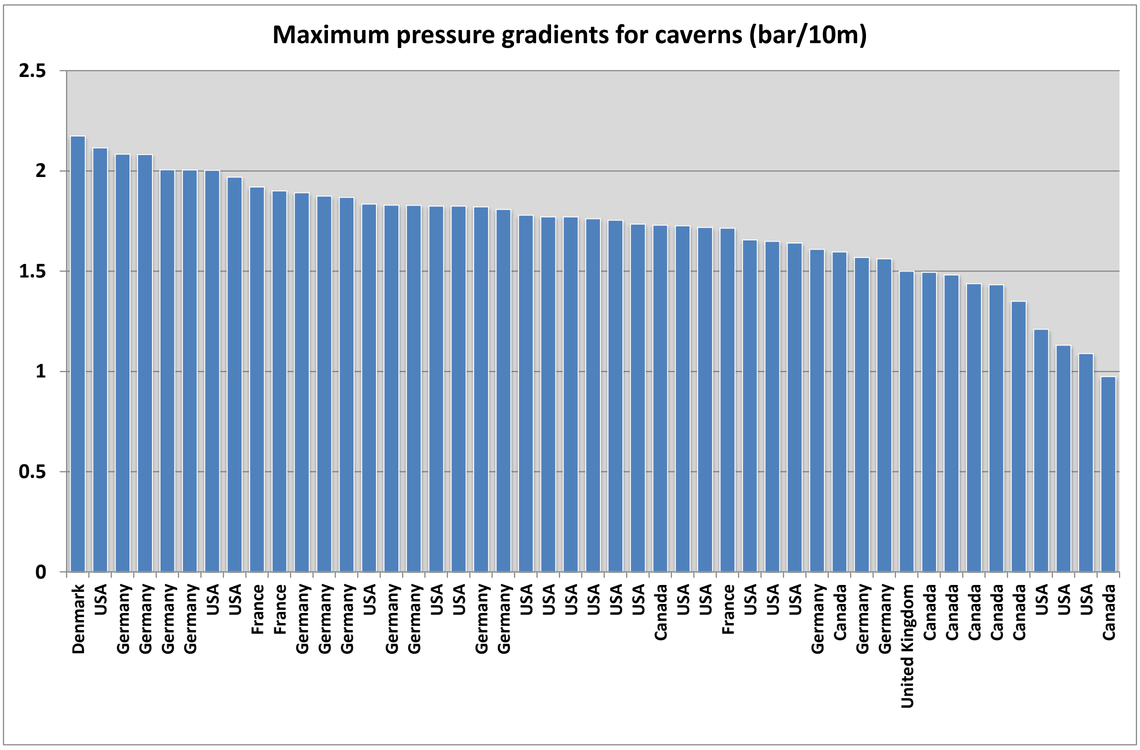


Figure 23 Maximum pressure gradients for caverns

<u>*Maximum allowable pressure gradients for aquifers*</u>
A maximum allowable pressure gradient for aquifers confirms that with a few exceptions the gradients are below 1.5 bar/10m.

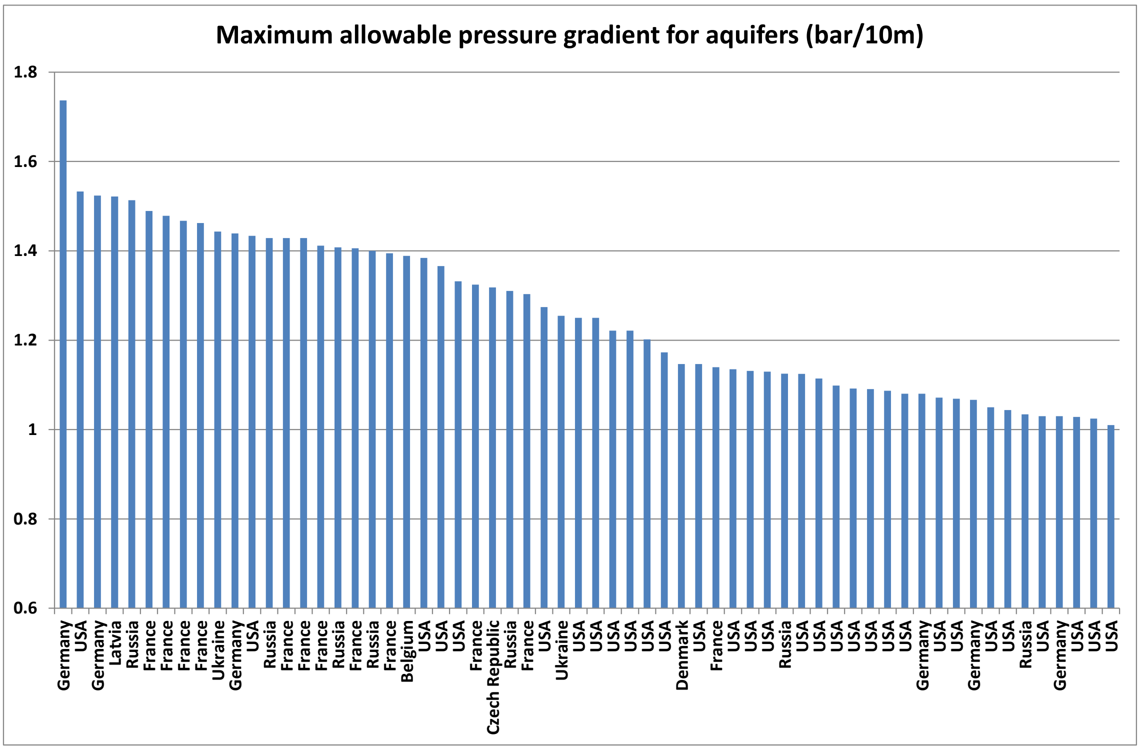


Figure 24 Maximum allowable pressure gradient for aquifers

<u>*Cushion gas volume vs working gas volume*</u>

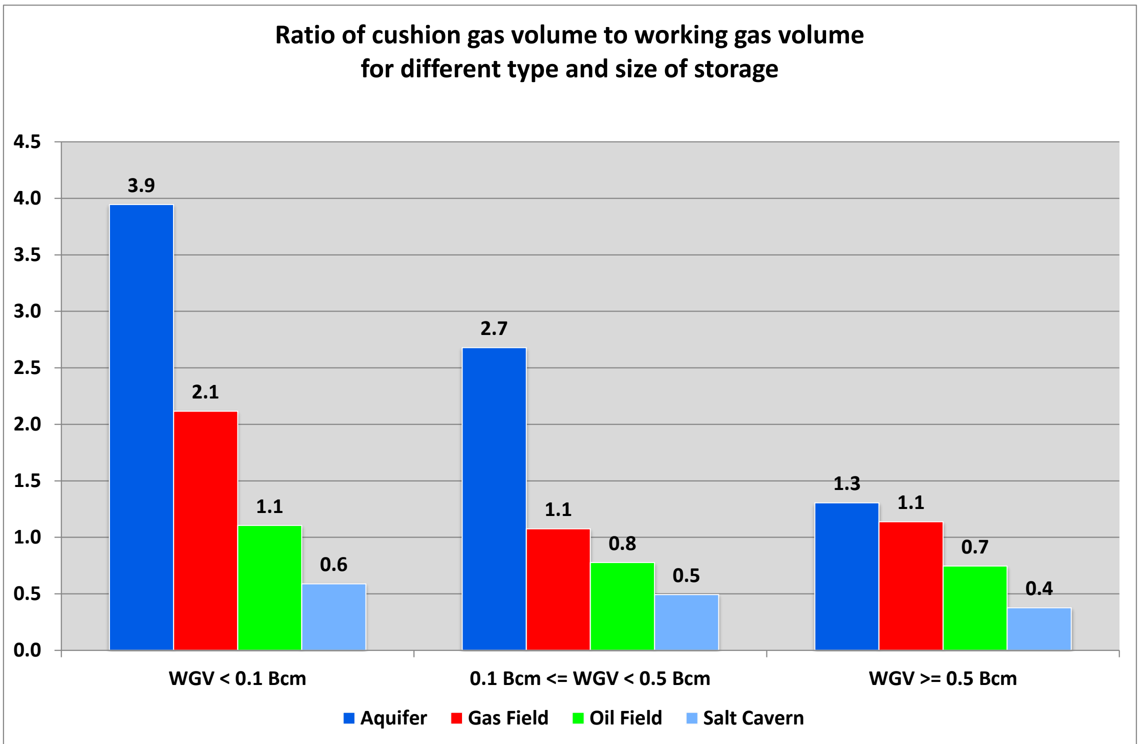


Figure 25 Ratio of cushion gas volume to WGV

Unit PWR (mcm/d per mcm of WGV in mcm)

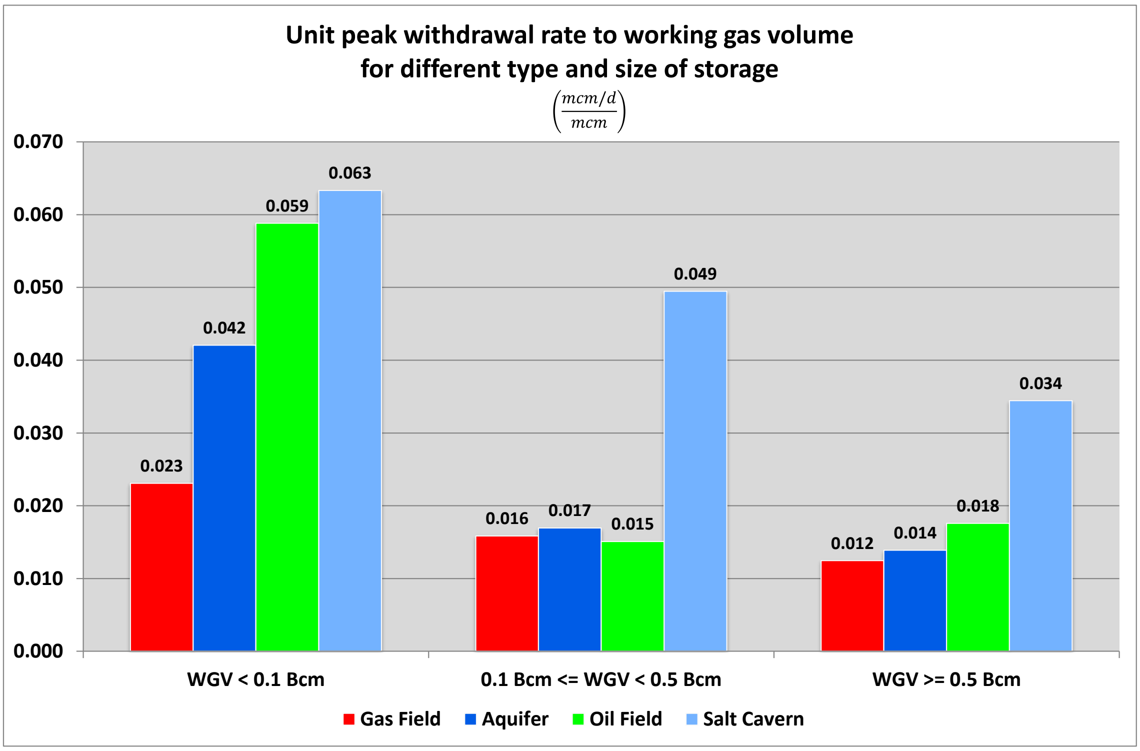


Figure 26 Ratio of peak withdrawal rate to WGV

Unit injection rate (mcm/d per mcm of WGV)

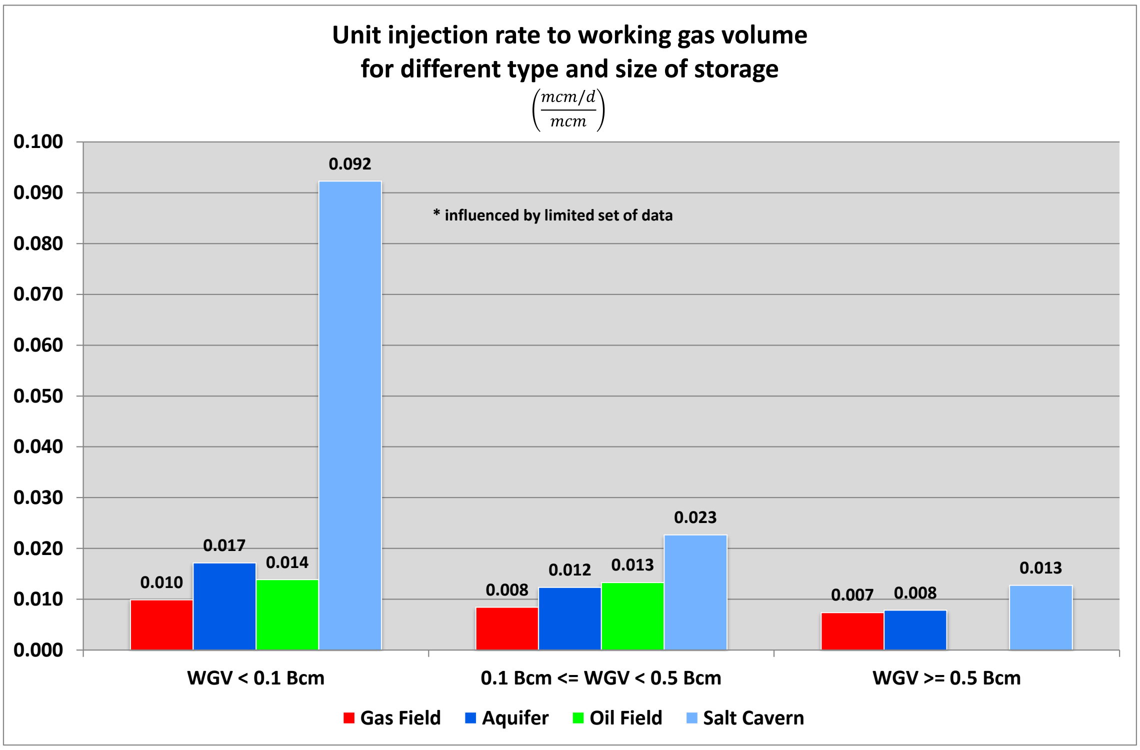


Figure 27 Ratio of injection rate to WGV

3.5 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 so far from France, Germany, Spain, Denmark, The USA, Russia, Austria, The Netherlands and Slovakia. The contributions are included in this report as received with marginal changes.

4 Report of SG 2.2: Best Practices

4.1 Introduction, objectives and Recommendation

Design and philosophy of UGS operating systems can be quite different in the world, according to the characteristics of the facilities, the countries where they are based, and the companies owning the sites. However, requirements from citizens and public authorities regarding safety and environmental issues are growing as well as demands from gas customers for flexibility and reliability. These demands are strong drivers to develop common or consistent practices within the UGS community.
The work programme of SG2.2 dedicated to Best Practices has been focussing on three specific items

- methane emissions of Underground Gas Storage
- well integrity assessment
- CO2 sequestration

Study group leader: H. Giouse (France)

Authors: P. Marion (France), H. Spreckels (Germany, H. Giouse (France)
Main contributors : J. Grappe (France) , Dimitar Shterev (Bulgaria)

4.2 Part 1: Methane emission reduction efforts in UGS operation

4.2.1 Background

All major companies have today a Quality, Health, Safety and Environmental (QHSE) policy and one of the major goal is the prevention of any pollution and the reduction of the environmental impact of their activities in order to contribute to the battle against global warming and to protect natural resources.
This includes primarily the reduction of emission of greenhouse gases through their activities. Among the greenhouse gases, methane is recognized as having a global warming power 21 to 23 times higher than that of CO2 (IPCC (Intergovernmental Panel on Climate Change), 1996 ; IPCC, 2001), so the release into the atmosphere of 1000 m^3(n) of methane (natural gas) is the same as releasing 16.33 tCO2e.
Even if gas storage operation is not a major contributor to methane emission, the gas companies of this branch of activities are involved in methane emission reduction programs. The aim of the study is to present the current situation and the main trends.

4.2.2 Results of a focussed questionnaire

Precise data are difficult to obtain for technical reasons, as shown by some previous studies (ie Marcogaz study, Jürgen Vorgang, WGC 2009 (1)).
To have some data to about the subject, the Study Group 2.2 has sent a questionnaire to all members of WOC2. Three simple questions were asked:
- Are there regulations in your country about methane emission? If not, are there demands from the Authorities linked to the delivery of the permit for operation?
- Sources of emissions: the sources considered are compressors (sealing leak and start/stop venting), venting for servicing part of the UGS facilities, well servicing (including well testing). Other sources are not considered like Emergency Shut Down venting and diffuse emission. The demand was to rank the three sources of CH4 emission selected above and to give percentage.
- Best practices: for the three sources mentioned above, to indicate for each what techniques yet used or planned to be for methane emission reduction.
We received a dozen of answers mainly from European Union and CIS. These answers to the three topics can be summarized as follows.

- Three countries reported to have methane emission regulations (United Kingdom, Germany and Russia)
- The ranking of three sources is very consistent among answers:
    1. compressor,
    2. venting part of facilities for servicing,
    3. well servicing including testing (for porous media storage)
- The answers about best practices for methane emission reduction are mainly related to two techniques:
    1. control of emission of seals of compressor by either gathering leak system for re-injecting in pipes or installation of encapsulated compressor
    2. recovery of gas during planned venting, including well testing, by re-injection in pipes.

4.2.3 Other sources of data

The main other source of data is the environmental report that all major companies in oil&gas business are publishing every year as part of their annual report, especially that are registered ISO 14001.
From these sources (3 Environmental reports from European Union and CIS), we have been able to calculate an average ratio of methane emission compared to working gas volume: approx. **500 m^3(n) per million m^3(n) of working gas, i.e. 0.05 %.(assuming 1 working gas volume cycled in a year)**
This figure shows a trend to reduction from the previous years.
In the IGU 2000 (2) report, the average emission factor was estimated to 0.1% of the working gas volume (0,05% at the lowest and 0,7% at the maximum).
Another recent paper can be looked at too, “LCA of the European gas chain : challenges and results” published at IGRC conference 2011 (3) ; the emission factor is estimated to be 0,1 %, and it is based on data from Marcogaz in 2004.

Another ratio can be calculated from the environmental reports of integrated gas companies. The emission of methane from **UGS operation represents around 5% of the total emission of the gas industry.** This ratio is calculated without Exploration and Production emissions. It will be significantly less considering the vented (or flared) gas of this branch of activity.

4.2.4 Conclusion of the part 1

Even if UGS is very low methane emitting activity, efforts in the recent years has been made to decrease emission. It can be noticed that:

- emerging technology in the last decade, driven by environmental regulations, such as electrical driven encapsulated compressor , will help to achieve zero emission for some UGS activity,
- reduction of natural gas venting during maintenance operation is developing quickly among UGS operators.

This has been made mainly by voluntary efforts of the operators, since regulations in the field of methane emission are not yet broadly implemented.

4.3 Part 2: Well Integrity Management for UGS.

4.3.1 Underground Gas Storage wells

The 2012 update of the IGU-WOC2 data-base (see SG2.1 report here above) reports that **23 000 wells** are currently operated on UGS facilities all over the world. This figure is to be compared to **116 000 wells drilled in year 2011** (4) for oil and production purpose.
One characteristic of UGS wells is that they could be in operation for decades. The following graphs show the estimated age of UGS wells worldwide and for the main regions of the world where UGS are operated: Europe, CIS and North America. The age has been estimated assuming that the age of the wells is equal to the age of the UGS. This is a rough approximation because some wells could be older (former oil or gas production wells in the case of UGS converted from depleted fields) and some wells could be younger in case development wells have been drilled after the UGS has been put in operation.

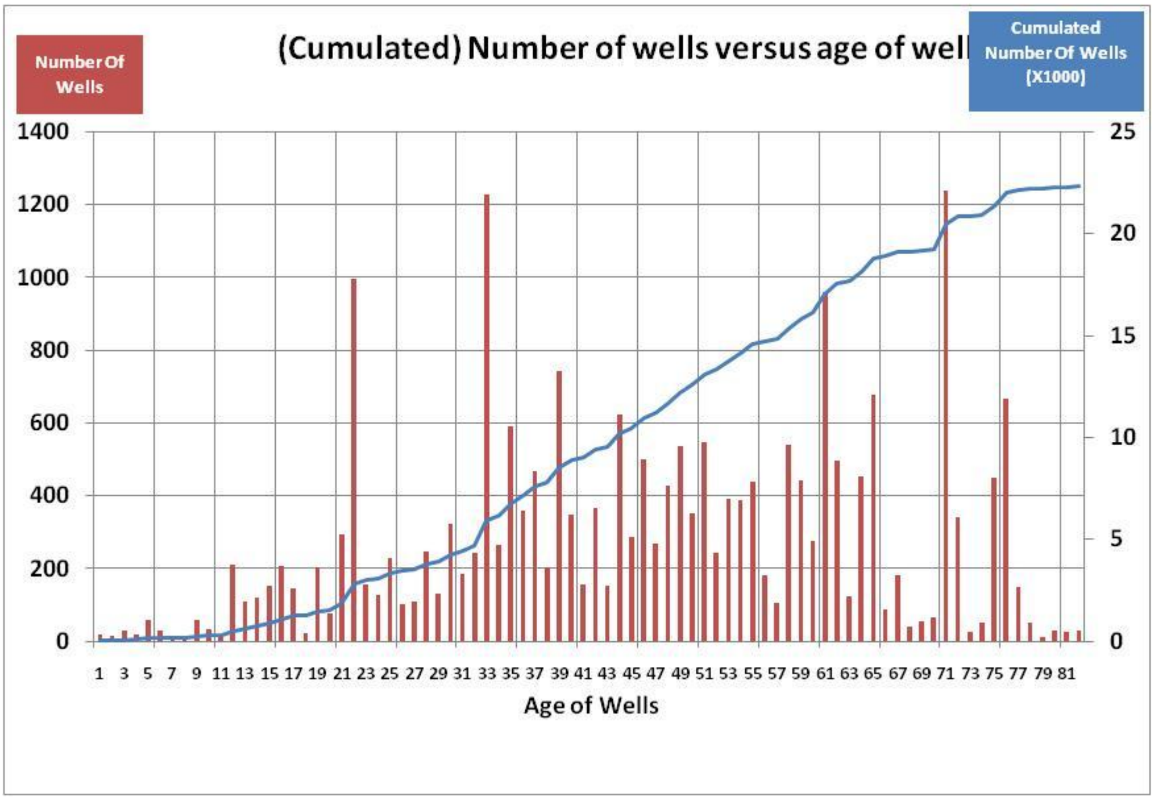


Figure 28 - Number of UGS wells and cumulated number of UGS wells worldwide

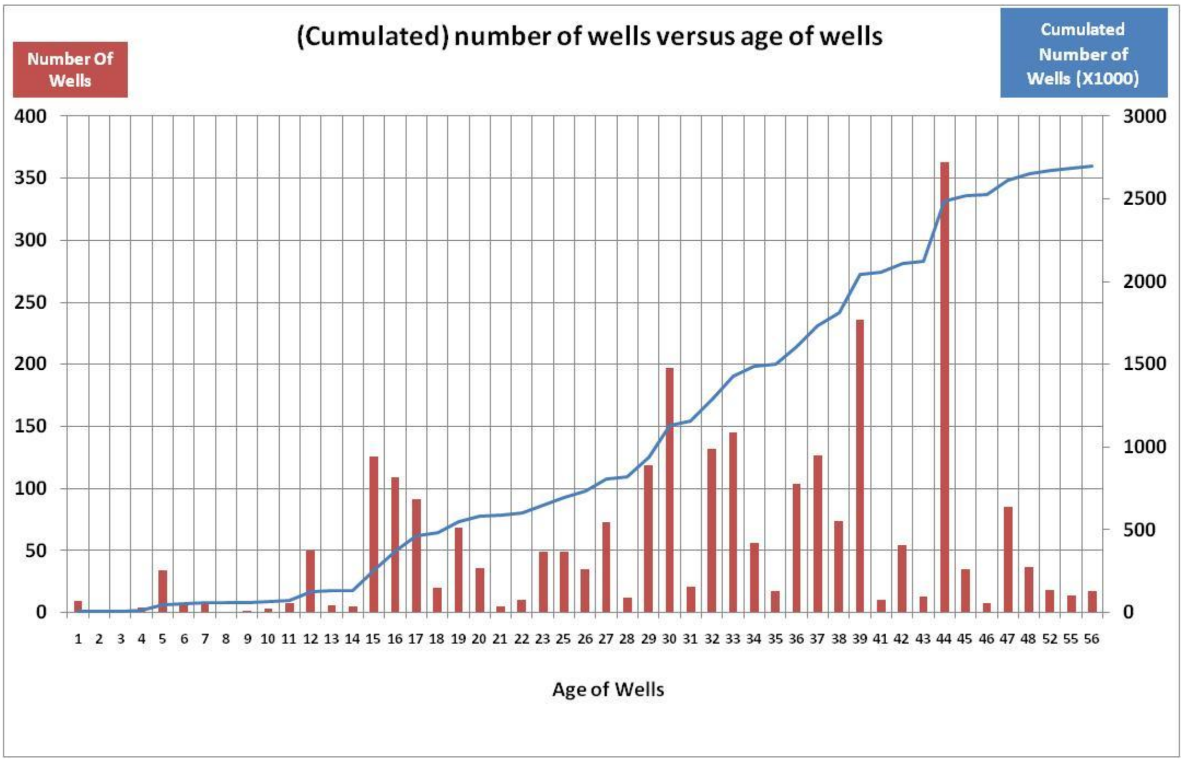


Figure 29 Number of UGS wells and cumulated number of UGS Wells-Europe

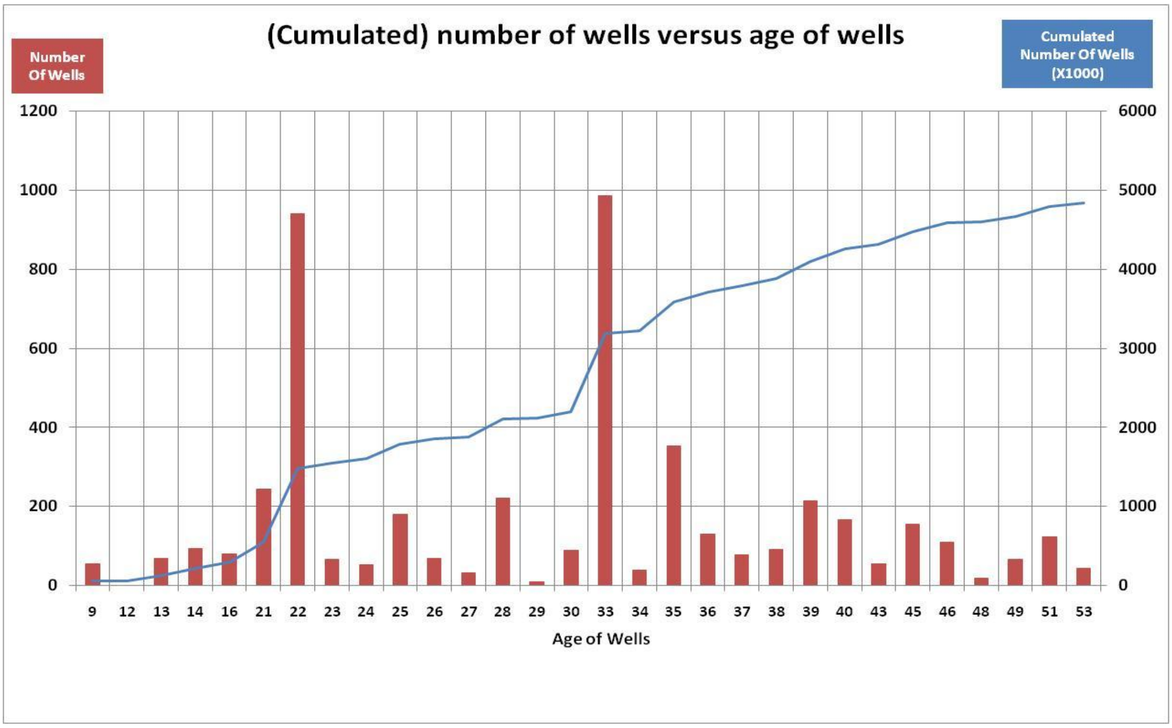


Figure 30 Number of UGS wells and cumulated number of UGS Wells-CIS

This simplified approach is probably sufficient to demonstrate that the older UGS wells have been operated for several decades and that many of them are around 30 years or more especially in Europe and CIS. This situation gives a very special interest to monitor the integrity of UGS wells.
The integrity of old wells is an important concern because of aging and corrosion phenomena of their infrastructure (cementation , casing) or of their completion (tubing, and other down-hole equipment as screen , valves, etc) and because they have been drilled, cemented and completed with vintage technologies (few casings to protect the upper aquifers, old technology and requirements for cementation, etc..)
.
The age is a key factor but the initial quality of the well and the conditions of operation have a huge influence on well integrity. Another characteristic of UGS wells as compared to oil and gas production wells is that they are submitted to pressure and temperature cycles as a result of the alternate injection and withdrawal phases implemented during storage operation. Conventional oil and gas fields wells are submitted to a regular reservoir pressure decline.

Some UGS wells are former oil and gas production wells and had been operated in those conditions during the first phase of their life. A specific assessment is needed to convert oil and gas wells to UGS wells. One important point of this assessment deals with the quality of the gas produced and the content of minor components (CO_2, H_2, O_2, etc..)

4.3.2 Integrity Management

The Well Integrity Management (WIM) is a topic of growing interest, whatever these wells are used for: exploration, production, gas storage and CO_2 storage.
This new concept of Integrity Management (linked to the lifecycle approach) comes from pipelines operation. It has been replacing progressively a uniform regulatory approach not taking into account for differences in the risks faced by individual pipelines due to their specific context (location, geological hazards, etc..). Recognizing that pipeline operators face different risks depending on such factors as location and the products they carry, regulatory bodies began exploring the concept of a risk-based approach to pipeline safety in the mid-1990s. The related integrity management approach requires individual pipeline operators to develop programs to systematically identify and address risks to the segments of their pipelines that could affect “high consequence areas” where a leak or rupture would have the greatest impact, such as highly populated or environmentally sensitive areas.

This Integrity Management approach has been enlarged by industrial assets operators. Now it can be presented as a global methodology or management system dedicated to any industrial asset. Asset Integrity is the ability of an asset to perform its required function effectively and efficiently whilst safeguarding life and the environment. The related management activities ensure that the people, systems, processes and resources which deliver integrity, are in place, in use and fit for purpose over the whole lifecycle of the asset.

Wells are key assets for storage operators and their integrity has to be controlled not only during their aging phase but starting from their drilling or building phase.

This report focuses on Well Integrity Management during the operation period (excluding the drilling and completion phase, and the ultimate decommissioning by plugging and abandonment).

4.3.3 Work-flow of well integrity management

A general work-flow is presented in figure 31. This flow chart presents activities to be performed and decisions to be made to achieve an efficient Well integrity Management (WIM). This process concerns all wells and has to be performed regularly. General recommendations are proposed as best practices for each step. They have to be adapted to each specific case

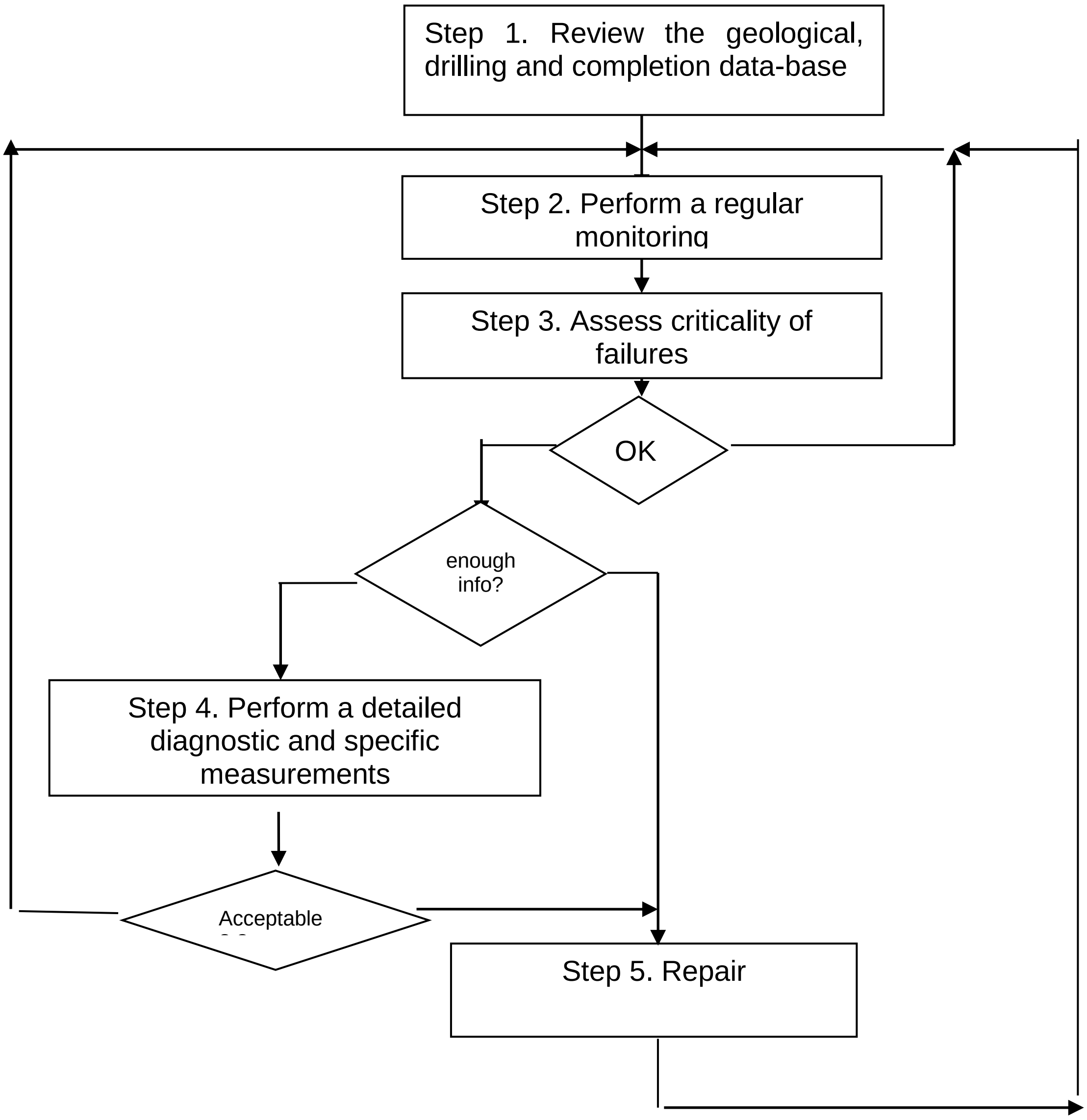


Figure 31 Work-flow of Well Integrity Management

Step 1 : Review the geological, drilling and completion Wells data-base

All the initial information on the wells should be easily accessible and safely preserved. This information should be either on paper (reports, logs, etc..) digitised or computerized. Different solutions taken from widely used and proved in industry software (as data warehouse) could be implemented for this purpose. Whatever is the medium, the wells operator has to manage the preservation and the availability of these data. That could mean to have several copies in different places and to re-copy regularly data, even old data, to be able to read them in a correct way at any time (from this perspective, checking absence of discrepancy between the various documents (such as e.g. revisions) is critical).
These initial information is very important, even if they are old or partial. One cannot reach some specific data from an existing well, even with new technologies ; some of them could be get back but with expensive measurements. As an example, the quality of the cement of a technical casing, behind a production casing is no longer accessible with the logging tools currently on the market). As another example, physical measurements on cores or cuttings could be made years after the drilling, if cores have been preserved , but the quality of some data would be less precise and reliable, especially for shale formations.
The wells to consider are all the wells of the UGS acreage, that is the mining licence area. All wells are important, exploration wells, operation wells and observation wells, even old production wells not used or abandoned (in particular, the status of abandoned wells in a depleted field is often poorly documented with impossibility to access the wellpath for assessment of the tightness of the cement plugs). Wells in the gas zone are more important than water wells (exploration wells, reinjection wells) but even water wells have to be managed because they contribute to the operation of the storage site.
These initial data is to be considered as a sort of portfolio of identity cards of the wells of the UGS.

Step 2 : Perform a regular monitoring

During the operation of the wells, measurements are done and should be recorded for analysis and interpretation. The parameters to be measured could depend on many factors , specially to the operator’s needs, the national regulations and technical availability of parameters. Here is an indicative list of parameters that could be measured on wells.

- visual integrity check on the well head and in the well cellar (and other measurements)
- pressure at the well head ,
- pressure in the different annulus, level of fluid in the annulus, pressure test of the annulus
- cathode protection level (if any)
- test of safety devices (as sub-surface security valves and their surface equipment)
- water production , sand production
- rate of production for a given pressure drop (or production tests at regular interval to check evolution of the well performance if any)

In some cases, corrosion inspection could be performed in the upper part of the production casing from the outside. Casing corrosion logging could be performed during a work over. These measurements are not needed regularly and are addressed in step 3.
The regular measurements could be performed every day, or every week or every year, according to the expected evolution of the parameters. Such a monitoring contributes to the safe operation of wells.
Recording these data on a mid-term basis (several years) or better on a long term basis is important to interpret physical phenomena in the well.
Every change of abnormal evolution of these parameters should be analysed.

Step 3 : Assess criticality of failures

On a regular basis, data collected by the monitoring should be interpreted to detect abnormal situations or negative trends.

These parameters could be directly or indirectly linked to the probability of failures or integrity problems. This analysis is based on the knowledge of the architecture of the well from the initial data (geological, drilling and completion data-base).

These failures could be more or less negative in their consequences according to the specific environment (on surface and in the subsurface) of the well.

The criticality analysis is the combination of the two approaches. A failure is more critical if it is probable and if its consequence would be negative. A failure is less critical if it is less probable and if its consequence would be of marginal importance.

The assessment of the criticality has to be adapted according to the concern (safety, environmental protection of aquifers, performance) and to the data available.

In any case, even for a single concern, that leads to a multi-parameter analysis and if several concerns are addressed, that leads to a multi-criteria approach.

This methodology is quite similar to risk assessment methods used in different industrial sectors and project management.

A ranking of the all the UGS wells could be obtained by this type of approach.

If not, a list of wells having critical integrity problems above a certain limit could be obtained. That means these wells would probably have integrity problems and if these problems do exist, they would have significant consequences

Step 4 : Perform a detailed diagnostic and specific measurements

The result of the previous step is to identify wells having critical integrity problems. That means that a more detailed diagnostic has to be performed on these wells. Extra-information has to be collected. The information has a value: to know whether a real integrity problem does exist or could appear at certain pressure conditions and what is its importance. This information has also a cost: it is the price of the operation or of the measurement needed to obtain this information.

The well operator would prefer methods with low cost or a cost in proportion with the value of the information.

Appropriate well-logging measurements for assessment of technical status and integrity of the wells should be conducted (evaluation of cement itself and cement bonds status as wells as tubing and casings). Depending on the specific problem, tracer measurements and gas and water-samplings at different depths could be implemented.

A key point is the necessity or not to work-over the well or not to obtain the information. In this case, the production tubing has to be pulled out and the well has to be fulfilled with mud to balance the reservoir pressure. This operation needs a rig and is quite expensive on top of standby of the well). It is risky too. That has to be taken into account in a risk management approach.

Gas analysis, borehole video, flow logging, temperature measurement in the tubing could provide information without killing the well removing the production tubing.

Measurements performed in the production tubing to investigate the production casing and2its integrity are, of course, valuable. But currently all corrosion and cement logs performed through tubing are not as precise as logging in the casing. Improvements of technologies or new methods are needed and are currently investigated. Their value for wells operators is obviously high.

The detailed diagnostic could not be based on a single measurement. Several logs and measures are often needed for understanding and confirmation. It could take time and in some cases during this time, the well could not be available for production.
With all the information coming from the initial data (Step 1), the regular monitoring (Step 2) and the extra-measurements, a diagnostic could be made on the well. Either the current situation of the well could last, till the next assessment, or it cannot. In this last case a repair job is needed. This repair job could be either corrective maintenance (that means the well cannot be operated till the repair operation) or preventive maintenance (that means that the well could be operated, possibly with restrictions, till end of the repair operation).

Step 5: Repair

As for special measurements, the preferred methods to repair are methods which could be performed without work-over, taking into account that a wok-over is expensive and possibly risky and not always successful. If a work-over is needed, measurement or logging could be included in the program of the operation to orientate it. One can combine two steps in one operation: perform a detail diagnostic (Step 4) and repair (Step 5) but in this case, the operation could be sophisticated and should be designed precisely.
In any case the operation has to be performed according a specific program, taking into account specific well data, coming from the initial data, the monitoring data and all the specific measurements available on the well. Even for wells with the same architecture and the same completion, a specific design has to be done, to take into account specific geology, operating condition, pressure during the operation, etc...
Once the repair job completed according to its design, the initial data of the well are updated and the well will be processed according to the general work-flow.

4.3.4 Conclusion of part 2

IGU WOC2 2009 report for the WGC in Buenos Aires presented the answers of UGS operators to a questionnaire on New Technologies and Best Practices. About wells maintenance, the analysis was the following:

“Wells maintenance programs are mainly based on case by case approach. But this method should evolve towards a long term planned maintenance program driven by risk assessment. At this moment this method is not yet used frequently”

A general trend towards global methodology to address well maintenance was foreseen even if the words “well integrity management” was not employed at that time.

To go on safe operation of UGS, responsible operators have to manage aging facilities and specially aging wells. This situation is a driver to Well integrity management implementation.

By giving some general recommendations considered as “Best Practices”, this report intents to be a step to support the efforts of UGS operators to include Well Integrity Management in their operation methods.

4.4 Part 3: CO2 sequestration

4.4.1 Introduction

WOC2 in close cooperation with PGCA have analysed the current status of carbon capture and sequestration and have described the results within a common report (see PGC A report). The report summarises the facts about the various segments of the CCS chain and also elaborates on the role of CCS in a sustainable gas industry.
Since the work of WOC2 concentrated specifically on geological storage of CO_2, the following paragraphs present a summary of the corresponding chapter of the full report, published under the responsibility of PGCA.
The 2007 Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report indicates that significant rise in CO_2 emissions could lead to a temperature increase in the range of 4-7°C, with major impacts on the environment and human activity. It is widely agreed that a 50% reduction of energy-related CO_2 emissions is needed by 2050 to limit the expected temperature increase to less than 3 degrees. To achieve this will take an energy technology revolution involving increased energy efficiency, increased renewable energies, the decarbonisation of power generation from fossil fuels and to a certain extent nuclear power.
As far as the power production sector is concerned CO_2 capture and storage (CCS) is the most viable technology currently available to mitigate greenhouse gas (GHG) emissions from large-scale fossil fuel usage. CCS involves the capture, transport and injection of CO_2 into suitable geological formations.

4.4.2 Geological Storage

Based on estimated capacities, CO_2 storage is very likely to be dominated by geological sequestration. In geologic storage, CO_2 is injected under high pressure into very deep underground porous rock formations. Usually, in their pores these rocks originally contain fluids such as oil, natural gas or water, the latter being too salty to use. Several natural trapping mechanisms have been keeping these natural fluids in place, often for millions of years. In geologic storage of CO_2 the same trapping mechanisms are made use of to safely store the CO_2 underground in suitable geological formations for thousands of years.
The CO_2 will preferably be stored as a liquid, and not as a gas, because gaseous CO_2 occupies more space and is more upward buoyant than denser liquid CO_2. In practice, the CO_2 is compressed prior to injection to a dense fluid state known as ‘dense phase’ or ‘supercritical CO_2’.

4.4.3 Trapping Mechanisms

A number of trapping mechanisms, shown in the following graph, are considered to be the most effective to facilitate underground storage of CO_2.

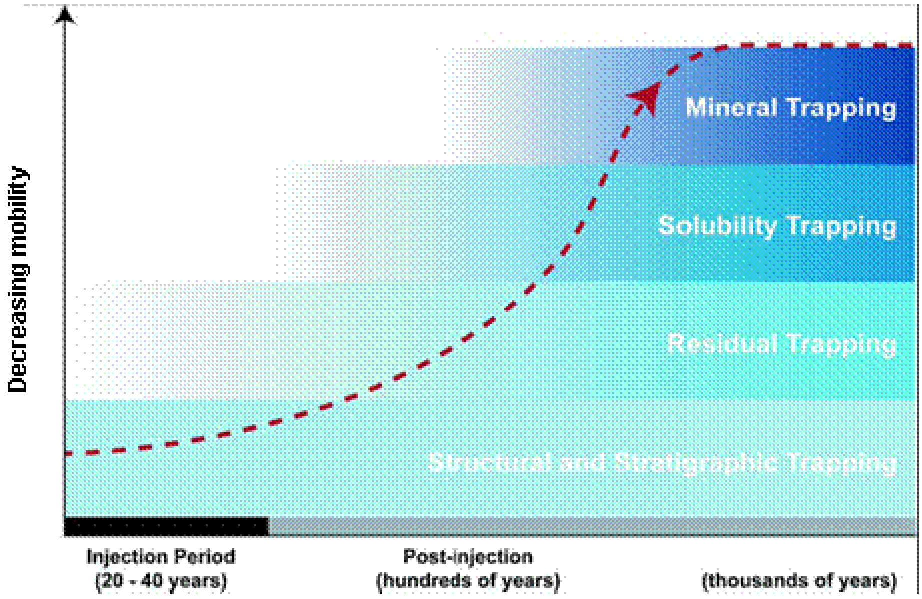


Figure 32 Showing different trapping mechanisms

4.4.4 Storage Site Capacity Estimates

Geological storage of CO2 can be undertaken in a variety of geological settings in sedimentary basins. Possible storage formations within these basins are oil fields, depleted gas fields, deep coal seams and saline formations. The efficiency of CO2 storage in geological media, defined as the amount of CO2 stored per unit volume, increases with increasing CO2 density. Depending on the rate that the temperature increases with depth in the earth's crust, the density of CO2 will increase with depth, until about 800 m or greater, where the injected CO2 will be in a dense supercritical state.

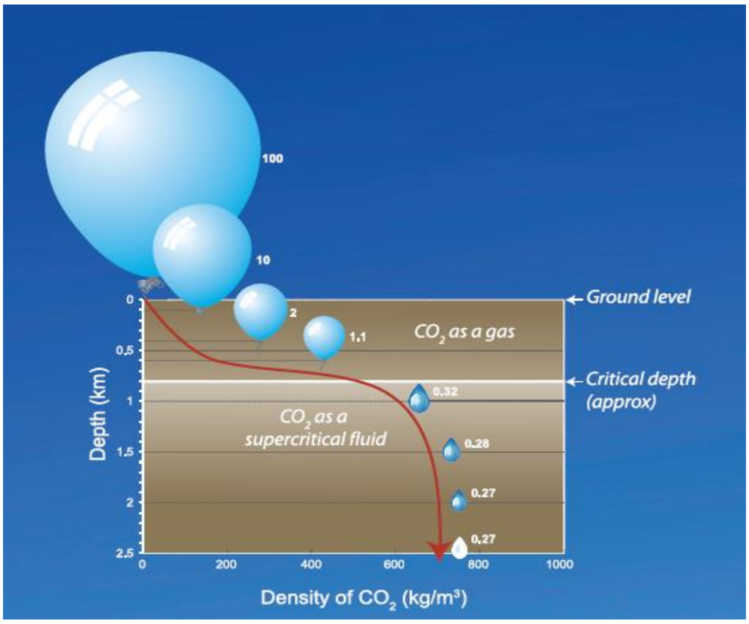


Figure 33 Density of CO_2 vs depth

Although the calculation of CO_2 storage capacity on an individual basis should be a straight forward task, due to the lack of data and their uncertainty the reliability of respective numbers given in the literature is limited. In order to overcome this situation and still provide the necessary numbers, global capacity estimates have been derived by simplifying assumptions and using very simplistic methods.
For currently discovered oil and gas fields global storage estimates that are based on proportionality suggest that these reservoirs have a capacity of up to **900 GtCO_2.**
Since hydrocarbon reservoirs occupy only a small fraction of the pore volume available in sedimentary basins the global storage capacity of deep saline aquifers is supposed to be **an order of magnitude higher than the capacity of oil and gas fields**. The uncertainty of these volumes remains high.
Based on numbers known about the methane potential in CBM projects and assuming that the ratio of adsorbed CO_2 to Methane is in the order of two, **up to 200 GtCO_2** could be stored worldwide in coal seams (IEA-GHG, 1998).

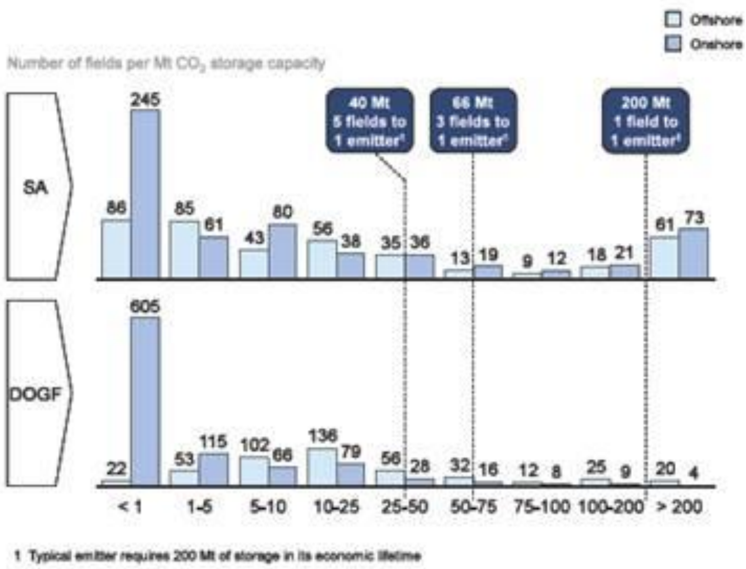


Figure 34 showing distribution of storage capacity in Europe (number of fields within capacity ranges; SA = Salines, DOGF: depleted oil or gas field

These volumes are available anywhere in Europe and this assessment does not take into account a realistic or economic distance between sources and storage sites.

4.4.5 Monitoring

Once the CO_2 is injected it is important to make sure it stays safely stored in the reservoir. This is done by monitoring techniques, such as measuring pressure of the storage site, seismic sensors, and sensors to detect changes in CO_2 levels at the surface.

If a leakage should occur, proper monitoring enables us to take measures to stop the leakage immediately.
A number of standard technologies are available for monitoring but the applicability and sensitivity of the techniques in use are somewhat site-specific. Given the long-term nature of CO2 storage, site monitoring may be required for very long periods. Existing monitoring

technologies have a limited capacity for measurement and verification of stored CO2, and it is therefore recommended that focus be directed at developing improved and new monitoring technologies.

4.4.6 Economics

CCS is a technology motivated by the need for climate change mitigation. It will achieve its objectives on commercial terms only when the cost of emitting CO_2 to the atmosphere is higher than the cost of CCS. In the absence of suitable financial mechanisms to support CCS, including significant public and private funding for near term demonstrations and longer-term integration of CCS into GHG regulatory and incentive schemes, high costs have precluded the initiation of large-scale CCS projects. Hence the near future rate of technology development will be influenced by both industry and public sector efforts in research, development and demonstration activities.

While the cost of CO_2 capture and compression generally represents by far the largest component of the CCS chain, at a project level, transport and storage costs still could render a project uneconomic.

Storage reservoirs exhibit a fairly high degree of natural variability in accessibility, field capacity, injectivity of wells, etc... This leads to a wide range of the total storage cost per tonne of CO_2 stored, e.g. the high cost scenario may be up to 10 times more expensive than the low case. Costs vary significantly from €1-7/tonne CO_2 stored for onshore depleted fields to €6-20/tonne for offshore saline aquifer structures.

High pre-FID (project phase, preceding the Final Investment Decision) costs for saline aquifers reflect the higher need for exploration compared to depleted oil and gas fields and the risk of spending money on exploring aquifers that are ultimately not suitable for long-term CO_2 storage.

The overall trend is such that

- Storage onshore is cheaper than offshore.
- Depleted hydrocarbon reservoirs are cheaper to develop than deep saline aquifers.
- Saline aquifers in offshore locations are the most expensive options and exhibit the widest cost range.

In consideration with the available reservoir capacity data, i.e.

- the greater storage capacity is found offshore,
- saline aquifer structures provide more capacity than depleted fields,

4.4.7 Conclusions of part 3

To be included in a project able to store several years or decades of emission from a source of CO2, the target reservoirs are at least an order of magnitude larger than usual Underground Gas Storage sites.

It turns out that, unfortunately, the least expensive storage reservoirs contribute the least to the total available capacity.

Technologies to sequestrate CO2 are available but have to be improved or adapted to the large scale of target and the long-term of projects. UGS operators are key players for these type of projects because of their knowledge, experience and long term feed-back of underground storage operation.

Nevertheless in the current economical context, few large CCS projects will probably be decided. CO2 injection will be implemented for production purpose, to separate CO2 from the gas produced and avoid to vent it and/or to use it for Enhanced Oil Recovery. These projects of injection either in the reservoir field or in another reservoir, will provide valuable experiments or improve knowledge and technology

5 Report of SG 2.3: Skills and competencies for UGS activities

Study group leader: Vladimir Onderka (Czech Republic)

Main contributors: Jana Kymplova (Czech Republic), Nikita Barsuk (Russia)

5.1 Introduction, Objectives and Recommendations

Since 2005, the storage sector has been noticing the beginning of a shortage of technical skills. It is a critical issue for companies either to operate and run maintenance on existing underground gas storage (UGS) facilities or to develop new projects. The UGS activity is strongly impacted as the needed skills are not only specific but also rather similar to the ones used in the Exploration and Production sector, which tends to receive more focus from companies than UGS activities.
All personnel difficulties related to the UGS industry can be described by the following:

1. Widely known shortage of skilled professionals in the UGS (multidisciplinary) business;

2. Aging of current specialist vs. lack of newcomers – specialists;

3. Lack of students/incentives for studies;

4. Lack of young talented specialists;

5. New technologies and IT to be adopted in UGS - needs for new skills;

6. Needs for continuous education, systems of knowledge management;

7. Gas is not perceived to be so green and sexy as before;

8. Public discussion on the end of the peak oil age;

9. Limited attractiveness of technical disciplines.

An example from “real life” (Internet Newspaper: “Neviditelný pes”, IX, 2011):
“Representatives of technical and natural sciences appear on the stage, equipped with their meticulously prepared PowerPoint presentations, which are frequently larded with video and audio recordings and other jewels of the multimedia age. Representatives of humanities can usually make do with much more modest facilities. In spite of that, the effect of their appearances is incomparable with their natural & technical science competitors’ poor achievements. When a multimedia presentation on the amazing GPS developments is offered, the lecture room is filled with emptiness. It bursts in seams just before Professor Martin Hilský’s arrival; he talks about translations of Shakespeare’s Sonnets, equipped only with a leather-bound copy of the “Stratford swans” in addition to his intellect. Once the excellent lecture on Elizabethan-age poetry ends, the lecture room is empty again. And then, only a couple of the hardcore fans can be seen in the auditorium waiting for equally spellbinding speeches on the production of various alcohols, animals’ magnetic orientation sense, or systems helping automobiles to read traffic signs.”

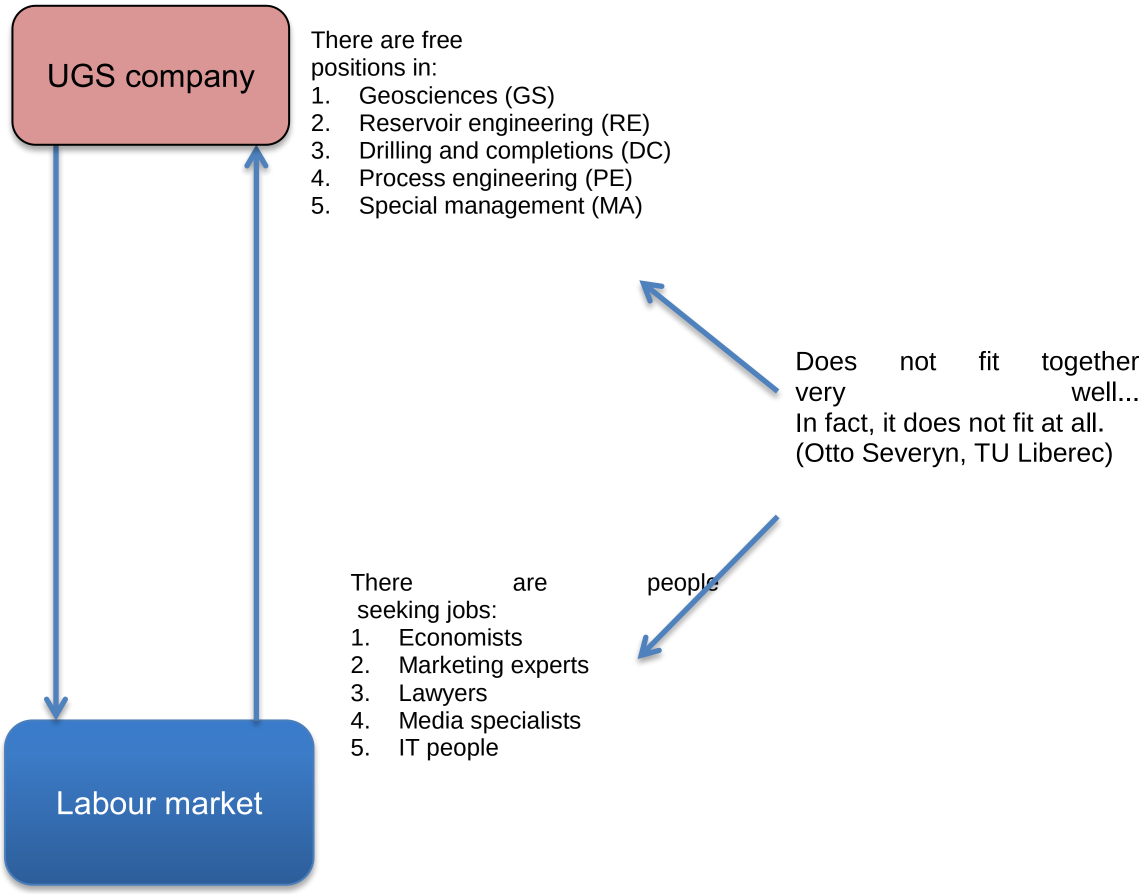


Figure 35 Attractiveness of specific studies

Objectives of the study

In recent years, human resources have become critically important in all areas of business including the gas business, and specifically the UGS business too. Recruiting suitable and qualified employees, motivating and remunerating them appropriately and training them continuously – these are the main objectives pursued by every HR department.
The first purpose of this study, described as Part A **Skills and Competencies Model,** was to provide a brief outline of the fundamental activities entailed in personnel management in theory and in practice, ranging from personnel planning to recruitment and selection of skilled employees working in the UGS industry such as petroleum or reservoir geologists and geophysicists, reservoir engineers, drilling and completion specialists, UGS managers and IT related key personnel. In this complex, it was also necessary to include other phenomena of the sustainable education model such as the adaptation process, performance evaluation, remuneration and motivation, and employee training and development, up to their release from the company. Every organisation behaves like a living organism, and personnel management therefore requires a strategic and process-based approach.
The second purpose of this study group, described as Part B, was to organise three two-week intensive advanced courses for 15 young UGS professionals from WOC2 member companies aged under 30, called **Young Employees Exchange Programme (YEEP)**.

Within the organisation of YEEP, it was necessary to arrange sponsorships and course providers, prepare entrance tests, syllabi, lectures and mentors, and handle all administration issues covering accommodation, visa, air tickets, etc.

Part A. Skills and Competencies Model

1. General conditions and outlook
2. Questionnaire structure and description
3. Survey response and Questionnaire analysis
4. Skills and Competencies Model of sustainable education development

where the aims were:

- to describe the skills, know-how and profiles of the professionals needed for the UGS activity;
- to assess the number of professionals needed currently as well as in the coming decade to achieve planned projects;
- to list the main educational programmes and degrees providing the required profiles in various countries;
- to define the types of training programmes;
- to facilitate exchanges of students between countries and companies during training periods;
- to indicate ways of providing the professionals and the required skills for the storage industry in the future and how to promote the attractiveness of the storage industry.

Part B. Young Employees Exchange Programme (YEEP)

- YEEP preparation
- YEEP implementation
- YEEP evaluation

Where the aims were:

1. Organise three advanced training courses for IGU/WOC2 members' employees in:
    1. Geosciences
    2. Reservoir engineering
    3. Treatment of natural gas
2. The sponsorships were provided by Gazprom, RWE Gas Storage and the Czech Gas Association
3. The providers of individual courses were:
    - Gubkin State University of Oil and Gas and Gazprom Vniigaz, Moscow, Russia
    - Technical University of Liberec, the Czech Republic
    - Institute of Chemical Technology Prague, the Czech Republic

This study group contributes to the work of Task Force 1: "Building Strategic Human Capacity", which was one of the special projects defined by the 2009-2012 Triennium.

5.2 General Conditions

Before entering into a specific UGS business it was necessary to obtain and describe some basics regarding the general conditions in society, education, culture and economy. The need for HR and education should reflect the current needs of society and at the same time should involve education strategies and requirements of human resources in the future.

Education provides for the transfer of knowledge, skills and competencies, which is essential for employees to tackle a broad range of tasks related to specific expertise and science. In the general context it is possible to see the relationship between an employee and an employer on a pyramid of needs and lifestyle and also on an employee life cycle in a company.

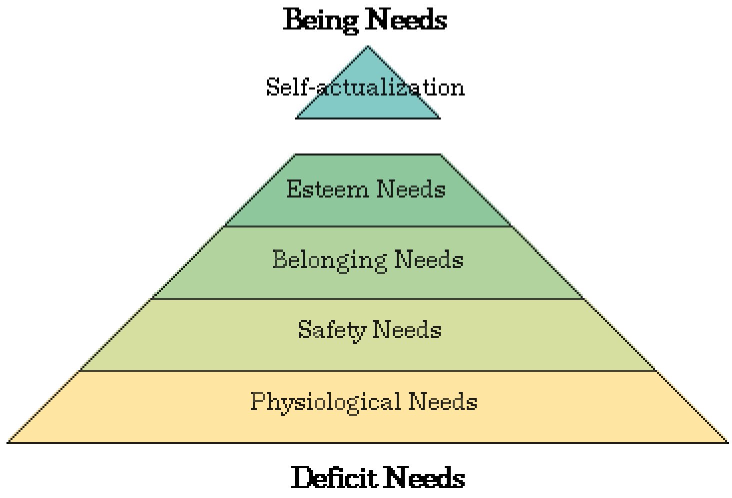


Figure 36 The Maslow hierarchy of needs

Beyond the details of air, water, food, and sex, he laid out five broader layers: the physiological needs, the need for safety and security, the need for love and belonging, the need for esteem, and the need to actualise the self, in that order.

5.3 Solution

5.3.1 PART A Skills and Competencies Model

5.3.1.1 Questionnaire structure and description

The aim was to analyse and describe the current status of known and sometimes alarming shortage of skilled professionals in the whole chain of the storage business and get an indication of the trends in the human sector of the underground gas storage business.
This survey was specifically focused on the professionals needed in individual branches, the legal and company requirements for participation in storage design and operation as well as the availability and attractiveness of educational programmes and job careers.
There were 25 questions on the whole, and related to:

1. Specific authorisations in certain positions ;
2. Availability of specific education (internal – in the company, external, universities, etc.);
3. Difficulties of companies in the filling of specific positions and activities;
4. Expected lack in specific positions and skills in the near future;

5. Key factors to recruit and retain important specialists.

In addition, another 10 questions of the Questionnaire were related to the international Young Employees Exchange Programme consisting of a set of free courses for young newcomers of WOC2 member companies.

5.3.1.2 Survey response and Questionnaire Analysis

Related questions and answers obtained in the survey amongst WOC2 members were clustered in order to describe a specific portion of the HR issue of the UGS business. Every cluster is evaluated by a specific expositor or expositors in order to obtain unbiased views from different countries, companies, and universities.

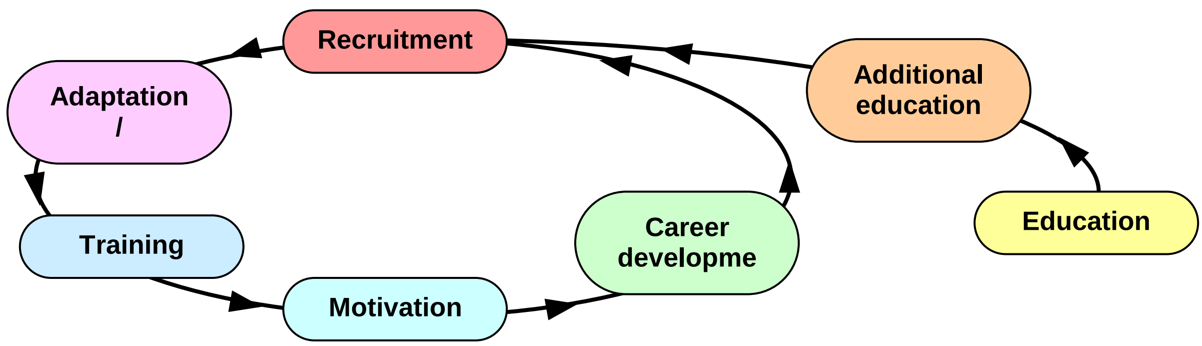


Figure 37: Example of life cycle of an employee

Legal issues, relationships
In many countries across Europe (and elsewhere) authorities require certified/responsible persons for specific positions in UGS company activities (Figures 38 and 39).

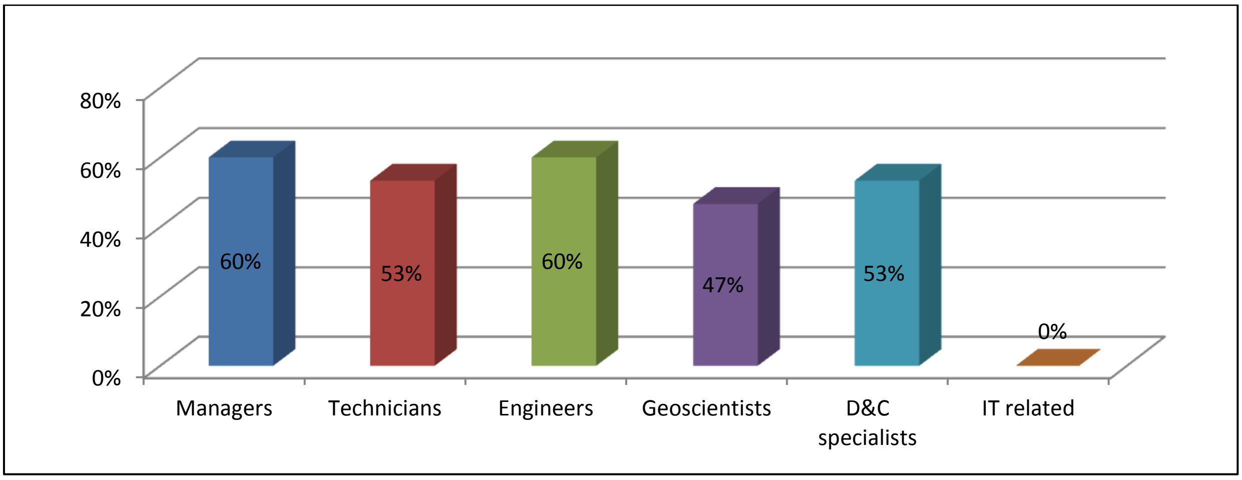


Figure 38 Does your UGS development and/or operation require any specific autorisation /legal requirements in the mentionned positions?

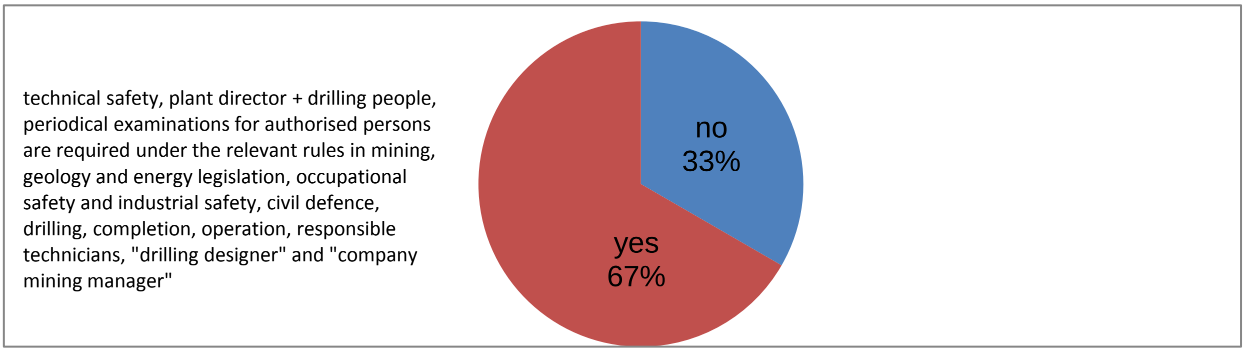


Figure 39 - Do the mining (and similar) authorities in your country require a periodical examination of authorised persons?

According to the results, in two thirds of the cases certification has to be periodically renewed, specifically in the case of managers, reservoir engineers and drilling and completion specialists.

Expositor: Andrei Kolesnichenko, Chief of the HR Department, Gazprom UGS, Russia:

The figures in general are corresponding to the conditions in Russia and Gazprom UGS system. The only difference can be seen in the need of specialist managers. The result in Gazprom's case could be approximately 45-47 %. It means that there is a high availability of candidates for specific management positions.

Education – External: Relationship between company and HR suppliers - universities

External – outsourced education is mainly provided by specialised universities and training/consultant companies. But the high standard educational process is mainly based on universities producing highly qualified graduates and consequently on a relationship between universities and the UGS industry.

Expositor: Leonhard Ganzer, Professor on the Institute of Petroleum Engineering, Technical University, Clausthal, Germany:

The Institute of Petroleum Engineering at TU Clausthal has a strong relationship with the German oil & gas industry.

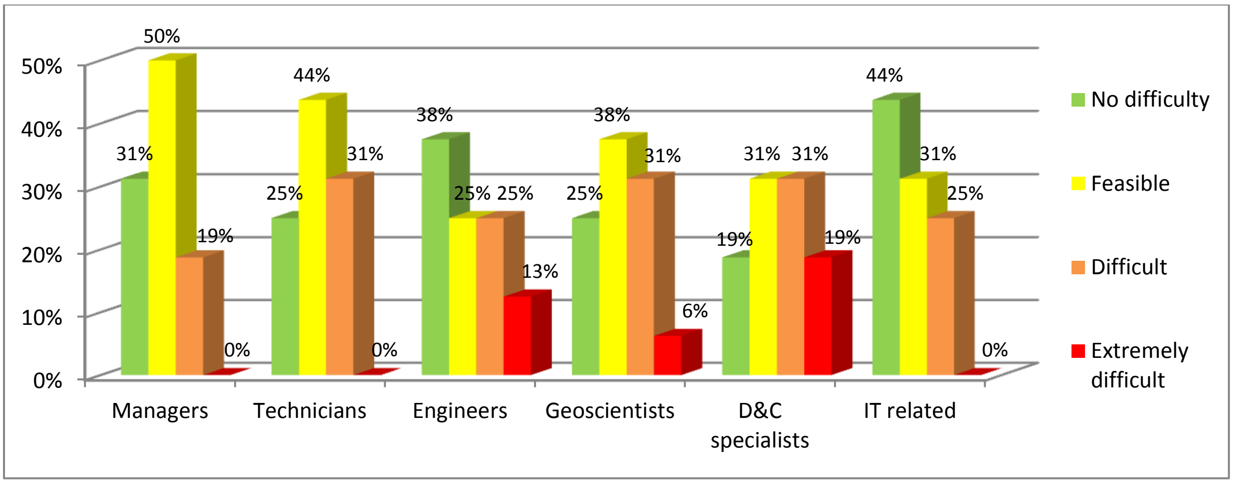


Figure 40 Which of the UGS position are sufficiently supplied by universities and others schools in your country?

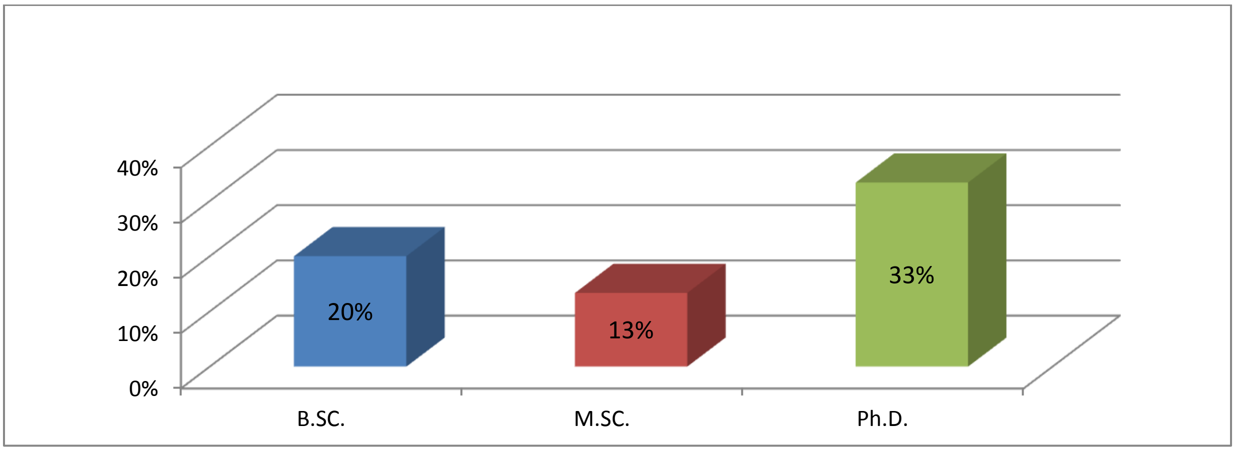


Figure 41 Does your company support talented students by scholarships on the level mentioned?

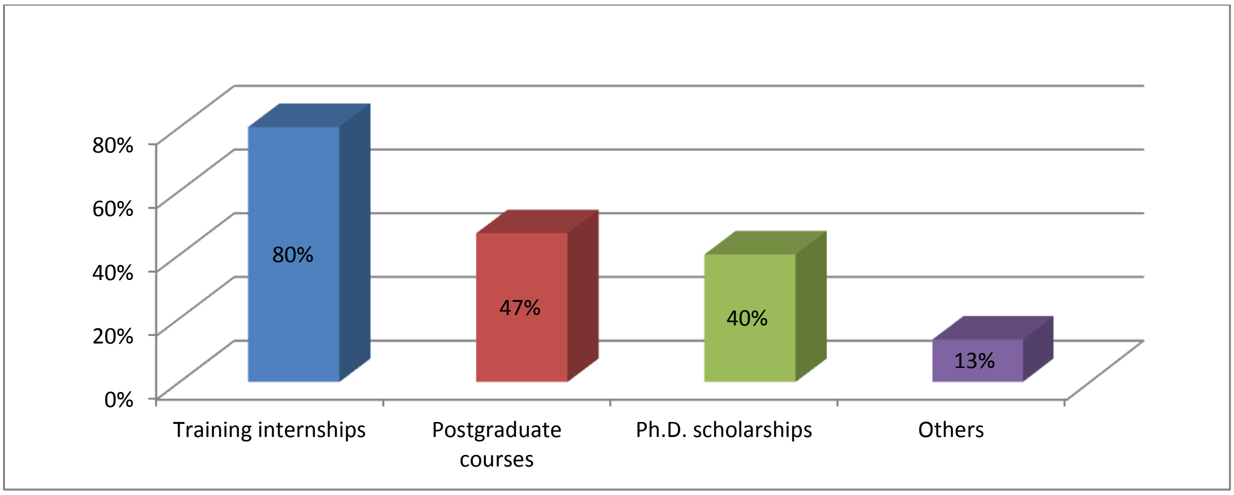


Figure 42 Does your company arrange some courses for graduate newcomers?

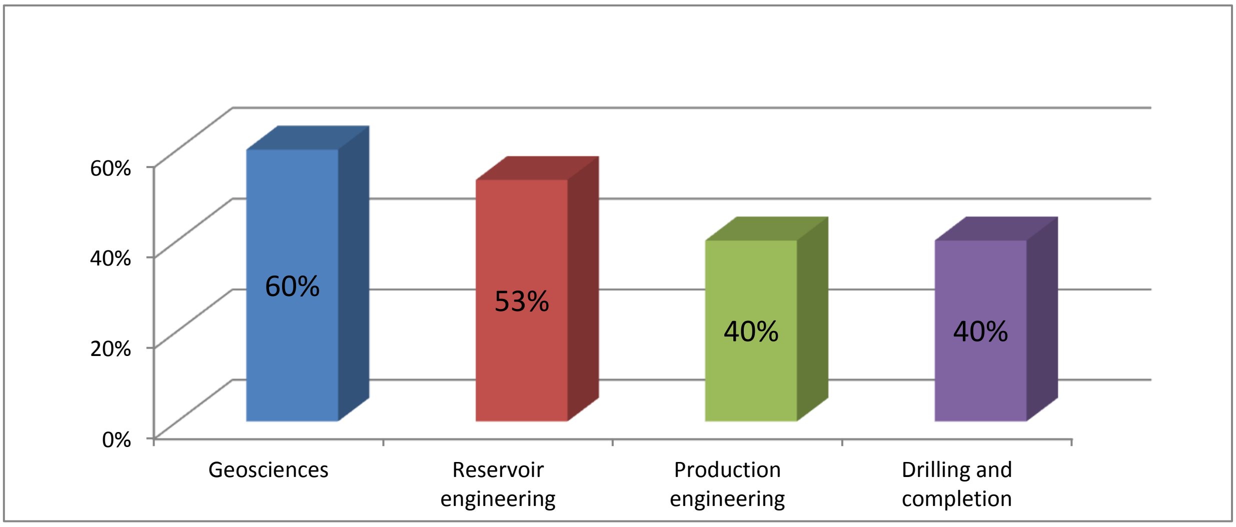


Figure 43 Does your company have any specific agreements with universities regarding support and development of specific disciplines?

Expositor: F. Kajánek, Head of HR, NAFTA, a.s., Slovak Republic:

1. Which of the UGS positions are sufficiently supplied by universities and other specific schools in your country?
   NAFTA's perspective is more or less in accordance with the graph; what is to be mentioned is the question of not only the quantity of the graduates but more of their quality. This is linked to the following pictures where is evident that the majority of the companies are spending money on additional trainings, internships and specific arrangements with universities
2. Does your company arrange some courses for graduate newcomers?
   It is a necessity to support new graduates to complete their education process in line with the company's needs
3. Does your company support talented students by means of scholarship?
   That is not NAFTA's practice due to the above fact (quality and quantity of graduates) and also the related labour legislation
4. Does your company have any specific agreements with universities regarding support and development of specific disciplines?
   We see the basic problem in this respect in the size of the sector in the relevant country. There is a link between the size of the sector (theoretical acceptance rate of the future graduates) and the capability of the academic sector to produce adequate numbers of graduates

Expositor: Andrei Kolesnichenko, Chief of the HR Department, Gazprom UGS, Russia:

Gazprom supports mainly bachelor and master studies. (80% in general), 20% is represented by PhD studies.

Education – Internal: Knowledge transfer within the company

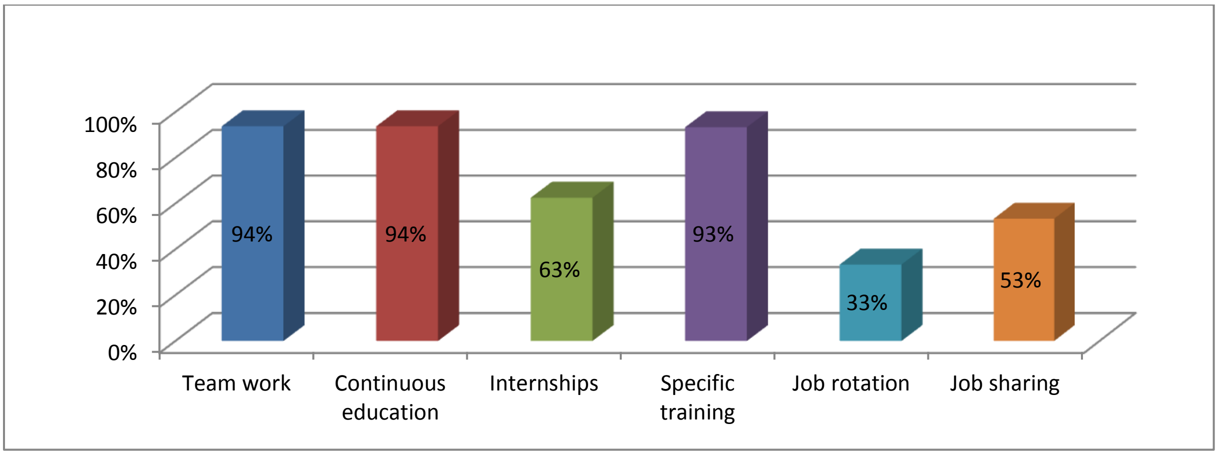


Figure 44: Is data and knowledge systematically transferred in your company in the area mentioned?

Highly qualified personnel is the key element for successful and safe UGS development and operation. Knowledge management system is one of the possible tools for in-house education, easy for implementation, largely available.

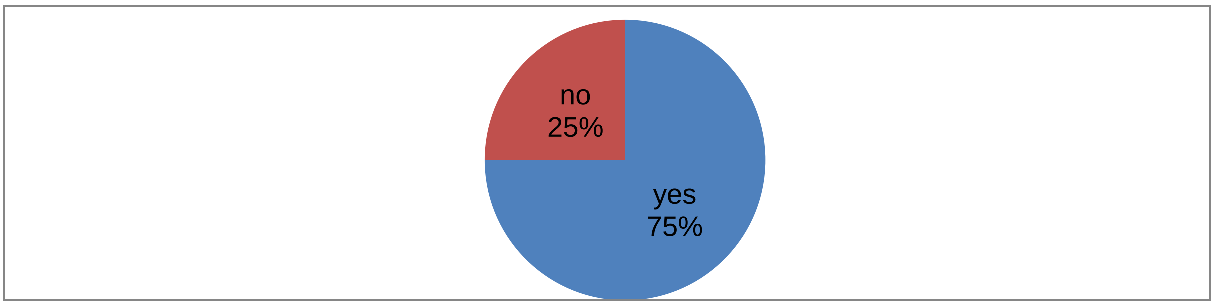


Figure 45: Does your company use a Knowledge Management System (KM System)?

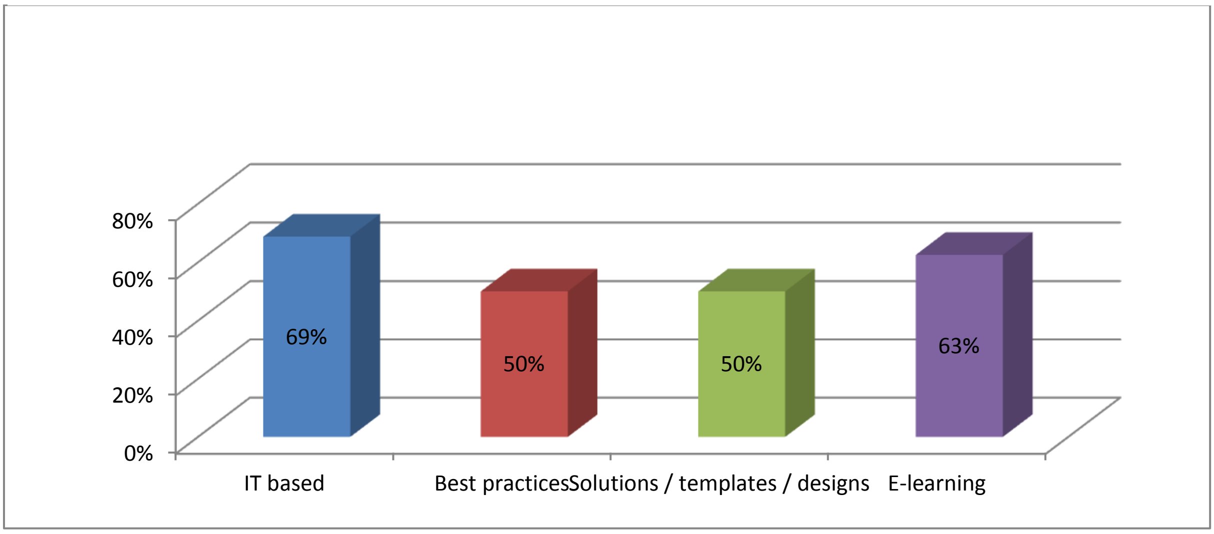


Figure 46: Does your company use a Knowledge Management System in the area mentioned?

Expositor: Lars Bach, CEO, Dong Energy, Denmark:

75% of companies involved in the gas business rely on internal knowledge management. It is a key element in doing business to ensure that the right people have the right competencies and to ensure that the companies have an overview of the knowledge base.
69% have an IT-based system that ensures quick and broad overview of the personnel. This relates to the fact that 63% offer an e-learning feature to ensure that staff have access to education and competency development.
50% of the companies rely on structured Best Practice systems together with templates and designs that guide the way for internal education.
It is considered to be a vital form of knowledge transfer in the gas business, as no structured educational programme for education in the gas business exists throughout Europe.
From our investigation into the gas business it is evident that the use of internal education is a vital and very important way of educating the people in gas business and it is a core part of ensuring that companies can continue to rely on the fact that the people employed have the right skills.

Knowledge is being transferred through teamwork, specific training and continuous education in up to 94% of the gas business. This provides a structured systematic way of ensuring that the skills and competencies are handed over from employee to employee. Internships where the companies give new employees a structured way of learning the business as an intern are used in 63% of the companies.
Job sharing where new employees are introduced to the business by on the job training together with experienced colleagues is used in 53% of the business. This offers a reliable way of ensuring that the knowledge already present can be handed over to new employees. However, this can also present a situation where possibly an unwanted way of doing business is handed over. Therefore it is always a challenge to ensure that on the job training relies on well-defined solutions or templates.
The issue of job rotation is used in 33% of the business. Job rotation is a reliable way of ensuring that people get a broad overview of the business and the different functions within a company. However, it is a more challenging situation to rotate specialists in a organisation, hence job rotation is used in a broader range of unspecialised job functions. Of course, it is possible to use job rotation if the same job arises in a different part of the company.

UGS Company activities/positions

Some key professions and activities related to UGS were selected in the distributed questionnaire. The following were found among the most difficult positions to be filled in your company: engineers, geoscientists and drilling specialists. Regarding the most difficult activities, exploration, design and planning and UGS development were found.

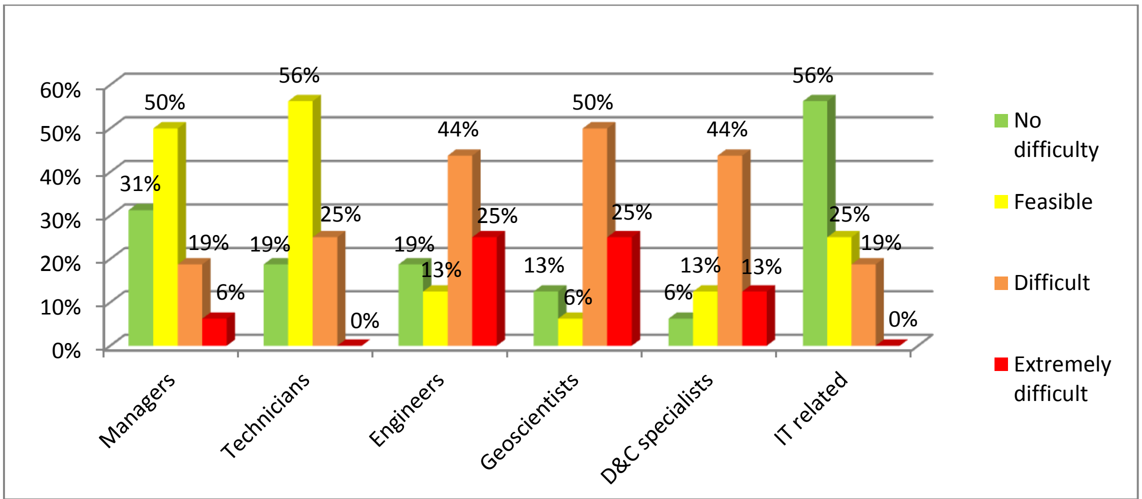


Figure 47: Which UGS positions are the most difficult to fill in your company/country?

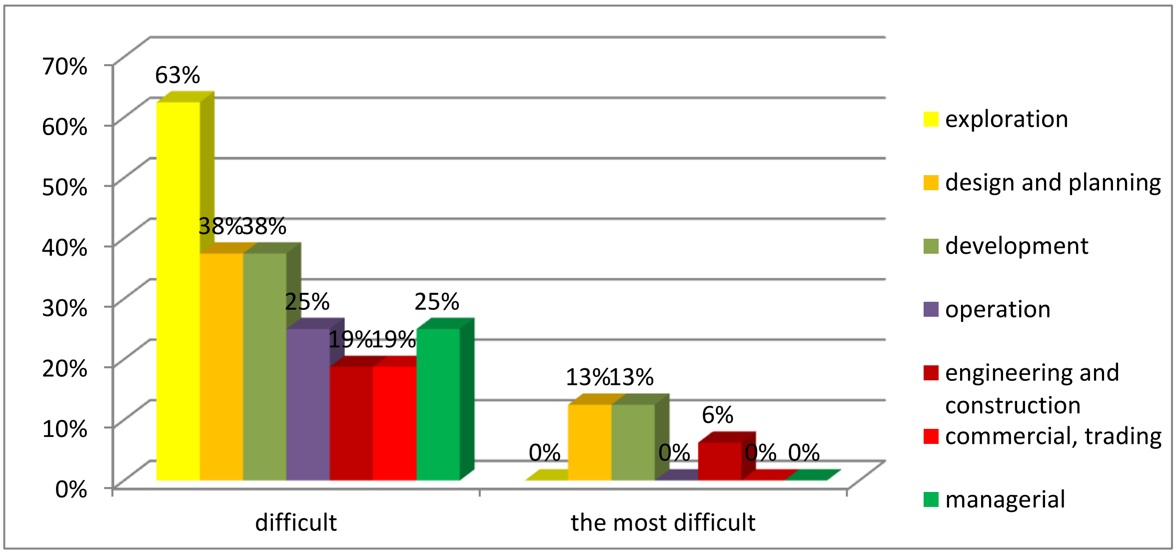


Figure 48 : Which of the activities are the most difficult to fill in your company?

Expositor: Frederick Metzger, Vice President, Gas Storage Engineering, Kinder Morgan Inc., the USA:

The situation in North America is similar. The "Baby Boomer" generation born after the 2nd World War through 1964 is beginning to retire. A very large number of people our age became Petroleum Engineers and Geoscientists in the 1970s and early 1980s during the oil crisis. Very few students were attracted to these fields in the late 1980s through 2005 due to the low price of oil and the trend in the oil industry to downsize and consolidate during this period.
The industry is now trying to catch up and salaries have grown considerably over the last 5 years and more students are being trained in Petroleum Engineering and the Geosciences. The newly trained people are being hired mostly in E&P to support the very large shale exploration and production activity that is ongoing in North America, and it is difficult to attract these people to UGS. One way to attract these people is to offer them summer intern positions to get them interested in UGS and also because, in my opinion, we can offer alternative living locations than the "oil patch" and that our positions are much less cyclical than E&P positions. We are also beginning to offer salaries that are more in line with E&P engineering positions for storage, at levels that are higher than for pipeline engineers.

Expositors: Helene Giouse and Michel Gouez, Storengy, France:

These top 3 most difficult positions to fill are not surprising. During the 2006-2007 boom of oil and gas activity (before the first crisis), experienced professionals with the following experience:

1. drilling engineers
2. reservoir engineers (among other geoscientists)
3. process engineers (among other engineers)

were very difficult to attract in UGS companies. They were very valuable people and Exploration/Production companies were able to pay them more than UGS operators.
The situation has not changed a lot even if the demand for these profiles has been decreasing since this peak of activity.
Another effect has to be taken into account. Valuable engineers have 10 or 15 years of experience. That means that they should have started their career around 2000. At that time Exploration/Production was not in a good shape and hired few young professionals. The cycling activity of oil industry, directly linked with the price of oil, has an immediate effect but also a delayed effect which is quite bad too. The gas industry is also impacted by these cycles, in a minor proportion.
The results about activities lead to two remarks.

- On the one hand, as the activities of exploration, design and planning and development could be directly linked with the 3 most difficult profiles to recruit, this result seems logical and could be explained in the same way.
- On the other hand, my opinion is that exploration and development is more attractive than regular operation, maintenance and revamping projects for professionals. Even if these regular activities are useful, complex, interesting and demanding in professional skills, engineers and business people generally do prefer developing new projects and facilities. For instance, a drilling engineer would prefer to drill an exploration well or an appraisal well on a new site than to perform a difficult work-over on a well-known UGS facility. In Europe, new UGS projects will not be so numerous

in the future and the need for skilled people will be mainly led by operation, maintenance and revamping. Unfortunately this type of activity is less attractive.

Skills shortage in UGS business in the near future

Skills shortage and aging of current UGS personnel are among widely known phenomena. Based on questionnaire results, the foreseen conditions will even be worse.

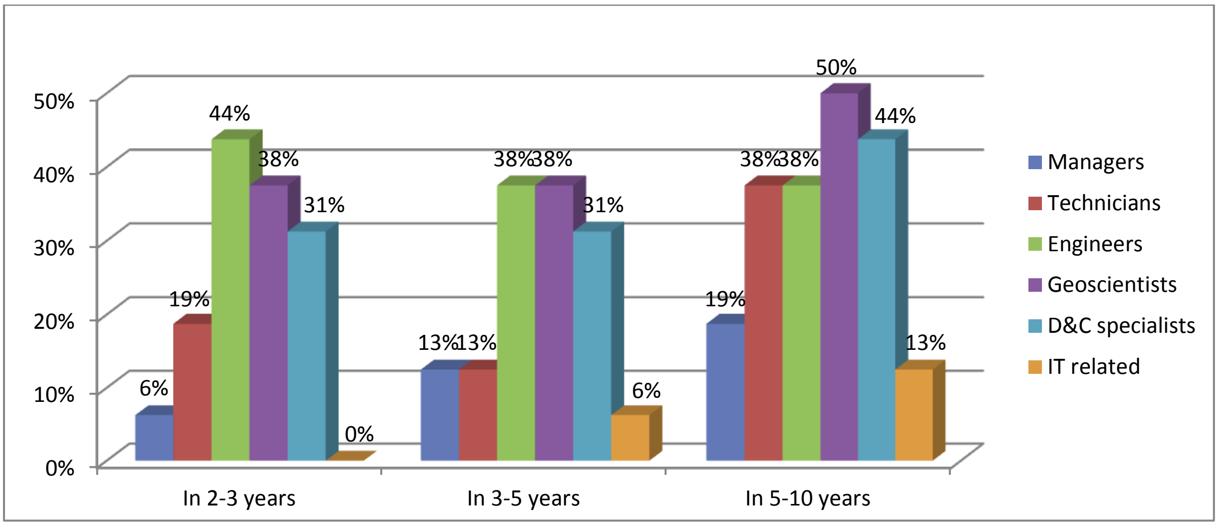


Figure 49: Shortage of which skills in UGS business in your country do you expect in the future?

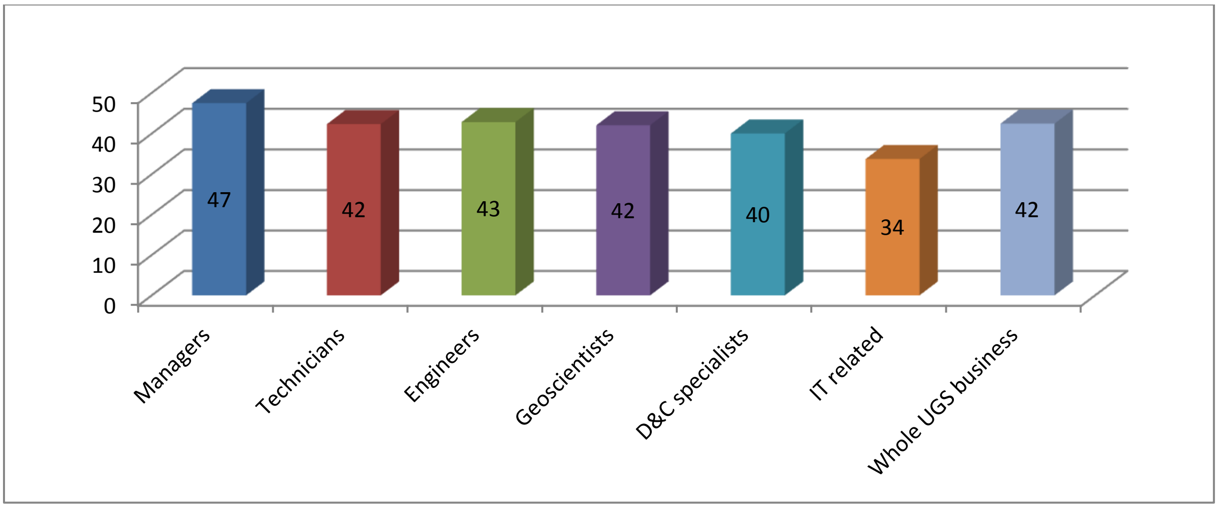


Figure 50: What is the average age of your employees? (in years)

Expositor: Hermann Spreckels, Vice President, E.ON Gas Storage GmbH, Germany:

Generally speaking I can confirm (from a country point of view and general experience) that the overall result in terms of employees' age meets my expectations. Except for the IT related qualifications, all groups are beyond 40 with a maximum age in the manager's category.
Average age of employees, graph:

From my company (EGS) point of view we have a slightly different situation. With respect to geoscientists and engineers the average age is substantially lower (37 and 39, respectively), whereas drillers, technicians and managers (41, 55 and 56, respectively) in our company exceed the average age resulting from the corresponding results of the questionnaire. Amazingly enough the total average is again 42.

The individual company situation depends on the recent restructuring and hiring activities. Since we had the chance to expand our team during recent years, the result for us was a drop in the average age for at least some of the disciplines considered. Although some of our key people will retire within the next 5 to 10 years, the general situation is less critical than discussed lately. This is due to the fact that some high potential young people have joined the company and there is enough time to acquire the experience needed from the "old" people within the years to come. The challenge certainly is to continuously provide the young potentials with attractive working conditions and interesting projects.

The current situation in our company is such that:

50% of the managers will retire within the next 5 – 10 years. The remaining 50% is younger than 40 and thus will stay for a much longer time (except for the normal churn and the corresponding consequences).

60% of the currently employed technicians will leave within the next 5 – 10 years. The remaining 40% is younger than 45.

30% of the currently employed engineers will leave within the next 5 – 10 years. The remaining 70% is younger than 50.

None of the currently employed geoscientists will leave within the next 5 – 10 years due to retirement. They are all younger than 40.

25% of the currently employed drilling and completion specialists will leave within the next 5 – 10 years. The remaining 75% is younger than 50.

Except for unforeseen early retirement agreements there is nobody due (for reasons of age) to leave the company within the next 2-3 or 3-5 years.

Looking at the analysis results it seems that E.ON Gas Storage is somewhat different from the other companies that have answered your questionnaire. I must say that the numbers given above do not include the commercial and administrative people, nor the people working in the operation team on site.

Key elements to recruit and retain specialists

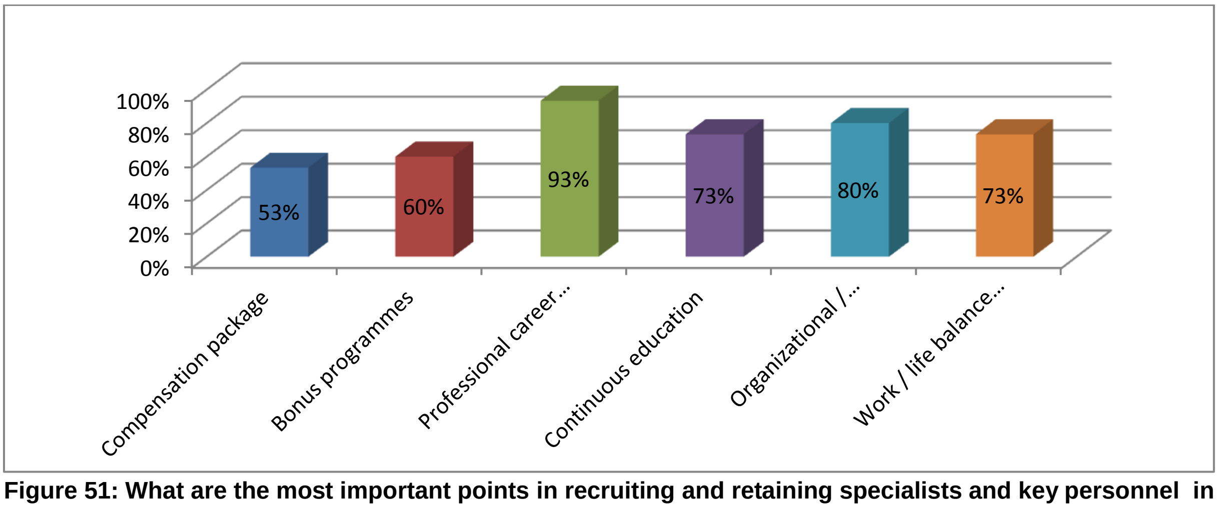


Figure 51: What are the most important points in recruiting and retaining specialists and key personnel in your company?

Expositor: Jitka Adámková, Head of HR, RWE Transgas, a.s., the Czech Republic:

A competitive pay plays a role in attracting and retaining talents. But this is certainly not the only motivator for them to join a company and stay in a position. Compensation package is only the short-term motivator, it is not possible to address the retaining of talents from the long-term point of view by continuously increasing wages. Generally, better wages or benefits do not retain real talents. The level of pay plays a role in the recruitment process, but after 1 – 2 years the motivators change. Employees become familiar with the job position content and start to look for other challenges. Important is the attractiveness of the respective business or industry, and the utility business is perceived by graduates as a conservative industry with fewer career opportunities, fewer opportunities to bring and implement new ideas (compared with e.g. banks or IT companies). Career opportunities are also not frequent due to the low churn rate.

Talents will leave their job not only in the case they are not rewarded well compared with the external market, but also when they do not have adequate advancement opportunities or are not using their skills to the maximum potential. To retain talent in the long-term, employers need to find different ways and means of tapping into an individual's enthusiasm for learning. Development opportunities are the key factor for retaining talent. Talents are interested in transferable skills that can be applied to a number of different employers and industrial sectors. In terms of benefits, a more and more important factor for retaining talents is the work-life balance aspects (flexible working hours, home office possibilities, remote working options). Young generation is not willing to spend so many hours at work as the older one. There is also a growing concern for environmental issues, especially from younger managers and generation. Performance culture is the important motivator generally. Regular feedback, appraisals, surveys and suggestion boxes, openness for dialogue and constructive criticism are important parts of it. Old leadership culture evaluates everybody in the same way without differentiation of performance, does not attract talent and is, to a certain extent, de-motivating. Unfortunately, this type of culture dominates in the utility industry due to its tradition. The new leadership is all about setting final results without standardising the ways, thereby allowing those with the greatest talent to find the best ways to achieve the desired success.

5.3.1.3 Skills and Competencies Model for sustainable education development

The methodology of education and development of science competence, "internal" and "external", reflects Bloom (Bloom, 1956); pupils develop individual components to gradually higher levels thus achieving higher objectives. In each of the free domains Bloom's Taxonomy it is based on the premise that the categories are ordered in degrees of difficulty. An important premise of Bloom's Taxonomy is that each category (or 'level') must be mastered before progressing to the next. As such, the categories within each domain are levels of learning development, and these levels increase in difficulty.

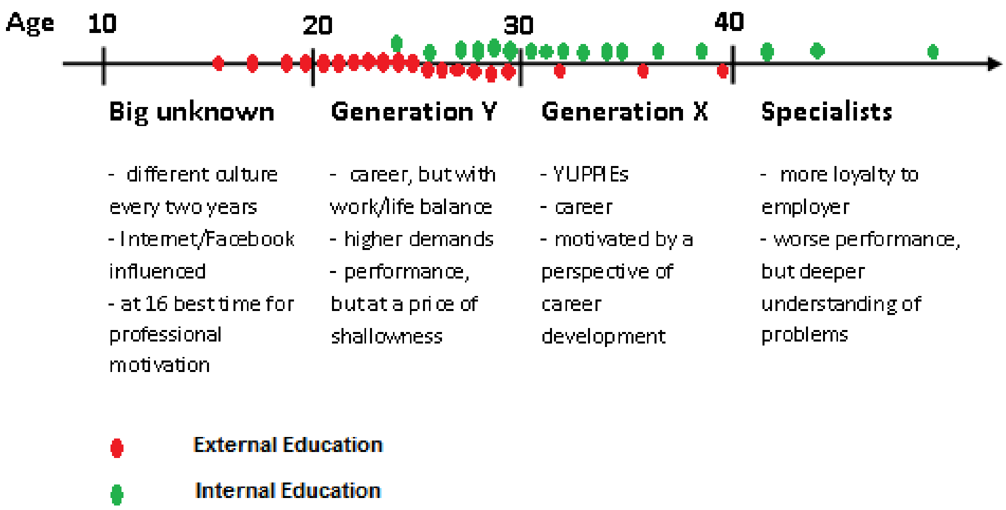


Figure 52: Age Model, Different approach to different generations

External education: means outside company, e.g. basic high school and university education, Internal education: means the education driven by a company. For the successful planning of HR, companies should start to attract pupils and students at a very young age, between 16 and 20 years. In higher age groups the need for specific education is decreasing and it is replaced by experience.

Universities – standard study

1. Goes into depth of problems
2. Cheap
3. Gives scientific background
1. Lengthy, time consuming
2. Not always what company needs

Universities – special courses

1. Can be tailored for a given company/people
2. Flexible places/times
3. Relatively cheap
1. Lecturers not always reflect practice
2. Fast, not much background

Consultancy companies

1. Giving training in what the GS business really needs
2. Fast, intensive
1. Expensive
2. Flexibility/tailoring for extra costs

In-house training

1. Gives knowledge which is specific for the company
2. Flexible, customisable
1. Usually no company training centre, extra work for older employees
2. Expect some prior background in the given field

Figure 53: Education Model

5.3.2 Part B: Young Employees Exchange Programme (YEEP)

The fact of the lack of qualified experts has a fundamental impact on the operation of underground gas storage facilities and the development of new storage capacities.
For these reasons, the International Gas Union (IGU) decided that during the 2009-2012 Triennium, in Study Group 2.3 (Skills and Competencies for UGS Activities) of Technical Committee WOC 2 (Storage), this problem would be addressed by an exchange study programme called Young Employees Exchange Programme (YEEP). This programme was prepared for companies that deal with the issues of underground gas storage in porous media.
The YEEP was dedicated to university graduates working, or starting to work, with the issues of underground gas storage and was divided into the following three fields describing the workflow from the storage reservoir to the gathering network, i.e., particular courses, which are:

- Course I

  Geological aspects of underground gas storage (UGS) design, construction and cyclic operation – Gubkin Russian State University of Oil and Gas in Moscow (Russia), supported by Gazprom
  20 June – 1 July 2011

- Course II

  Reservoir Engineering – Technical University in Liberec (the Czech Republic) – supported by RWE Gas Storage
  4 – 15 July 2011

- Course III

  Treatment of Natural Gas – Institute of Chemical Technology in Prague (the Czech Republic) – supported by the Czech Gas Association
  18 – 29 July 2011

Based on the entrance test, results of 15 nominees from 5 countries were selected.
The **YEEP** was dedicated to young newcomers to the UGS industry. The Young Employees Exchange Programme was run in the spirit of the IGU, i.e., free of charge, based on WOC2 members' sponsorship. Other important facts were as follows:

- Course providers: universities;
- Course financing was provided by sponsors, i.e., participation was free of charge for the attendees;
- All overhead charges (e.g., travel costs, accommodation, insurance etc.) was covered by the attendees' employers;
- Attendees received the lectures (on CDs);
- Each course ended with a leaving test;
- Based on overall results, the best three IGU WOC2 Young Employees Exchange Programme "Students" were selected and they obtained the award with an opportunity to attend the 25th World Gas Conference – The Youth Programme in Kuala Lumpur 2012 free of charge.

5.3.3 Conclusions

The importance of education in general for the well-being and prosperity of any society and industry is well recognised. But the lack of highly skilled, talented and competent personnel in many technical disciplines is felt in several parts of the world, specifically in Europe. The same conditions are felt in specific branches within the UGS industry such as lack of petroleum geologists and geoscientists, reservoir engineers, drilling and completion specialists.

Among the negatives why the attractiveness is relatively low are the following issues:

- A relatively long chain of required education, starting with technical branches at secondary schools, through relatively difficult university studies and long-term training/adaptation process in the company. A specific relationship between the industry and the educational environment, working together, is required.
- Negative perception of hydrocarbons and technology related to gas production such as hydraulic fracturing applied for unconventional gas due to negative impacts on the environment.
- Rigidity of the gas business and society and low salary increases with a slow position/career growth.
- Workplaces, UGS locations often out of big cities and need for travelling.

On the other hand, based on the analysis of the questionnaire, among the pros and positive future UGS HR development we have evaluated the following:

- Stability of the UGS business specifically if society recognises that gas can be a good solution for a low carbon future.
- Very good starting salary and other compensation packages and bonuses.
- Good environment for personal specialisation and education throughout the UGS specialist's career.

Through information and awareness, but more importantly by building people's capacity to innovate and implement solutions, education is essential for the safe and optimised UGS development and operation.

6 Appendixes

6.1 List of figures

Figure 1 WGV distribution by regions 11
Figure 2 WGV by countries 14
Figure 3 Development of new storage capacity over trienniums 15
Figure 4 WGV distribution by regions 15
Figure 5 WGV distribution by storage types...16
Figure 6 Specific WGV and No. of UGS by countries 17
Figure 7 Reported planned WGV distribution by regions 18
Figure 8 Reported planned WGV distribution by storage types..19
Figure 9 Reported WGV distribution by type of project 19
Figure 10 New projects WGV status...20
Figure 11 Layer visualisation of WGV by countries...21
Figure 12 Layer visualisation of WGV by storage types...21
Figure 13 Layer visualisation of UGS by storage types...22
Figure 14 The Glossary...23
Figure 15 World – Storage demand forecast 27
Figure 16 Europe – Storage demand forecast 28
Figure 17 CIS – Storage demand forecast..29
Figure 18 North America – Storage demand forecast 30
Figure 19 Others – Storage demand forecast 31

Figure 20 Perspectives for the integration of renewable into the gas system........................37
Figure 21 UGS facilities per WGV distribution 38
Figure 22 Original vs maximum allowable pressure gradient..39
Figure 23 Maximum pressure gradients for caverns 39
Figure 24 Maximum allowable pressure gradient for aquifers...40
Figure 25 Ratio of cushion gas volume to WGV 40
Figure 26 Ratio of peak withdrawal rate to WGV 41
Figure 27 Ratio of injection rate to WGV 41
Figure 28 - Number of UGS wells and cumulated number of UGS wells worldwide.............44
Figure 29 Number of UGS wells and cumulated number of UGS Wells-Europe 45
Figure 30 Number of UGS wells and cumulated number of UGS Wells-CIS.........................45
Figure 31 Work-flow of Well Integrity Management 47
Figure 32 Showing different trapping mechanisms 52
Figure 33 Density of CO_2 vs depth..52
Figure 34 showing distribution of storage capacity in Europe (number of fields within capacity ranges; SA = Salines, DOGF: depleted oil or gas field 53
Figure 35 Attractiveness of specific studies 56
Figure 36 The Maslow hierarchy of needs...58
Figure 37: Example of life cycle of an employee...59
Figure 38 Does your UGS development and/or operation require any specific autorisation /legal requirements in the mentionned positions?...59
Figure 39 - Do the mining (and similar) authorities in your country require a periodical examination of authorised persons?...60
Figure 40 Which of the UGS position are sufficiently supplied by universities and others schools in your country?..60
Figure 41 Does your company support talented students by scholarships on the level mentioned? 61
Figure 42 Does your company arrange some courses for graduate newcomers?.................61
Figure 43 Does your company have any specific agreements with universities regarding support and development of specific disciplines? 62
Figure 44: Is data and knowledge systematically transferred in your company in the area mentioned? 62
Figure 45: Does your company use a Knowledge Management System (KM System)?.......63
Figure 46: Does your company use a Knowledge Management System in the area mentioned? 63
Figure 47: Which UGS positions are the most difficult to fill in your company/country?.........64
Figure 48 : Which of the activities are the most difficult to fill in your company? 65
Figure 49: Shortage of which skills in UGS business in your country do you expect in the future?..66
Figure 50: What is the average age of your employees? (in years) 66
Figure 51: What are the most important points in recruiting and retaining specialists and key personnel in your company?...67
Figure 52: Age Model, Different approach to different generations.......................................69
Figure 53: Education Model...69
Figure 54 Development of WGV in Germany...84
Figure 55 Locations of German storage facilities...85
Figure 56 WGV distribution by storage types (Germany)..86
Figure 57 Storengy storage groups and associated products (2011-2012)...........................93
Figure 58 TIGF storage services (2011-2012)...94
Figure 59 Underground natural gas storage facilities in the lower 48 states 97
Figure 60 Cumulative North American storage development..98
Figure 61 WG by the US State/Canadian province 2011 99
Figure 62 Top North American storage operators 2011 100
Figure 63 North American storage types 101
Figure 64 North American storage – reservoir geology..102

Figure 65 Total number of wells operated by company 2011 103
Figure 66 the US national storage inventory 104
Figure 67 Russian UGS facilities 106
Figure 68 The Netherlands - Load Duration Curve in 114
Figure 69 Overview of Dutch Gas Distribution system 115
Figure 70 Interconnections of UGS Lab complex to gas grids 116

6.2 List of Tables

Table 1 WGV capacity by countries 13
Table 2 The overall summary for the world 17
Table 3 The overall summary for Europe 18
Table 4 Storage demand forecast 26
Table 5 Energy sources in Germany 83
Table 6 Gas supply 83
Table 7 Pore storages vs caverns in Germany 84
Table 8 Parametres of Serrablo UGS 88
Table 9 Parameters of Gaviota UGS 89
Table 10 Parameters of Yela UGS 89
Table 11 UGS in France (June 2011) 92
Table 12 Data of UGS in Russia 107

6.3 List of abbreviations

Abbreviations

BNA	The Bundesnetzagentur
CAES	Compressed Air Energy Storage
CCS	Carbon Capture Storage
CEGH	Central European gas hub at Baumgarten
CCS	CO_2 capture and storage
CGV	Cushion Gas Volume
CIS	Commonwealth of Independent States
CO_2	Carbone Dioxide
DME	Dimethyl ether
E & P	Exploration & Production
EDF	Electricité de France
EGL	Etzel Gas Lager
EIA	Environmental Impact Assessment
EMAS	Eco-Management and Audit Scheme
EMI	Energy Markets International
ERGEG	European Regulators Group for Electricity and Gas
EU	European Union
FERC	Federal Energy Regulatory Committee
GGPSSO	Guidelines of Good Practice of Storage System Operators
GHG	Greenhouse gas
GIS	Geographic Information System
GRI	Gas Research Institute
GSE	Gas Storage Europe
GTS	Transport system operator in Netherlands
H_2	Hydrogen
HR	Human ressources
IGU	International Gas Union
IPCC	Intergovernmental panel on climate change
IPPC	Integrated Pollution Prevention and Control

LBEG	Landesamt für Bergbau, Energie und Geologie
LDC	Load Duration Curve
LDCs	Local Distribution Companies
LNG	Liquefied natural gas
MoU	Memorandum of Understanding
NE	Northeast
NOx	Nitrogen Oxide
NW	Northwest
p	Pressure
PGC B	Programme Committee B
PWR	Peak withdrawal rate
QHSE	Quality, Health, Safety and Environment
R&D	Research & Development
SG	Study Group
SSO	Storage System Operator
SSSV	Subsurface Safety Valves
SW	Southwest
TIGF	Total Infrastructure Gaz France
TPA	Third Party Access
TSO	Transmission system operator
TU	Technical university
UGS	Underground Gas Storage
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
USA	United States of America
WGC	World Gas Conference
WGV	Working Gas Volume
WIM	Well Integrity Management
WOC	Working Committee
YEEP	Young employees exchange programme

6.4 Units and conversion factor

UNITS

cm/h	Cubic meter per hour
bcm	Billion Cubic Meters
bcm/d	Billion Cubic Meters per day
mcm	Million Cubic Meters
mcm/h	Million Cubic Meters per hour
mcm/d	Million Cubic Meters per day
kWh	Kilowatt Hour
MW	Megawatt
Km^2	Square kilometer - unit of surface area
m	Meter
inch (“)	1 inch = 25.4e-3 m
degree(^{o})	A unit of angle measurement/a unit of temperature measurement
Bcf	Billion Cubic Feet (1Bcf = 10^9cf); 1 cf = 0.028cm
Tcf	Trillion Cubic Feet 1Bcf = 10^{12}cf); 1 cf = 0.028cm

Note: decimal marker is the dot

6.5 List of WOC2 members

Surname	Name	Country	
Hassan	Benmansour	Algeria	
Mr	Benferrah	Algeria	
Michael	Kreuz	Austria	
Dimitar	Shterev	Bulgaria	
Mariana	Pavlova	Bulgaria	
Nikolina	Tabakova	Bulgaria	
Ivaylo	Pandurski	Bulgaria	
Nikolai	Hristov	Bulgaria	
Donghou	Wei	China	
Guosheng	Ding	China	
Zhang	Yuwen	China	
Zhang	Gangxiong	China	
Wang	Qing	China	
Vladimir	Onderka	Czech Republic	SG 2.3 leader
Jana	Kymplova	Czech Republic	
Lelf	Hansen	Denmark	
Lars	Bach	Denmark	
Jorma	Venäläinen	Finland	
Hélène	Giouse	France	Chair and SG 2.2 sub group leader
Madeleine	Lafon	France	
Remy	Champavere	France	
Pierre	Marion	France	
Michel	Gouez	France	
Jacques	Grappe	France	
Fabien	Favret	France	
Michel	Agor	France	
Wicquart	Emmanuelle	France	
Hermann	Spreckels	Germany	
Joachim	Wallbrecht	Germany	
Gunar	Lenk	Germany	
Amer	Abdel Haq	Germany	
Hiromi	Sugiyama	Japan	
Seita	Shimizu	Japan	
Genta	Takagi	Japan	
Abd Aziz	Abd Rashid	Malaysia	
Eddy	Kuperus	Netherland	
Wieslaw	Rokosz	Poland	
Jerzy	Stopa	Poland	
Joao	Regueira	Portugal	
Luis	Ferreira da Costa	Portugal	

Kangwon	Lee	Republic of Korea	
Sava	Radulovic	R. Srbija	
Serguei	Khan	Russia	
Dmitry	Pavlenkov	Russia	
Alexander	Grigoriev	Russia	
Nikita	Barsuk	Russia	
Sergey	Vlasov	Russia	
Inna	Kononenko	Russia	
Nadezhda	Vlasenko	Russia	
Marya	Khaydina	Russia	
Andrey	Kolesnichenko	Russia	
Rosa Maria	Nieto	Spain	
Ana Maria	Garcia Dominguez	Spain	
Yue	Wu	UK	
Robert	Pearson	UK	
Ladislav	Goryl	Slovakia	Vice chair and SG 2.1 leader
Vladimir	Lorenc	Slovakia	
Stanislav	Bilik	Slovakia	
Frantisek	Kajanek	Slovakia	
Ivars	Scerbickis	Lithuania	
Frederick	Metzger	USA	

6.6 Appendix SG2.1_1 Summary by countries

				UGS in Operation					Planned in Existing and Greenfield		Total
Region	Nation	Type of Storage	No. of UGS	Total Installed max Working Gas Volume (bcm)	Total Cushion Gas Volume (bcm)	Total Peak Withdrawal Rate (mcm/d)	Total Injection Rate (mcm/d)	Total No. of Storage Wells	Total Planned max Working Gas Volume (bcm)	Total Planned Peak Withdrawal Rate (mcm/d)	Total Working Gas Volume (bcm)
Asia	China	Gas Field	9	2.7	3.3	37.9	19.4	93	16.6	0.0	19.3
		Oil Field	1	0.5	0.5	2.1	3.9	36	0.0	0.0	0.5
		Salt Cavern	2	0.8	0.0	0.0	0.0	0	0.0	0.0	0.8
		Total	12	4.0	3.8	40.1	23.3	129	16.6	0.0	20.6
	Pakistan	Gas Field	1	0.0	0.0	0.0	0.0	0	0.4	0.0	0.4
		Total	1	0.0	0.0	0.0	0.0	0	0.4	0.0	0.4
	Total		13	4.0	3.8	40.1	23.3	129	17.0	0.0	21.0
Asia Pacific	Australia	Gas Field	7	1.6	0.5	16.5	0.0	5	2.1	0.0	3.7
		Total	7	1.6	0.5	16.5	0.0	5	2.1	0.0	3.7
	Japan	Gas Field	4	1.1	0.7	2.0	1.1	13	0.0	0.0	1.1
		Total	4	1.1	0.7	2.0	1.1	13	0.0	0.0	1.1
	New Zealand	Gas Field	1	0.3	0.0	0.0	0.0	0	0.0	0.0	0.3
		Total	1	0.3	0.0	0.0	0.0	0	0.0	0.0	0.3
	Total		12	3.0	1.3	18.5	1.1	18	2.1	0.0	5.1
CIS	Armenia	Salt Cavern	1	0.1	0.0	4.0	1.2	18	0.1	0.0	0.2
		Total	1	0.1	0.0	4.0	1.2	18	0.1	0.0	0.2
	Azerbaijan	Gas Field	3	4.2	1.7	14.5	13.0	125	0.0	0.0	4.2
		Total	3	4.2	1.7	14.5	13.0	125	0.0	0.0	4.2
	Belarus	Aquifer	1	0.4	0.3	4.0	0.0	40	0.0	0.0	0.4
		Gas Field	2	0.6	0.3	4.8	2.4	0	2.5	0.0	3.1
		Salt Cavern	1	0.2	0.0	0.0	0.0	0	0.8	0.0	1.0
		Total	4	1.2	0.6	8.8	2.4	40	3.3	0.0	4.5
	Kazakhstan	Aquifer	2	0.7	0.6	6.5	0.0	89	0.0	0.0	0.7
		Gas Field	1	3.6	0.0	22.2	0.0	266	0.0	0.0	3.6
		Total	3	4.2	0.6	28.7	0.0	355	0.0	0.0	4.2
	Kyrgyzstan	Gas Field	1	0.1	0.0	0.0	0.0	10	0.0	0.0	0.1
		Total	1	0.1	0.0	0.0	0.0	10	0.0	0.0	0.1
	Russia	Aquifer	9	15.7	18.1	139.9	103.3	692	7.8	100.0	23.5
		Gas Field	16	50.0	74.4	417.8	358.8	1940	1.0	40.1	51.0
		Salt Cavern	4	0.0	0.0	0.0	0.0	0	2.3	100.8	2.3
		Total	29	65.6	92.6	557.7	462.2	2632	11.1	240.9	76.7
	Ukraine	Aquifer	2	1.9	1.9	16.0	11.0	107	0.0	0.0	1.9
		Gas Field	11	30.9	29.4	284.9	185.6	1689	0.0	0.0	30.9
		Total	13	32.8	31.3	300.8	196.6	1796	0.0	0.0	32.8
	Uzbekistan	Gas Field	3	5.4	0.0	31.0	29.0	353	0.0	0.0	5.4
		Total	3	5.4	0.0	31.0	29.0	353	0.0	0.0	5.4
	Total		57	113.6	126.7	945.5	704.4	5329	14.5	240.9	128.0
Europe	Albania	Gas Field	1	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0
		Salt Cavern	1	0.0	0.0	0.0	0.0	0	0.2	0.0	0.2
		Total	2	0.0	0.0	0.0	0.0	0	0.2	0.0	0.2
	Austria	Gas Field	11	7.5	3.0	85.6	69.2	183	0.9	8.8	8.3
		Total	11	7.5	3.0	85.6	69.2	183	0.9	8.8	8.3
	Belgium	Aquifer	1	0.7	0.6	15.0	7.8	12	0.0	0.0	0.7
		Total	1	0.7	0.6	15.0	7.8	12	0.0	0.0	0.7
	Bosnia & Herz.	Salt Cavern	1	0.0	0.0	0.0	0.0	0	0.1	0.0	0.1
		Total	1	0.0	0.0	0.0	0.0	0	0.1	0.0	0.1
	Bulgaria	Gas Field	2	1.7	0.5	4.0	0.0	17	0.0	0.0	1.7
		Salt Cavern	1	0.0	0.0	0.0	0.0	0	0.4	1.0	0.4
		Total	3	1.7	0.5	4.0	0.0	17	0.4	1.0	2.1
	Croatia	Gas Field	1	0.6	0.4	5.8	4.3	22	0.4	4.1	1.0
		Oil Field	1	0.0	0.0	0.0	0.0	0	0.5	0.0	0.5
		Total	2	0.6	0.4	5.8	4.3	22	0.9	4.1	1.5
	Czech Republic	Aquifer	1	0.2	0.2	4.9	2.5	20	0.0	0.0	0.2
		Gas Field	6	3.5	2.1	52.3	34.4	220	0.0	0.0	3.5
		Oil Field	1	0.0	0.0	0.0	0.0	0	0.5	0.0	0.5
		Rock Cavern	2	0.1	0.0	6.0	6.0	5	0.2	0.0	0.3
		Total	10	3.7	2.2	63.2	42.9	245	0.7	0.0	4.4
	Denmark	Aquifer	1	0.6	1.0	10.8	4.8	14	0.0	0.0	0.6
		Salt Cavern	1	0.4	0.3	14.4	4.0	7	0.0	0.0	0.4
		Total	2	1.0	1.3	25.2	8.8	21	0.0	0.0	1.0
	France	Aquifer	12	11.3	13.8	184.7	120.2	322	0.4	0.0	11.6
		Gas Field	2	0.1	0.0	0.5	0.0	0	0.8	0.0	0.8
		Salt Cavern	5	1.0	0.7	56.0	12.0	38	0.7	17.5	1.7
		Total	19	12.4	14.5	241.1	132.2	360	1.8	17.5	14.2
	Germany	Abandoned mine	1	0.0	0.0	1.0	1.2	1	0.0	0.0	0.0
		Aquifer	7	0.8	1.5	27.8	13.4	81	0.0	0.0	0.8
		Gas Field	12	9.3	7.1	139.2	82.2	167	1.0	0.0	10.3
		Oil Field	3	0.4	0.3	13.5	3.4	43	0.0	0.0	0.4
		Salt Cavern	38	9.8	3.5	343.6	126.6	197	12.7	32.4	22.5
		Total	61	20.3	12.4	525.0	226.8	489	13.7	32.4	34.1
	Greece	Gas Field	1	0.0	0.0	0.0	0.0	0	0.4	0.1	0.4
		Total	1	0.0	0.0	0.0	0.0	0	0.4	0.1	0.4
	Hungary	Gas Field	7	6.3	4.6	81.4	47.8	221	1.3	15.0	7.6
		Total	7	6.3	4.6	81.4	47.8	221	1.3	15.0	7.6
	Ireland	Gas Field	2	0.2	0.0	2.8	1.0	3	0.9	0.0	1.1
		Salt Cavern	1	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0
		Total	3	0.2	0.0	2.8	1.0	3	0.9	0.0	1.1
	Italy	Aquifer	1	0.0	0.0	0.0	0.0	0	3.2	0.0	3.2
		Gas Field	23	17.4	9.8	347.9	139.5	351	8.6	0.0	26.0
		Total	24	17.4	9.8	347.9	139.5	351	11.8	0.0	29.2
	Latvia	Aquifer	1	2.3	2.1	24.0	16.8	180	1.0	0.0	3.3
		Total	1	2.3	2.1	24.0	16.8	180	1.0	0.0	3.3
	Lithuania	Aquifer	1	0.0	0.0	0.0	0.0	0	0.5	0.0	0.5
		Total	1	0.0	0.0	0.0	0.0	0	0.5	0.0	0.5
	Netherlands	Gas Field	4	5.0	39.1	141.0	39.6	24	4.1	57.6	9.1
		Salt Cavern	2	0.2	0.0	20.0	0.0	0	0.2	0.0	0.4
		Total	6	5.2	39.1	161.0	39.6	24	4.3	57.6	9.5
	Poland	Gas Field	7	2.3	7.4	19.2	18.6	105	0.2	0.0	2.4
		Salt Cavern	2	0.4	0.2	20.6	9.6	11	0.3	9.6	0.7
		Total	9	2.7	7.5	39.8	28.2	116	0.4	9.6	3.1
	Portugal	Salt Cavern	2	0.1	0.2	7.2	0.0	4	0.2	0.0	0.4
		Total	2	0.1	0.2	7.2	0.0	4	0.2	0.0	0.4
	Romania	Gas Field	10	3.5	5.4	26.2	14.0	170	3.2	15.0	6.7
		Total	10	3.5	5.4	26.2	14.0	170	3.2	15.0	6.7
	Serbia	Gas Field	2	0.0	0.0	0.0	0.0	0	1.4	10.0	1.4
		Total	2	0.0	0.0	0.0	0.0	0	1.4	10.0	1.4
	Slovakia	Gas Field	2	2.7	3.1	32.9	28.9	220	0.0	0.0	2.7
		Oil Field	1	0.3	0.0	6.0	4.6	9	0.3	0.0	0.5
		Total	3	3.0	3.1	38.9	33.5	229	0.3	0.0	3.2
	Spain	Aquifer	2	1.1	0.9	15.0	7.0	0	1.1	15.0	2.1
		Gas Field	7	2.3	2.1	12.7	9.0	11	1.6	25.0	3.9
		Total	9	3.4	3.0	27.7	16.0	11	2.7	40.0	6.0
	Sweden	Rock Cavern	1	0.0	0.0	1.0	0.4	1	0.0	0.0	0.0
		Total	1	0.0	0.0	1.0	0.4	1	0.0	0.0	0.0
	Turkey	Gas Field	3	1.9	1.9	16.0	11.8	20	1.4	0.0	3.3
		Salt Cavern	2	0.0	0.0	0.0	0.0	0	1.5	35.8	1.5
		Total	5	1.9	1.9	16.0	11.8	20	2.9	35.8	4.8
	United Kingdom	Gas Field	15	3.9	5.1	57.2	24.5	30	17.4	25.6	21.3
		Oil Field	1	0.3	0.0	9.0	7.0	0	0.0	0.0	0.3
		Salt Cavern	11	0.7	0.3	44.7	54.4	11	5.6	0.0	6.2
		Total	27	4.8	5.4	110.9	85.8	41	22.9	25.6	27.8
	Total		223	98.7	116.9	1849.8	926.7	2720	72.7	272.4	171.4
L.America & Caribbean	Argentina	Gas Field	1	0.1	0.2	1.9	2.1	12	0.0	0.0	0.1
		Total	1	0.1	0.2	1.9	2.1	12	0.0	0.0	0.1
	Mexico	Gas Field	1	0.0	0.0	0.0	0.0	0	1.4	0.0	1.4
		Salt Cavern	1	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0
		Total	2	0.0	0.0	0.0	0.0	0	1.4	0.0	1.4
	Uruguay	Aquifer	1	0.0	0.0	0.0	0.0	0	1.7	0.0	1.7
		Total	1	0.0	0.0	0.0	0.0	0	1.7	0.0	1.7
	Total		4	0.1	0.2	1.9	2.1	12	3.1	0.0	3.2
Middle-East	Iran	Aquifer	1	0.2	0.2	0.0	0.0	0	0.0	0.0	0.2
		Gas Field	3	1.2	0.0	9.0	7.0	9	4.6	36.0	5.8
		Total	4	1.4	0.2	9.0	7.0	9	4.6	36.0	6.0
	Total		4	1.4	0.2	9.0	7.0	9	4.6	36.0	6.0
North America	Canada	Gas Field	43	13.2	7.1	110.3	0.0	383	0.3	0.0	13.5
		Oil Field	6	2.9	0.9	18.4	0.0	67	0.0	0.0	2.9
		Salt Cavern	11	0.6	0.2	47.8	0.0	34	0.6	0.1	1.2
		Total	60	16.7	8.2	176.6	0.0	484	0.8	0.1	17.5
	USA	Aquifer	52	10.0	27.2	257.3	0.0	1553	0.3	0.1	10.3
		Gas Field	324	89.7	78.3	1628.7	0.0	11373	9.7	34.1	99.4
		Oil Field	24	13.9	12.1	279.8	0.0	1120	0.5	0.0	14.4
		Salt Cavern	75	7.8	2.7	426.3	0.0	260	15.3	54.7	23.1
		Total	475	121.4	120.3	2592.1	0.0	14315	25.8	88.9	147.2
	Total		535	138.1	128.4	2768.7	0.0	14799	26.7	89.0	164.7
Celkový Total			848	358.8	377.5	5633.4	1664.5	23007	140.7	638.3	499.4

Appendix SG2.1_1 Summary by countries

6.7 Appendix SG2.1_2 Summary by regions

Region	No. UGS Nations	StorageType	UGS in operation					Planned UGS					Total	
			Installed Capacities					Planned Projects in existing UGS		New Greenfield UGS Projects		Potent. UGS		
			No. of UGS	Working Gas Volume	Cushion Gas Volume	Peak Withdrawal Capacity	No. of storage wells	Working Gas Volume	Peak Withdrawal Capacity	Working Gas Volume	Peak Withdrawal Capacity	Working Gas Volume	Working Gas Volume	Peak Withdrawal Capacity
				(bcm)	(bcm)	(mcm/d)		(bcm)	(mcm/d)	(bcm)	(mcm/d)	(bcm)	(bcm)	(mcm/d)
North America														
		Abandoned mine	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Aquifer	50	10.0	27.2	257.3	1 553.0	0.0	0.0	0.3	0.1	0.0	10.3	257.4
		Gas Field	345	102.9	85.4	1 739.0	11 756.0	1.0	10.0	8.7	24.1	0.3	112.9	1 773.1
		Oil Field	28	16.8	13.0	298.2	1 178.0	0.0	0.0	0.5	0.0	0.0	17.3	298.2
		Rock Cavern	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Salt Cavern	52	8.4	2.9	474.1	303.0	1.5	0.0	12.6	54.5	1.7	24.2	528.6
		Total	**475**	**138.1**	**128.4**	**2 768.7**	**14 790.0**	**2.6**	**10.0**	**22.1**	**78.7**	**2.0**	**164.7**	**2 857.3**
Europe														
		Abandoned mine	1	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
		Aquifer	24	16.9	19.9	282.1	629.0	1.4	0.0	4.3	15.0	0.5	23.0	297.1
		Gas Field	81	68.1	91.5	1 024.7	1 764.0	4.1	22.4	33.5	123.6	5.8	111.4	1 170.7
		Oil Field	5	1.0	0.3	28.5	52.0	0.3	0.0	1.0	0.0	0.0	2.2	28.5
		Rock Cavern	2	0.1	0.0	7.0	6.0	0.0	0.0	0.0	0.0	0.2	0.3	7.0
		Salt Cavern	35	12.7	5.1	506.5	268.0	4.8	0.0	15.4	95.3	1.6	34.5	601.8
		Total	**148**	**98.7**	**116.9**	**1 849.8**	**2 720.0**	**10.6**	**22.4**	**54.1**	**233.9**	**8.1**	**171.4**	**2 106.1**
CIS														
		Abandoned mine	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Aquifer	12	18.6	20.8	166.4	928.0	0.0	0.0	7.8	100.0	0.0	26.4	266.4
		Gas Field	35	94.7	105.9	775.1	4 383.0	0.0	0.0	1.0	40.1	2.5	98.2	815.2
		Oil Field	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Rock Cavern	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Salt Cavern	2	0.3	0.0	4.0	18.0	0.9	0.0	2.0	100.1	0.3	3.5	104.1
		Total	**49**	**113.6**	**126.7**	**945.5**	**5 329.0**	**0.9**	**0.0**	**10.8**	**240.2**	**2.8**	**128.0**	**1 185.7**
Middle-East														
		Abandoned mine	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Aquifer	1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
		Gas Field	1	1.2	0.0	9.0	9.0	2.1	36.0	0.0	0.0	2.5	5.8	45.0
		Oil Field	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Rock Cavern	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Salt Cavern	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	**2**	**1.4**	**0.2**	**9.0**	**9.0**	**2.1**	**36.0**	**0.0**	**0.0**	**2.5**	**6.0**	**45.0**
Asia														
		Abandoned mine	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Aquifer	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Gas Field	6	2.7	3.3	37.9	93.0	0.0	0.0	12.4	0.0	4.6	19.7	37.9
		Oil Field	1	0.5	0.5	2.1	36.0	0.0	0.0	0.0	0.0	0.0	0.5	2.1
		Rock Cavern	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Salt Cavern	2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
		Total	**9**	**4.0**	**3.8**	**40.1**	**129.0**	**0.0**	**0.0**	**12.4**	**0.0**	**4.6**	**21.0**	**40.1**
Asia Pacific														
		Abandoned mine	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Aquifer	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Gas Field	9	3.0	1.3	18.5	18.0	0.0	0.0	0.0	0.0	2.1	5.1	18.5
		Oil Field	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Rock Cavern	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Salt Cavern	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	**9**	**3.0**	**1.3**	**18.5**	**18.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.1**	**5.1**	**18.5**
L.America & Caribbean														
		Abandoned mine	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Aquifer	0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	1.7	0.0
		Gas Field	1	0.1	0.2	1.9	12.0	0.0	0.0	1.4	0.0	0.0	1.5	1.9
		Oil Field	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Rock Cavern	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Salt Cavern	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	**1**	**0.1**	**0.2**	**1.9**	**12.0**	**0.0**	**0.0**	**3.1**	**0.0**	**0.0**	**3.2**	**1.9**
World														
		Abandoned mine	1	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
		Aquifer	87	45.7	68.1	705.8	3 110.0	1.4	0.0	14.1	115.1	0.5	61.7	820.9
		Gas Field	478	272.7	287.5	3 606.2	18 035.0	7.3	68.4	57.0	187.7	17.7	354.6	3 862.4
		Oil Field	34	18.2	13.8	328.8	1 266.0	0.3	0.0	1.5	0.0	0.0	20.0	328.8
		Rock Cavern	2	0.1	0.0	7.0	6.0	0.0	0.0	0.0	0.0	0.2	0.3	7.0
		Salt Cavern	91	22.2	8.1	984.6	589.0	7.2	0.0	30.0	249.9	3.6	62.9	1 234.5
		Total	**693**	**358.8**	**377.5**	**5 633.4**	**23 007.0**	**16.1**	**68.4**	**102.5**	**552.7**	**22.0**	**499.4**	**6 254.5**

Appendix SG2.1_2 Summary by regions

6.8 Appendix SG2.1_3 The UGS Glossary

UGS Glossary – English

Glossary of relevant technical Underground Gas Storage Terminology

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. All of this 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: Pore storage - 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 related to any existing storage facility
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 a 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/or injected gas volumes

Term	Definition
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 an UGS, based on the installed subsurface and surface facilities and technical limitations
Withdrawal Profile	Dependency between the withdrawal rate and the 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, the working gas volume can be withdrawn 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 in the storage reservoir or cavern the working gas volume is nearly withdrawn, i.e. at or close to its cushion gas volume
Injection Rate	Flow rate at which gas can be injected into

Term	Definition
	an UGS, based on the installed subsurface and surface facilities and technical limitations
Injection Profile	Dependency between the injection rate and the 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 turn over cycles of the working gas volume, which can be achieved by withdrawal and injection in one year
Undeveloped Storage Capacities	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, compressors, process facilities) 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 is the outcome of geological/technical engineering and has to ensure the integrity of the UGS. The maximum allowable pressure is related to a datum depth and normally has to be

Term	Definition
	approved by authorities
Pressure Datum Depth	Vertical reference depth in a pore storage, normally related to the sea level, used for pressure normalisation and correlation throughout the reservoir. In caverns the vertical depth below surface of the last cemented casing shoe is normally used as the reference level for pressures
Caprock of a Pore Storage	Sealing formation for gas overlying the pore storage horizon. Caprock is a geological barrier of the pore storage and 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 saturation contact extent. The boundary is normally defined by the gas water contact
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
Normal conditions- Gas volumes are related to temperatures and pressures at normal conditions: 273.15 K (0°C) and 1.01325 bar (1.013 10^{-5} Pa)	

Appendix SG2.1_3 The UGS Glossary

6.9 Appendix SG2.1_ 4 Germany

General

Natural gas, as the second important source of energy behind oil (33.6%), provides about 22% of the total primary energy. The natural gas consumption increased by 4% in 2010 to some 96.4 bcm. The significant increases of gas consumption from previous years cannot be observed any more. Further impacts can be expected from renewable energies.

Energy Sources	Share in %	
	2009	2010
Oil	34.8	33.6
Natural Gas	21.6	21.8
Coal	10.9	12.1
Lignite	11.2	10.7
Nuclear	11.0	10.9
Renewables	10.2	10.9

Table 5 Energy sources in Germany

Despite some indigenous production, which is still of great importance, some 85% of the gas consumption has to be imported.

Several sources contribute to the supply of gas according to the following shares:

Country	Share in %	
	2009	2010
Germany	15	14
Netherlands	16	21
Norway	30	28
Russia	33	32
Denmark and United Kingdom	6	5

Table 6 Gas supply

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 as the first UGS developments originate back to the 50-ties.

In Germany, 47 underground gas storage facilities, operated by some 23 companies, provide according to LBEG (mining authority) Jahresbericht Erdöl und Erdgas in der Bundesrepublik Deutschland 2010 21.3 bcm of installed working gas volume @ 31/12/2010 as shown in the following table:

		Pore Storage	Caverns	Total
Total installed working gas volume of UGS in operation (bcm)	1.	12.1	9.2	21.3
Total peak withdrawal rate in operation mcm/d		199.0	316.2	515.2
Number of storages in operation		23	24	47
Total working gas volume from planned storage projects extension of existing UGS and Greenfield UGS (bcm)	2.	1.0	10.3	11.3
Expected total max. working gas volume storage facilities in operation and planned (bcm) (1.+ 2.)	3.	13.7	20.1	33.8

Table 7 Pore storages vs caverns in Germany

Reported new storage capacities are mainly developed in salt cavern facilities. In addition some new developments in aquifer facilities are under consideration.

In total the working gas volume capacity would increase to some 34 bcm in case all projects would be developed.

In the following Figure 54[1], the development of working gas volume (bcm) since the beginning of UGS operation in Germany is shown.

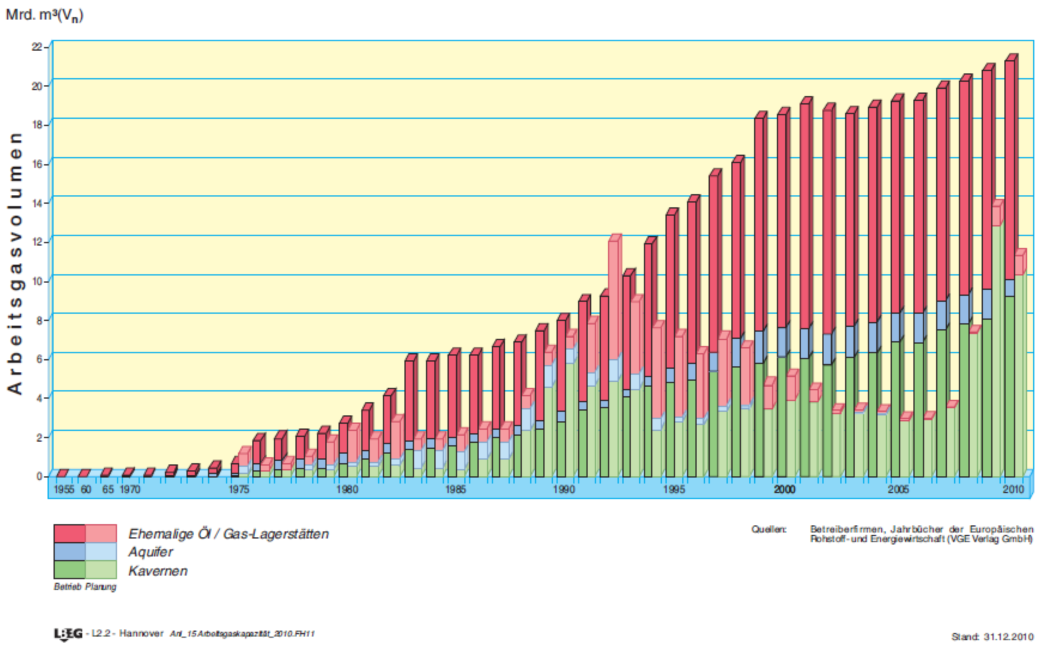


Figure 54 Development of WGV in Germany

Since 1990 the existing working gas volume has more than doubled. About 22% of the total gas consumption is available in UGS facilities. A further increase of installed storage capacities can be expected based on the UGS projects under development. In the future, a further increase of the existing competition in the storage business can be expected.

The location of the German storage facilities is presented in the Figure 55 [2]:

[1] LBEG Jahresbericht Erdöl und Erdgas in der Bundesrepublik Deutschland 2010
[2] LBEG Jahresbericht Erdöl und Erdgas in der Bundesrepublik Deutschland 2010

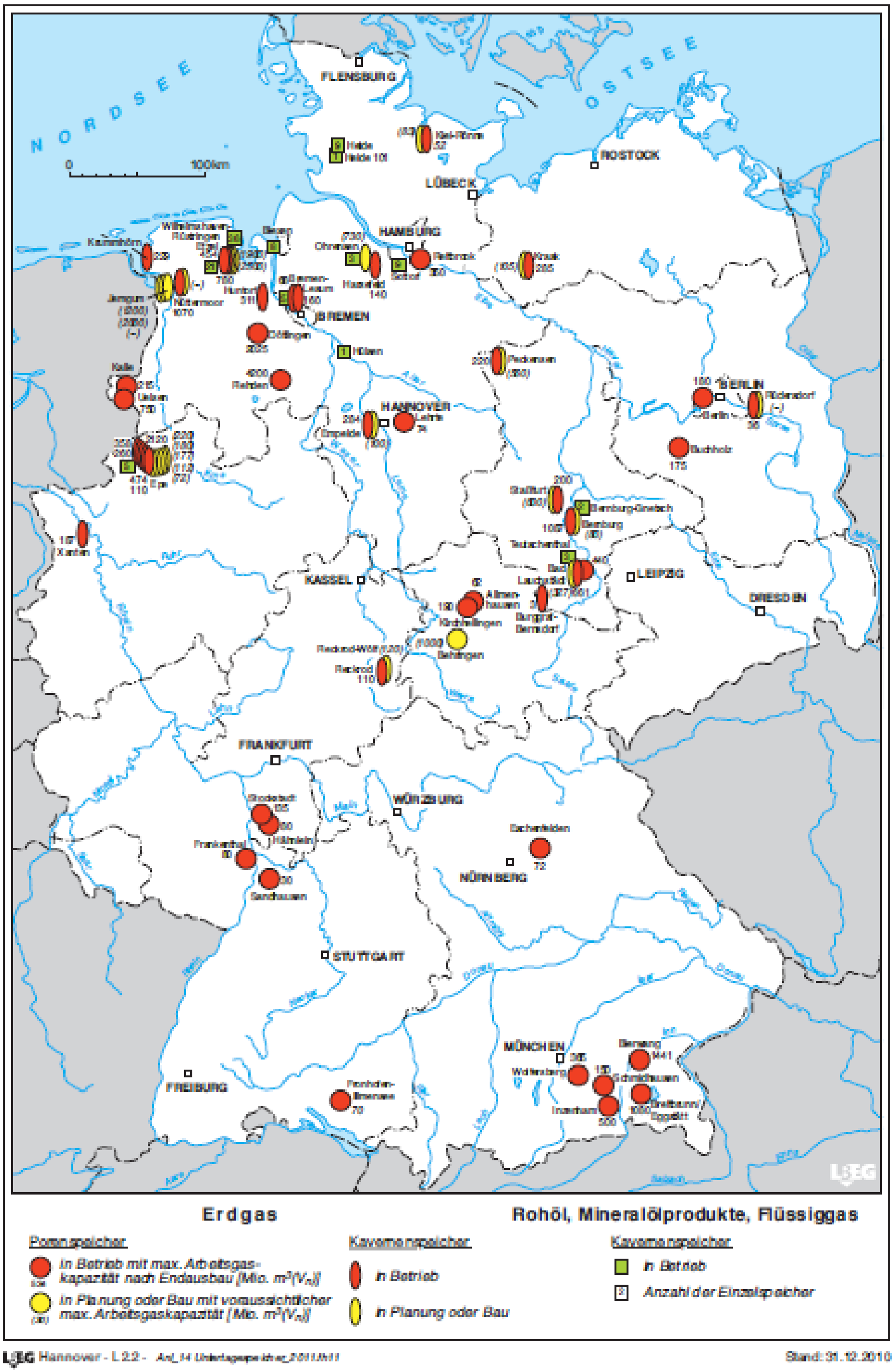


Figure 55 Locations of German storage facilities

Due to favourable geological conditions in North Germany sufficient additional storage volume can be developed in salt rock (only in N Germany) and porous rock mainly in depleted hydrocarbon reservoirs 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, 43% in Germany compares to 5% in the world. Concerning storages in gas fields only 51% of the total WGV is stored in this UGS type compared to 78% in the world.

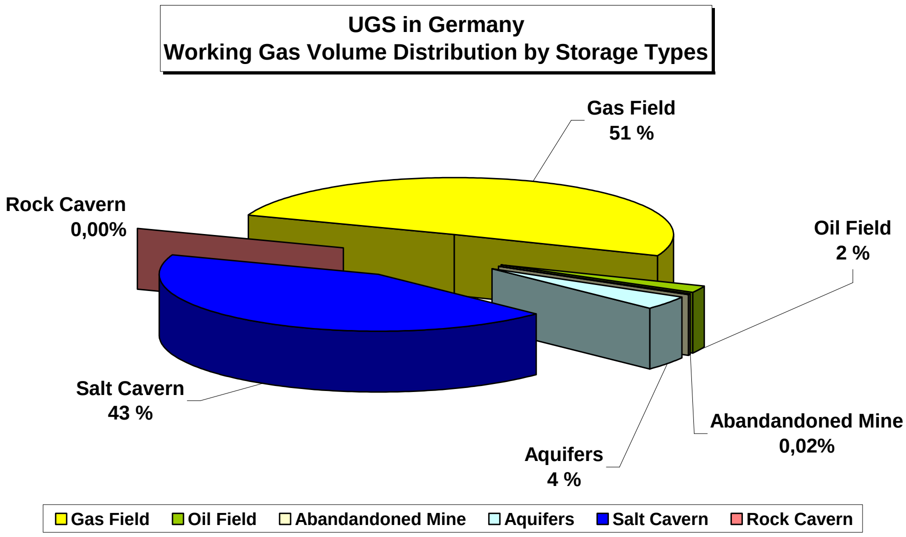


Figure 56 WGV distribution by storage types (Germany)

The storage market cannot be looked at as a national market. Storage capacities are marketed as well on an international scale. The Austrian UGS Haidach and UGS 7 Fields for example are connected to Germany only and provide 3.8 bcm in addition to the German market.

Legal

Some of the German storage companies are involved in the domestic E&P business 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 a pore storage facility. New applications for storage permission ("Betriebsplanantrag") are required independently 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").

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 their systems according to the requirements already in force.

The regulatory authority – the Bundesnetzagentur (BNA) – monitors and guides 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 degree of fulfilment of all requirements has been monitored by corresponding European and national inquiries (EU Commission, ERGEG, BNA). Despite all new complex developments, including requirements of infrastructure modifications, the degree of an accomplishment is quite satisfactory in Germany.

The 3rd EU legislative Energy Package is transferred into national law.

Technology:
Due to favourable geological conditions (overburden rocks) higher storage pressures than initial ones are operated in some UGS based on the required studies and approvals. 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 3D seismic surveys, followed by comprehensive 3D modelling and simulation of the storage dynamics. Most of the UGS are equipped with subsurface safety valves (SSSV).

The trend to leach a higher geometrical volume in salt caverns up to 1.1 mcm, in the case of favourable geology, shape and rock mechanics has allowed for this enlargement, thus reducing specific investment.

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

Operational models which include cavern operation as well as rock mechanical and thermodynamic modules and related operational limits for the operational window are implemented.

6.10 Appendix SG2.1_5 Spain

In 2010, the proportion of total Spanish energy consumption accounted for by natural gas is currently around 420.109 kWh. This represents 24% of the total primary energy demand and 17%, of the final energy demand. More than 7,000,000 clients, 25,220 MW installed in power generation (combined cycles) and 6,000 MW in co-generation are figures which show the importance of the gas sector.

According to a study by Energy Markets International (EMI), the gas industry's economic impact exceeds 8,500 million Euros, with investments over 11,000 million Euros, during the last decade. The ability to generate employment has reached 90,000 jobs, bearing in mind those covered by installers. In 2010, we witnessed natural gas consumption being maintained when compared to the previous fiscal year. In fact, there was a 10% increase on conventional demand, that is, within the industrial, commercial and domestic sectors. In contrast, the demand for gas in power stations decreased due to heightened hydraulicity and more electricity generation stemming from renewable sources. However, natural gas continues to be the main source of electricity generation in Spain, followed by nuclear energy, wind energy and hydropower. Spain positions itself as one of the European countries with the most diversified natural gas production. LNG has played a key in these results, enabling 76% of the gas that reaches our shores.

Enagás was appointed the Technical System Operator of Gas System pursuant to Royal Decree Law 6/2000 of June 23rd. Its core remits in this role include guaranteeing continuity and security of supply and efficient coordination between access points, storage facilities and distribution network.

UNDERGROUND NATURAL GAS STORAGE IN SPAIN
There are two underground gas storage facilities in Spain. Enagás manages both of them: those at Serrablo and Gaviota, natural gas fields which have been depleted. The Serrablo underground gas storage is located between the towns of Jaca and Sabiñánigo (Huesca). Gaviota is an "off-shore" underground gas storage located near Bermeo (Vizcaya).

Serrablo
Serrablo gas storage facility is located within the Huesca region, between the cities of Sabiñánigo and Jaca. Serrablo was the first depleted gas field transformed into an underground gas storage in Spain, once the field production ceased in February 1989. From 1978 to 1983, ENIEPSA (today Repsol-YPF) drilled 14 wells and two gas reservoirs were discovered: Aurin & Jaca, both of them set up Serrablo Field. Gas storage set up first phase comprised a revamping of the surface facilities to increase its treatment capacity, new compression units and a new well drilled in the Aurin reservoir. In a second phase, a new revamping of the surface facilities was performed, sidetracks were drilled in some wells and an additional well was drilled in the Jaca formation.

Serrablo main figures appear in the following table:

WGV (mcm)	**680**
Cushion gas (mcm)	**420**
Max.injection rate (mcm/d)	**3.8**
Max. production rate (mcm/d)	**6.8**

Table 8 Parametres of Serrablo UGS

Gaviota

The Gaviota storage facility is located in the Bay of Biscay, 8 km. off Cape Matxitxako, north east of Bermeo (Biscay). The storage facility is in a depleted gas field covering a surface area of 64 km^2. It is located at a depth of 2,150 m in fractured limestone from the Upper Cretaceous. The Gaviota storage facility is accessed from a platform anchored to the seabed with 20 pylons and connected by a gas pipeline to an onshore processing plant. History of the storage facility is summarised in the following stages:

- 1976: First exploratory survey and discovery of the Gaviota Field
- 1980: Feasibility studies confirming the possibility of commercial exploitation
- 1982/1983: Gaviota I and II operating concessions awarded until 2013
- 1983: Start of construction of the platform and onshore installations. Lying on the pipelines joining the two facilities.
- 1986: First commercial output of gas
- 1994: Gaviota opened as underground storage facility after production ceases and necessary adaptation is complete.

Gaviota main figures appear in the following table:

WGV (mcm)	**979**
Cushion gas (mcm)	**1700**
Max. injection rate (mcm/d)	**4.5**
Max. production rate (mcm/d)	**5.7**

Table 9 Parameters of Gaviota UGS

NEW GAS STORAGES UNDER CONSTRUCTION IN SPAIN

During the last two years new underground gas storages facilities have been under construction Yela & Castor Project.

Yela Project:

Yela will be the first underground gas storage located in an aquifer formation in Spain. Yela is located in Brihuega around 100 km to NE from Madrid. NE/SW Elongated Anticline Structure, bounded on the SE flank by a low angle reverse Fault dipping NW.

During the years 2009-2011 the 11 wells needs to construct the Yela storage facilities were drilled. In 2009 and 2010 the 17-1/2” and 12-1/4” stages were completed, including drilling, pipe laying and cementing as far as top structure and reservoir section. In December 2010 started the last stage of the drilling section hollowing the reservoir section and it was completed in the 2nd quarter 2011. Work also been completed on reconditioning the wells drilled in the previous years for monitoring. Surface facilities contraction is at the final stage. Yela will start the operation in the first quarter 2012.

Yela main figures appear in the following table:

WGV (mcm)	**1050**
Cushion gas (mcm)	**950**
Max. injection rate (mcm/d)	**10**
Max. production rate (mcm/d)	**15**

Table 10 Parameters of Yela UGS

Castor Project:
Castor has been developed in an offshore depleted oil field (Amposta) exploited by Shell during the 70´s and 80´s. This facility is 21 km from the coast and the water layer is around 60 m.
This future gas storage facility, the Castor Project, will have storage capacity of 1.3 bcm and will begin operating in mid-2012. Offshore platform construction started in September 2009. In August 2010 commenced development wells drilling operations. Onshore plant construction started in March 2010. Process platform and auxiliary modules set up in November 2011. Castor will be in operation in May 2012.

Castor main figures appear in the following table

WGV (mcm)	**1300**
Cushion gas (mcm)	**600**
Max.injection rate (mcm/d)	**8**
Max. production rate (mcm/d)	**25**

THE TRENDS IN THE UGS BUSINESS IN SPAIN
On the legal point of view, activity of underground storage of gas is submitted to specific rules and laws. Gas storage is a regulated activity in Spain.

Spanish law distinguishes between regulated activities, which include transportation (regasification of LNG, underground storage and transportation of natural gas) and distribution; and non-regulated activities, which include production and supply. Any company engaging in a regulated activity must engage in only one regulated activity. However, a group of companies may conduct unrelated activities, provided that different companies within the group engage in each regulated activity (both corporate and financial unbundling are required).

Tariffs and tolls related to third parties access to UGS facilities are published yearly.

The Regulation (EC) No 715/2009 of the European Parliament and Council, states that "transmission system operators, LNG and underground storage facilities will take all reasonable steps in order to allow the free exchange of capacity rights and to facilitate this exchange in a transparent and non-discriminatory way". According to what is specified in that regulation, Enagás offers consumers a tool to facilitate the exchange of contracted capacity at its facilities. Through this site interested parties can submit capacity offers and request for capacity in the secondary market.
Regulatory framework, Main rules and laws applied to UGS activities in Spain, are summarised as follow:

- Law 34/1998, October 7th, Hydrocarbons sector which establishes the general basis, principles and model of organization of the exploration, transmission, distribution and commercialization of hydrocarbons.
- Royal Decree 949/2001, August 3rd, which regulates the third parties access to gas facilities and establishes the integrated economic system for the natural gas sector.
- Order ITC/3862/2007, December 28th, which establishes the mechanism of assignment of the capacity of natural gas storages and creates a capacity market (BOE 22.02.2008)

6.11 Appendix SG2.1_6 Denmark

General:
Denmark, Sweden and part of Nord Germany has since the beginning of the 1980- ties been supplied with natural Gas from the Danish part of the North See through two direct transmission lines to Denmark. The production is now declining in the Danish sector and its means that Denmark in the coming years starts import of natural gas from Russia, Norway and other countries but transported through Germany.

The natural gas consumption in Denmark is going down with a few %/year and one of the reasons is that the use of biomasses is growing.

Legal:
The third EU liberalisation package has been approved and its means that its now is law in all 27 EU countries. It also means more competition between storages and lower prices for customers.

Environmental:
Both Danish Storages have project for increasing storage capacity but it is very difficult to get permission from the authorities. The cavern storage in Lille Torup has just got permission to releaching the exiting seven caverns for necessary maintenance but not for increasing the storage capacity with new caverns.

Technical:
The Danish TSO Company Energinet.dk is at the moment building a new compressor station and pipeline between Ellund (border to Germany) and Egtved. Both installations will be ready for operation in 2013 and it is the first time pipeline compressors will be installed and into operation in Denmark.

6.12 Appendix SG2.1_7 France

UNDERGROUND NATURAL GAS STORAGE IN FRANCE

In 2011 there are 15 underground gas storage facilities in France, comprising:

- 11 facilities located in aquifer layers
- 3 facilities located in salt cavities
- 1 facility in a depleted gas field

They represent a total working volume of 12.6 bcm and include one L-gas facility (Gournay) located in an aquifer formation whose capacity accounts for approximately 10% of total working gas volume.

Twelve facilities are owned by Storengy (77% of total storage capacity), two by TIGF (21% of total storage capacity) and one by Geomethane (2% of total storage capacity).

TIGF (Total Infrastructures Gaz France), subsidiary of Total, has been created in January 2005 to operate the storage activities and transmission infrastructures of Total in the Southwest of France.

Storengy is a company of GDF SUEZ founded on 1st January 2009 as a legally distinct entity dedicated to underground natural gas storage activities.

UGS facilities are pooled and marketed by different storage groups and products depending on the geographical position and physical characteristics of the facilities as well as gas quality. The products offered take into account the physical constraints of access to storage. Each year, the utilization rules regarding injection and withdrawal rates, or inventory are reviewed and defined in the storage access contract.

OPERATORS	PRODUCTS / SERVICES	STORAGES	TYPE	CAPACITY
Storengy	Sediane Littoral, Serene Sud, Sediane Sud	Soings-en-Sologne, Céré-la-Ronde, Chémery	Aquifer	4.5 bcm
	Serene Nord, Serene Nord 30/30, 60/60, 90/90, 120/120,	St-Clair-sur-Epte, Germigny-sous-Coulombs, Cerville, Trois Fontaines	Aquifer	2.1 bcm
	Sediane	Beynes, St-Illiers-la-Ville	Aquifer	1.2 bcm
	Sediane B	Gournay-sur-Aronde (L gas)	Aquifer	1.3 bcm
	Saline	Etrez, Tersanne	Salt Caverns	0.75 bcm
Géométhane	Saline	Manosque	Salt Caverns	0.27 bcm
TIGF	Dynamic Service, Balanced Service	Lussagnet	Aquifer	1.1 bcm
		Izaute	Aquifer	1.4 bcm
France Total Storage Capacity				12.6 bcm

Table 11 UGS in France (June 2011)

The commercial offers of French storage operators are published on their web sites (www.storengy.com ; www.tigf.fr). As regards Manosque (Geomethane), this facility is operated by Storengy and its capacity is marketed by Storengy in the Saline product.The commercial products of the French storage operators are regularly reviewed and adjusted to be able to best respond to market needs.

Each storage group is connected to a transmission network through an Interconnection Point and associated with a balancing zone. At present there are 3 balancing zones in France: North Zone, South Zone and South-West Zone (or: PEG Nord, PEG Sud and TIGF, respectively).

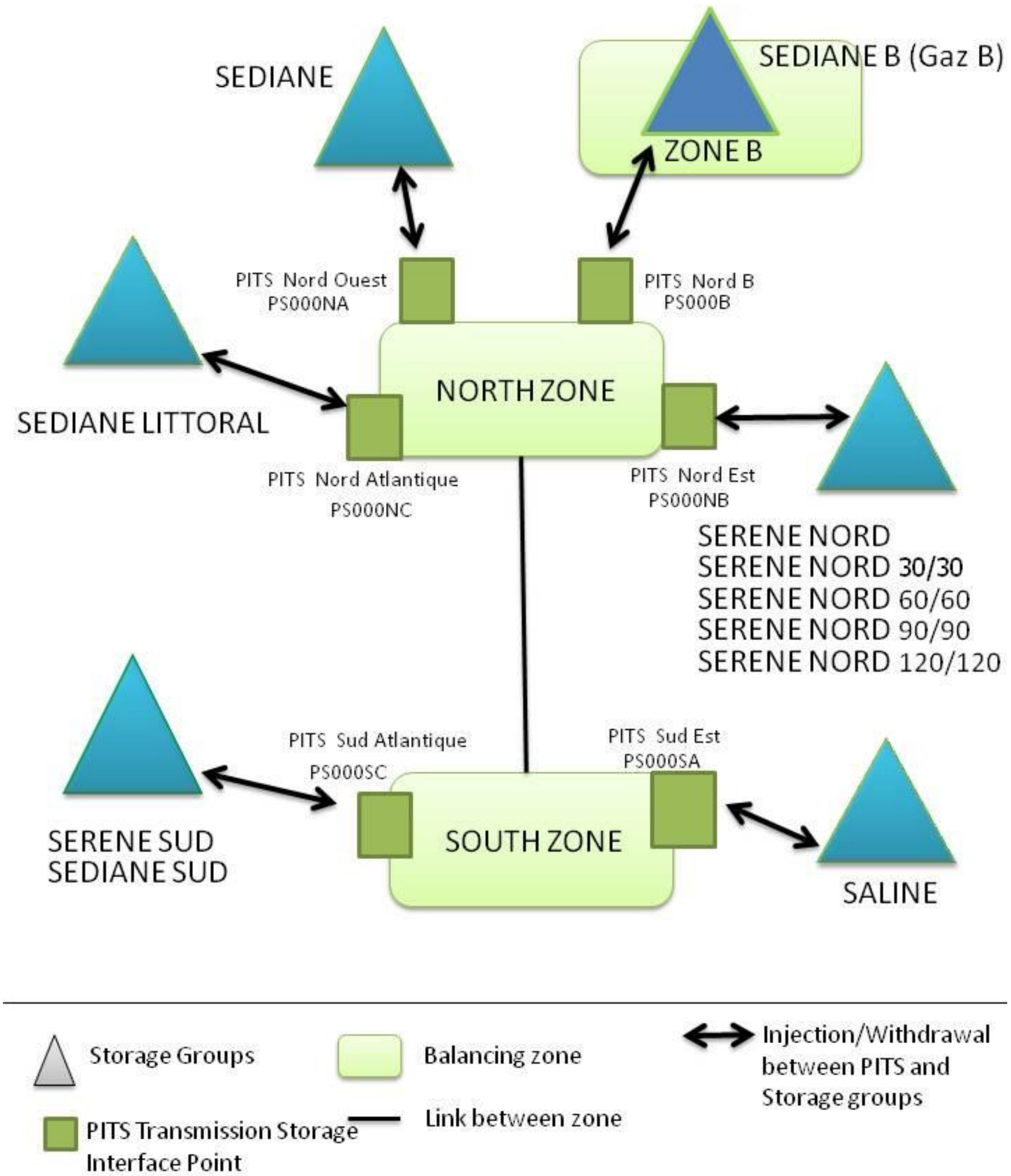


Figure 57 Storengy storage groups and associated products (2011-2012)

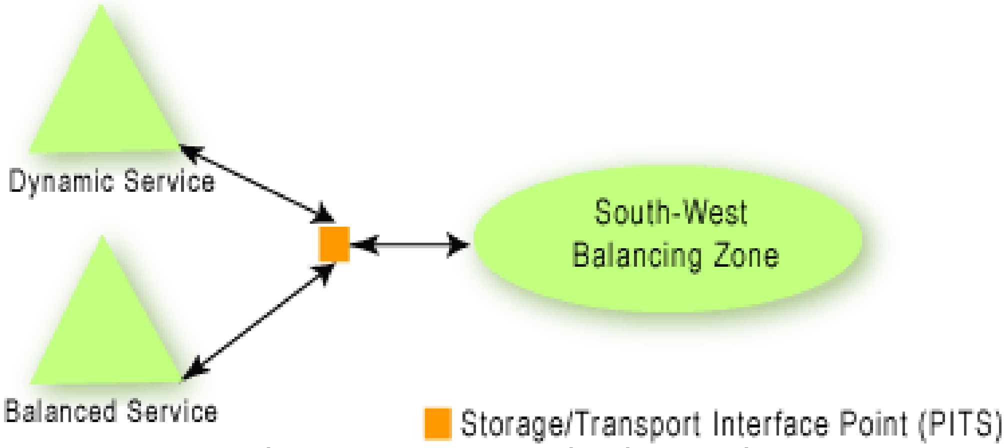


Figure 58 TIGF storage services (2011-2012)

Legal aspects

Regulatory framework:
The Second European Gas Directive 2003/55 introduced an obligation to provide third-party access (TPA) to storage where technically and/or economically necessary for the supply of customers. The directive left to Member States the choice between “regulated” and “negotiated” access regime to storage. In France, it was transposed by the law no. 2004-803 of 9th August 2004 which introduced negotiated TPA on a transparent and non-discriminatory basis to all storage facilities/group of storage facilities.

Following the adoption of the so-called Third Energy Package, in 2009, a number of storage-related provisions have been included in the new amended Gas Directive 2009/73 (the so-called Third Gas Directive) as well as the Gas Regulation 715/2009.

The Third Gas Directive provides for the legal separation of storage operators. It maintains the possibility to choose between negotiated and regulated access to storage although the applicable regime will depend on the criteria defined by Member States or by national regulations when the directive is transposed into national law. The Gas Regulation incorporates the previously voluntary Guidelines for Good Practice for Gas Storage System Operators (GGPSSO) making them legally binding. As a result, the regulation contains provisions relating to TPA access to storage, capacity allocation and congestion management as well as transparency and secondary markets.

In France the Third Energy Package provisions are transposed by the Ordinance no. 2011-504 of 9th May 2011. As regards the Third Gas Directive, the Ordinance confirms the requirement of transparency and non-discrimination and maintains a negotiated access to storage. As regards the Gas Regulation, its provisions are directly applicable and do not require a transposition into the national law. The Gas Regulation has entered into force on 3rd March 2011.

Beyond the requirements stemming from the Third Package, the organization of access to storage in France is further defined by the national law through the decree no. 2006-1034 of 21 August 2006. In accordance with the decree, storage capacity is allocated based on the "capacity goes with the customer" principle (customer based allocation). In line with this principle, whenever a customer switches to a new supplier, this new supplier gets the storage capacity rights related to the customer.

Health, Safety and Environment:
The safety rules applicable to UGS facilities in France comply with the "Seveso 2" directive.

The main applicable texts in the area of health, safety and environment 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 the 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)
- "CO_2 quotas" directive
- other directives, concerning wastes for example, as electric equipment

Moreover, a number of national environmental legal provisions apply to UGS facilities:
- general environmental regulation on air, water and wastes
- specific regulation for industrial "risky" facilities: those facilities are subject to an administrative authorization or declaration before the start of exploitation.

The storage facilities are therefore subject to operating authorizations (law of July 1976).

From an environmental point of view, important efforts have been made to develop integrated management systems for environment protection. The implementation of environmental management system is made on a voluntary basis based on the 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 an international certificate when EMAS allows to be registered on a list held by the European commission.

All Storengy UGS facilities are ISO 14001 certified since 2006.

New developments
In order to respond to the growing market needs, French storage operators develop and optimise their facilities on a continuous basis. Some development or exploration works are also carried out to find possible new storage sites in salt or aquifer layers.

Several storage sites are undergoing comprehensive revamping works, for example Beynes, Saint-Clair, Saint-Illiers and Tersanne. These revamping works are focused on:
- compressors, in order to reduce NOx and CO_2 emissions,
- gas treatment facilities, in order to secure performance,
- wells, in order to maintain reliability and performance.

In 2010 and subsequently in 2011, a new facility was put into operation by Storengy at Trois Fontaines near Saint-Dizier, in the Haute-Marne region. This new storage was developed in a depleted gas field.

Another new Storengy facility is in the final phase of construction. It is located in Hauterives in the Northern part of the Drôme region, at about 20 km from Romans-sur-Isère. The project involves creation of two caverns with a possibility of extension in a later stage.

TIGF is currently increasing capacities of Lussagnet. To be carried out over a ten-year period, this project plans gradual replacement of the injection/withdrawal wells with wells with a larger diameter, installation of new compressors and the construction of new facilities for processing withdrawn gas.

Pécorade is a TIGF project in a depleted oil field near Mont-de-Marsan in the Landes region. This project could bring a working gas volume around 0.750 bcm.

The development of Manosque by Geomethane is also ongoing with the creation in progress of two new caverns and the extension of the existing surface installations.

A new salt cavern facility is also under study by EDF near Dax in the Landes region. The exploration permit was granted in July 2009 and a first well was drilled in 2010.

The future storage development in France will depend on the gas market development as well as the stability and predictability of the regulatory environment.

6.13 Appendix SG2.1_8 The USA

There are over 100 natural gas storage operators in the United States, with over 400 active underground storage facilities in 30 states. These facilities have an estimated maximum working storage capacity of 4,300 Bcf (1 cf = 0.028cm) of natural gas, and the capability of maximum daily deliverability of 90 Bcf per day. US storage operators manage about 14,500 injection/withdrawal wells of which about 235 are horizontal. The industry also operates about 2,900 pressure control or observation wells.

Published reports indicate that there are 13 natural gas operators in Canada, with over 50 underground storage facilities in 5 provinces. These facilities have an estimated maximum working storage capacity of over 630 Bcf of natural gas, and the capability of maximum daily deliverability of 7 Bcf per day. Canadian storage operators manage approximately 600 injection/withdrawal wells of which about 40 are horizontal. The industry also operates about 140 pressure control or observation wells.

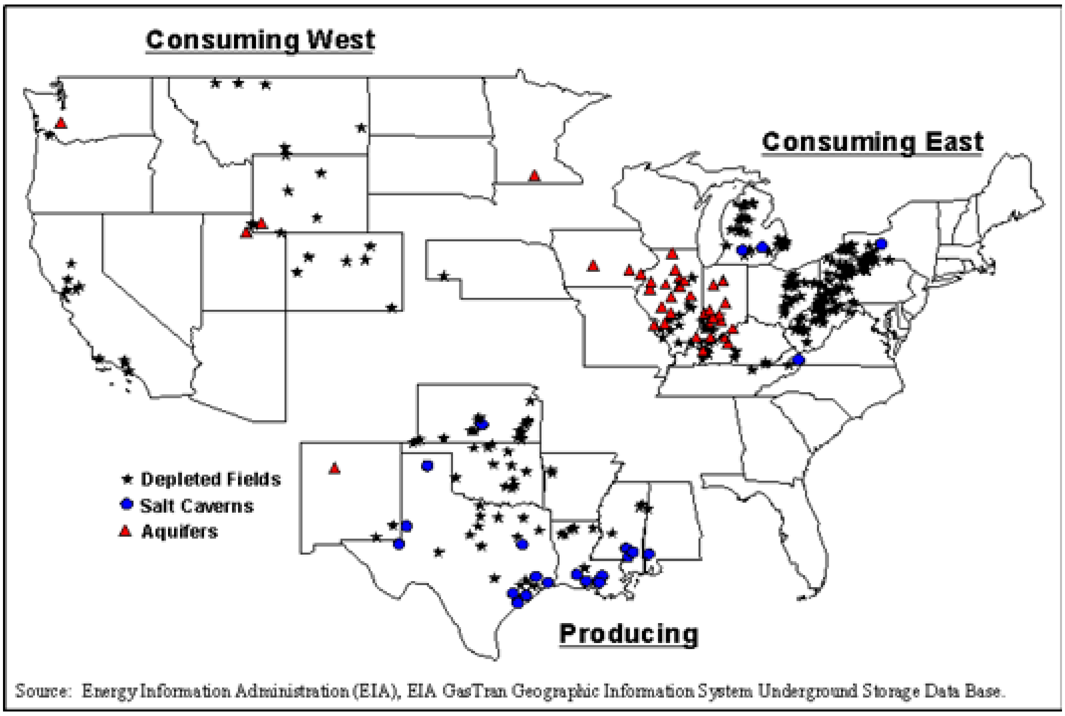
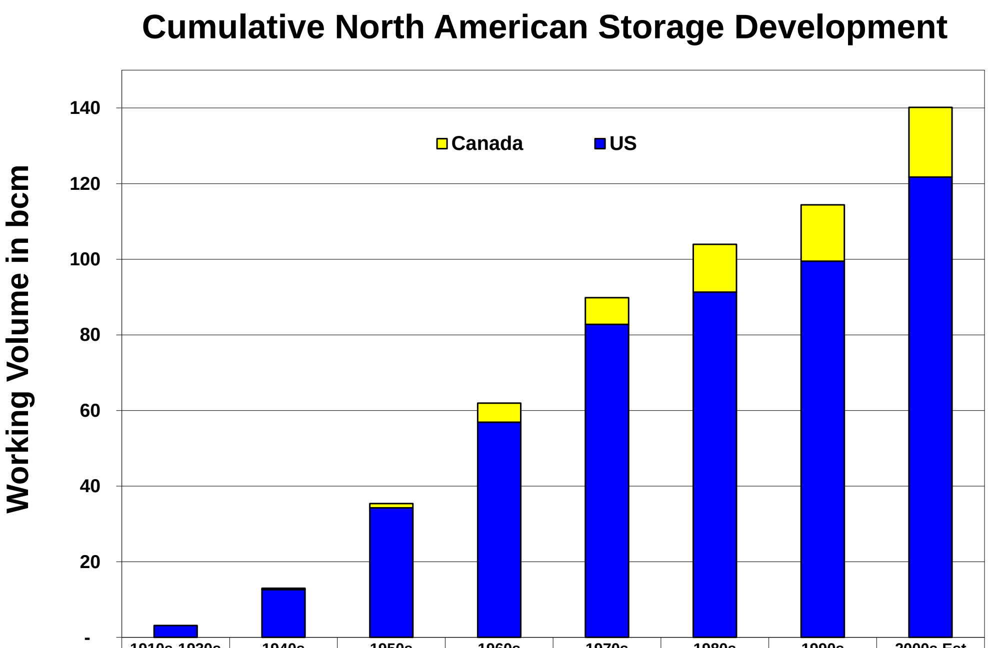


Figure 59 Underground natural gas storage facilities in the lower 48 states

The first instance of successfully storing natural gas underground in North America 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



	1910s-1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s Est
Canada	0.0	0.4	1.1	5.0	7.0	12.6	14.9	18.4
US	3.1	12.7	34.3	56.9	82.8	91.3	99.5	121.8

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Figure 60 Cumulative North American storage development

The development of underground natural gas storage fields grew rapidly after World War II. (Figure 60). 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, was not possible. In order to be able to meet seasonal demand increases, underground storage fields were the only option.
The rate of growth in storage field development slowed in the 1990's as 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 non-discriminatory 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 centres. 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.

During the past 10 years it is estimated that working storage capacity has grown by about 800 Bcf. Primarily the growth has been in expanding and building new high deliverability salt caverns along the Gulf Coast region. Another economic approach has been to expand or convert cushion gas to working gas in existing depleted reservoirs and aquifers. This has been accomplished by drilling new wells, stimulating existing wells and adding new surface facilities. In general the development of significant new gas storage in depleted reservoirs is hindered by high acquisition costs and the cost of cushion or base gas.

This past year (2011) has seen a significant slowdown in new storage construction and expansion. Though many projects have been proposed and filed with FERC, construction has been delayed for a variety of economic reasons. The rapid development of shale oil and gas has brought US production to all time record levels. A recent slowdown in natural gas directed drilling has not yet slowed the growth in natural gas production. Some of this growth is associated with production in the shale that are high in liquid content. Associated gas is coming to market if there are available transport options. Natural gas is actually being flared in some locations, like North Dakota, where transport options are currently not available.

Several major pipelines have been completed over the past 5 years that have served to move stranded gas, primarily in the Rockies region, to market. The combination of record production and new pipelines has resulted in reducing gas prices to the lowest levels in 10 years and regional price spreads have been reduced significantly. In the short term, this has lowered the demand for new storage service and has left US national inventories at record levels. (See further discussion and charts below).

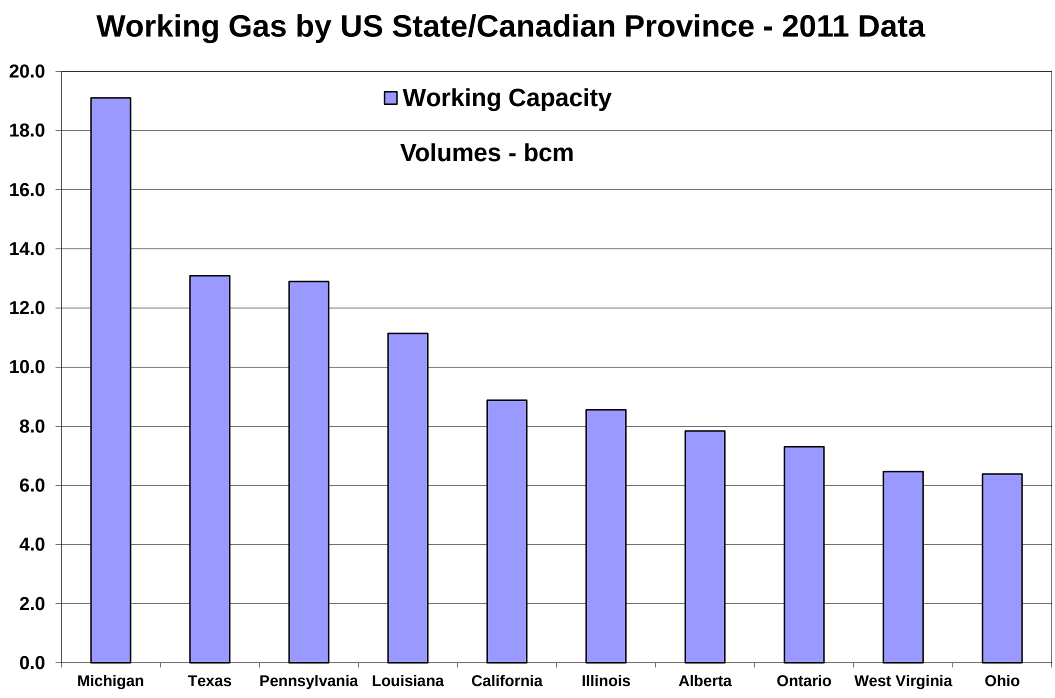

Figure 61 WG by the US State/Canadian province 2011

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 Midwestern US natural gas utility and pipeline companies during the rapid growth period of the 1950s to the 1970s.

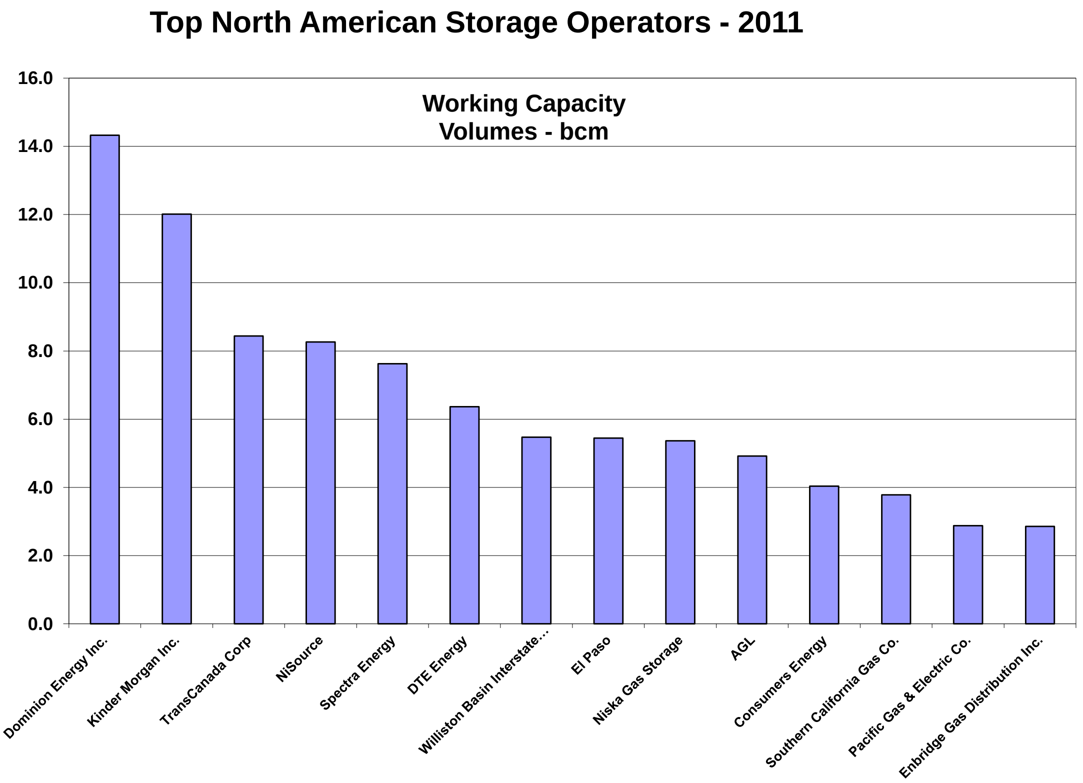

Figure 62 Top North American storage operators 2011

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 be 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 revenue 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.

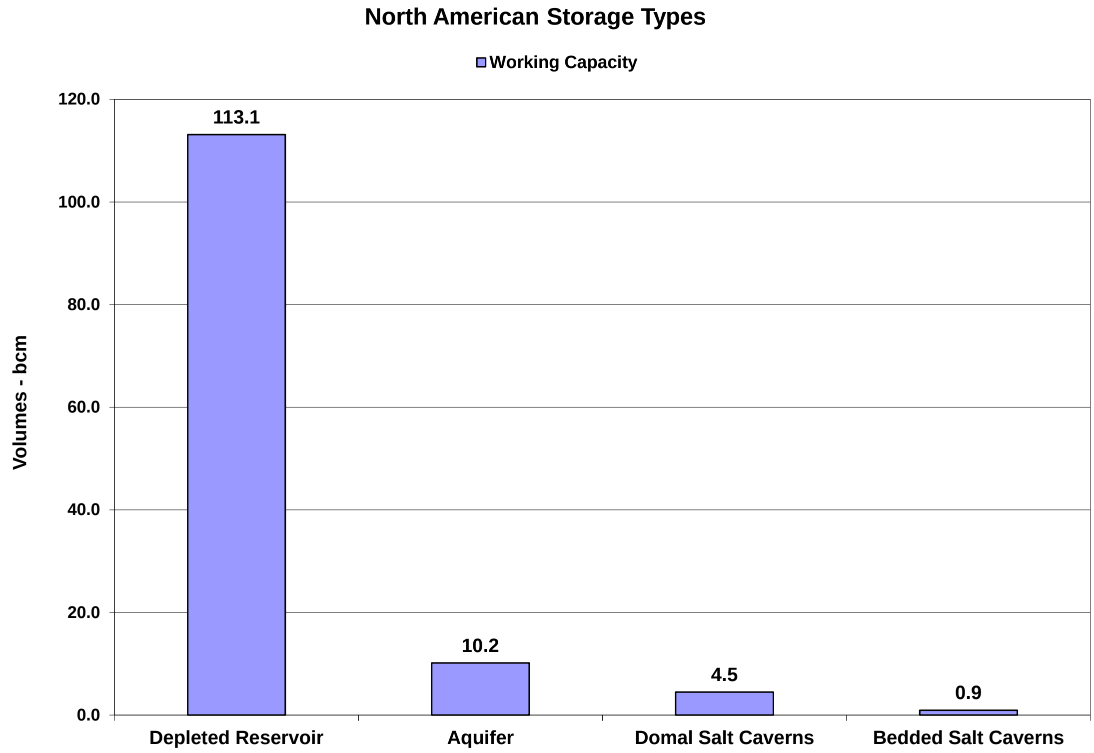

Figure 63 North American storage types

Most existing gas storage in the United States is in depleted natural gas or oil fields that are close to consumption centres. 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 overlain 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.

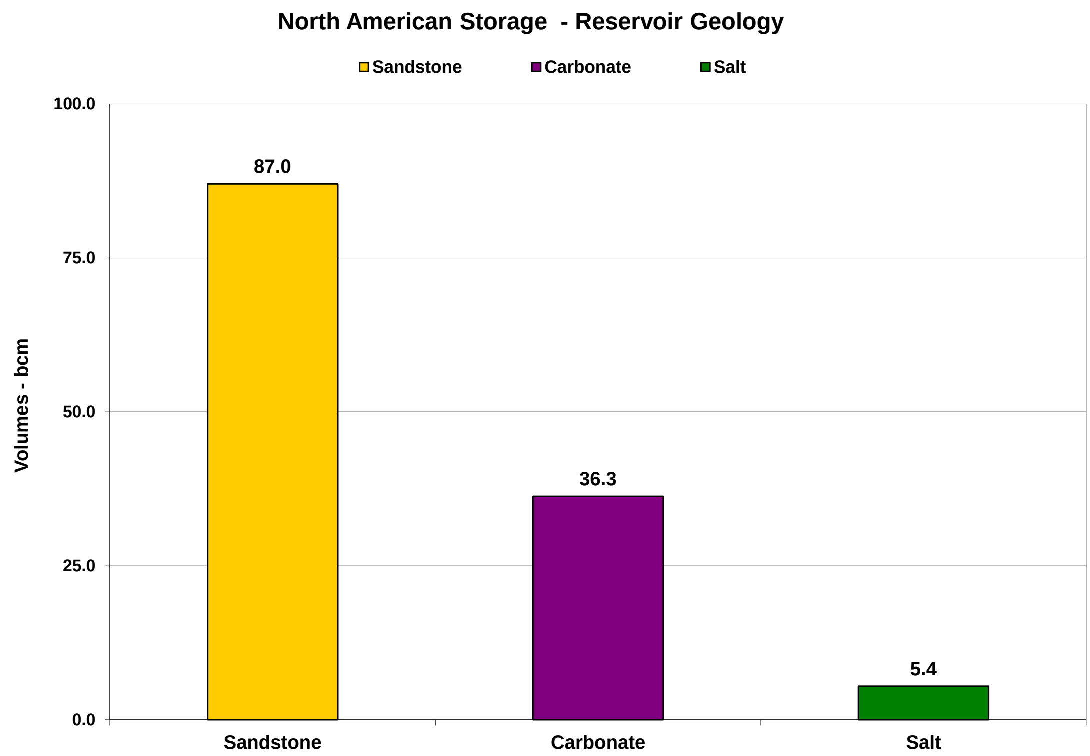

Figure 64 North American storage – reservoir geology

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.

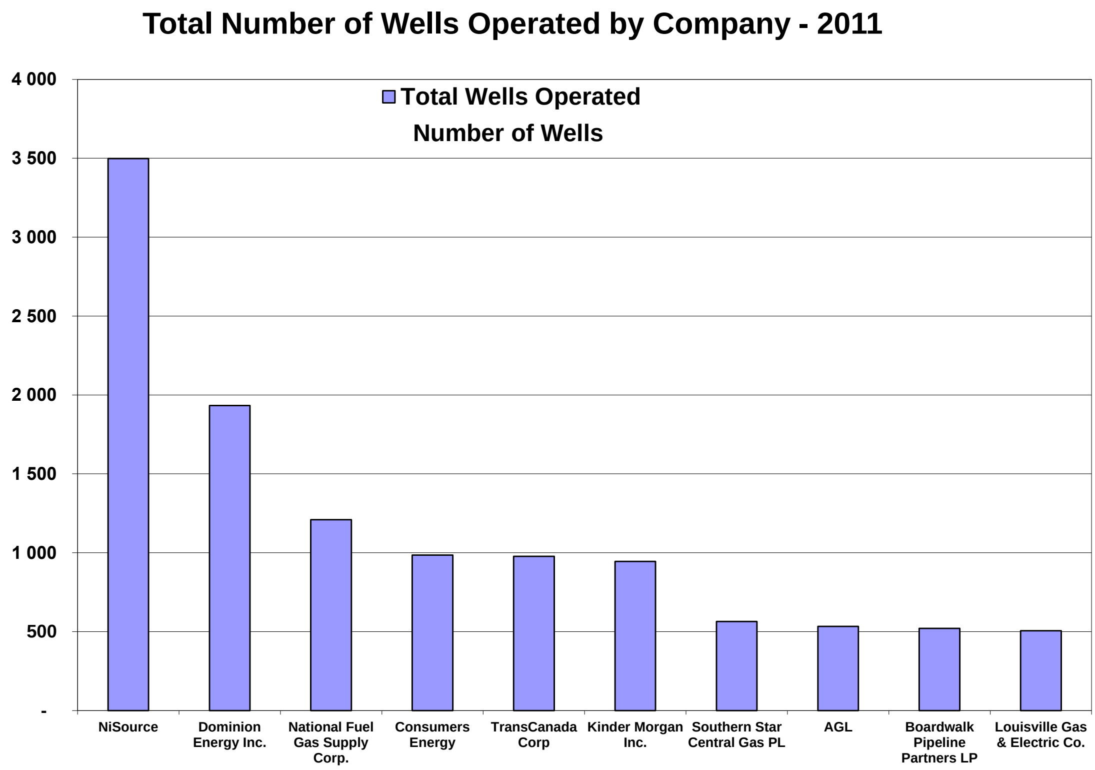

Figure 65 Total number of wells operated by company 2011

There are over 18,000 storage facility wells in North America, and some 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.

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 to be very successful in improving both capacity and deliverability. Many new storage projects and most of the expansion projects today use horizontal or deviated drilling technology to minimize the number of wells required, the amount surface acreage required and to limit the length of the gathering lines.

Overview of Current Storage Activity

The state of the US storage industry has changed considerably over the past 10 years, and the changes are accelerating due to the "shale technology revolution". This author, in presentation at the 2009 World Gas Conference, reviewed this revolution and suggested that this would delay the Alaskan gas pipeline and significantly reduce the need for imported LNG into the United States. Indeed, the Alaska pipeline has been delayed indefinitely and there is a strong possibility that the United States will be a net exporter of LNG in the next decade. The collapse of gas prices and significant reduction in regional price spreads has changed the storage industry. Gas storage is affected today more by financial drivers rather than the weather. As a result expanding capacity has been filled by marketers and left in the ground when pricing is more favourable in the supply market.

The recent history of US storage activity can be readily observed in the chart below. While significant expansion has occurred over the past 10 years, the actual amount of gas cycled has held steady at just over 2.0 Tcf (1 cf = 0.028cm) per season. This has resulted in higher inventories at the end of winter almost every year. This creates a challenge for storage engineers that are responsible for fields that must be cycled to minimize the impoundment of gas. The challenge will be even greater this coming year. A much warmer than normal winter, in addition to record production, will leave US storage inventories at the highest level ever seen at the end of the withdrawal season.

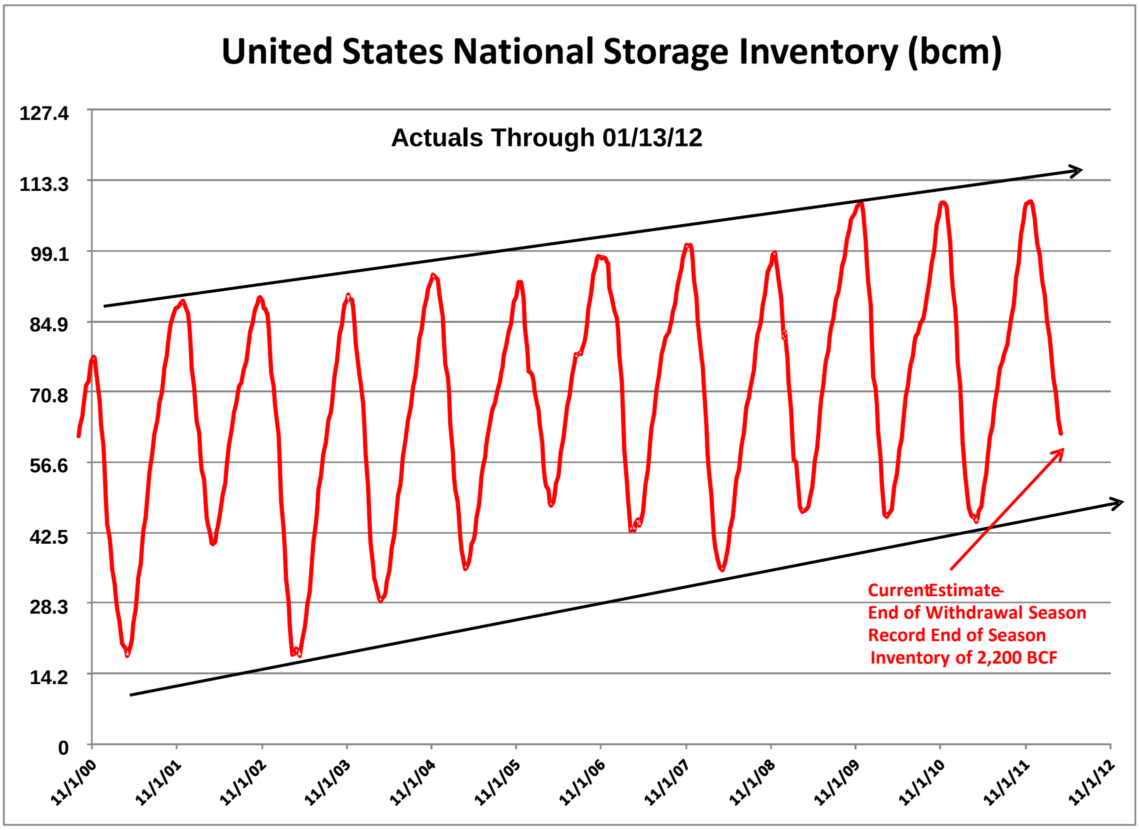

Figure 66 the US national storage inventory

*This report was prepared using information from the American Gas Association (AGA) and the United States Energy Information Administration (EIA) by Frederick W. Metzger; member of the IGU WOC 2.

6.14 Appendix SG2.1_9 Russia

Over 50 years in Russia was created the developed system of underground gas storage. The storage system in Russia is a part of the Gas Transmission System, and mainly provides the following functions:

- Regulation of seasonal fluctuations in gas supply in the country
- Provide consumers with additional volumes of gas upon the occurrence of cold winters
- Increasing mobility ESG with fluctuations in gas demand (market up)
- Ensure the reliability of export supplies of gas
- Long-term reservation of gas to ensure stable economic development in the case of the delayed start-up facilities for production and transportation of gas

Currently in Russia there are 25 underground gas storage facilities, of which eight were built in the aquifer structures and 17 - in depleted oil fields operated by Gazprom’s subsidiary Company “Gazprom UGS”.

Figure 67 Russian UGS facilities

The main owner of the gas storage system in Russia is "Gazprom". The total volume of gas storage facilities operating by "Gazprom" is 110 bcm, of which 65.2 bcm – working gas and 44.8 bcm - Long-term reserve. The maximum daily withdrawal rate at the beginning of the season -647.7 mcm/d.

The main Data of UGS in Russia as of January 01, 2010 shown in the Table 12:

	Aquifer	Oil/Gas Field	Salt Caverns	Total
Installed working gas volume (bcm)	13.9	50.1	-	64.0
Maximum withdrawal rate per day (mcm/day)	176.6	443.4	-	620
Number of storage in operation	8	17	-	25
Total working gas volume from planned storage projects extension of existing UGS and Greenfield UGS (bcm)	11.4	11.2	0.9	23.5
Expected total max. working gas volume storage facilities in operation and planned (bcm)	25.3	61.3	0.9	87.5

Table 12 Data of UGS in Russia

The projected growth in gas demand determines the need to continue the UGS business development. By 2020 Gazprom is going to increase the peak daily send-out of Russian UGS facilities to 1 bcm.

At present, Gazprom is constructing several UGS facilities in Russia:

- the Udmurtia reserving complex in an aquifer;
- the Kaliningradskoye UGS facility in salt caverns;
- the Volgogradskoye UGS facility in salt caverns;
- the Bednodemianovskoye UGS facility in aquifer.

Between 2012 and 2015 the Company is planning to initiate construction of, Novomoskovskoye and Shatrovskoye UGS facilities along with gas storages in the Republic of Tatarstan.

Gazprom will retrofit and expand some of the existing UGS facilities, namely Kasimovskoye, Kushchevskoye, Punginskoye, Sovkhoznoye and Stepnovskoye.

A wide scope of work is to be performed in Eastern Siberia and the Far East to find the formations suitable for constructing the underground facilities for natural gas and helium concentrate storage

6.15 Appendix SG2.1_10 Austria

General:
In the year 2010 Austria has imported 7.133 bcm, domestically produced 1.716 bcm and consumed 9.117 bcm. The difference covers own use for domestic production and movements from / into storage inventories.

Available working gas volumes in UGS and send out capacities increased in 2011 considerably to about 7.4 bcm and roughly 85 mcm/d. The split for the providers of the gas storage services are presently OMV Gas Storage 2.43 bcm and 30 mcm/d, RAG 1.2 bcm and 15 mcm/d. The remaining working gas volume is split to E.ON Gas Storage (EGS) 1.15 bcm, Wingas 0.9 bcm and Gazprom 1.8 bcm.

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.

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 2 new storages have been developed in the depleted gas field of Haidach as well as the UGS “7 Fields”, i.e. a certain number of different smaller reservoirs used as one UGS. These 2 UGS are connected only to Germany in Burghausen (at the moment). They are operated by RAG, but SSO’s are EGS, Wingas and Gazprom.

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 in operation.

Hence, OMV Gas Storage has worked out a feasibility study investigating a reservoir (Ebenthal) which is producing gas since 2008, located 10 km north of Baumgarten in about 2700 m depth with very high permeability. A volume of up to 1.8 bcm with very high deliverability is probable. The production will be stopped in 2016 and the field adopted for UGS mainly in context with the realization of Nabucco or another pipeline.

Marketing Policy:
The use of storage to balance the seasonal swing is still the basis for storage in Austria. 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.

Unbundled services are negotiated with customers. The results are tailor made products representing the true demand.

According to the recent poor situation on the storage market a trend can be observed where tariffs of products are connected to summer/winter spreads. A development to short term contracts is evident.

In order to deal with the legal requirements newly developed capacities are considered to be marketed primarily in auction or via an open season process.

Legal:
The gas law from 2011 governs as far as gas storage is concerned the following:

- Access to gas storage has to be granted to producers, traders and suppliers, registered in a EU country, 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 per cent 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

- New projects have to be marketed by auctions and/or open seasons

The GGPSSO (guidelines of good practice for storage system operators), introduced in 2005 by ERGEG (European Regulators Group for Electricity and Gas), are observed very clearly in Austria. They are similar to the Austrian Gas Law.

Construction and installations related to an UGS is regulated by the Austrian mining law 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 and 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 supervised by 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.

All projects realized during the last view years are equipped with compressors driven by E-motors. This is supposed to be worth also for projects in the future, if technical and economical applicable.

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 most suitable reservoirs and the optimum location for drillings in order to concentrate wells in clusters. Horizontal wells have been considered to supplement the existing vertical wells if it is feasible. Recent studies recommend increasing the diameter to 9 5/8”.

Injecting inert gas as cushion gas has been considered (mainly CO_2), but has not yet reached a status to be a viable solution.

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

6.16 Appendix SG2.1_11 The Netherlands

Background

The gas sector is very important for the Dutch economy. Natural gas revenues amount to around 10 billion euros per year. Half of all energy consumption in the Netherlands is based on natural gas, and the Netherlands is the largest natural gas producer in the European Union.

Main source of gas supply is the Groningen field, one of the ten largest gas fields in the world. There are also hundreds of small gas fields in the Netherlands and under the Dutch part of the continental shelf (offshore). The so-called “small fields policy” has successfully promoted exploration for and exploitation of these small fields.

The Groningen gas field is operated by NAM (50% Shell, 50% ExxonMobil) and has an expected ultimate gas recovery of approximately 2800 bcm, of which almost 65% has been produced to date. A 2 billion euros investment programme has been executed including a full facilities upgrade of the 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 mcm in one hour whilst it supplies a maximum of around 300 mcm/d capacity. The Groningen system is designed around a capacity failure criterion of 1 hour per 20 years.

Although gas reserves are diminishing the Netherlands can maintain this position until around 2025. Around that time the Netherlands will have changed from a net exporter to a net importer of gas.

Underground gas storage facilities have been constructed in order to be able to handle declining capacity of the Groningen field.

UGS

Currently there are four UGS facilities in the Netherlands, of which two are operated by NAM (Grijpskerk, Norg), one is operated by TAQA (Alkmaar) and one is operated by N.V.Nederlandse Gasunie (Zuidwending), while Essent, Nuon, Dong, RWE and Eneco have erected UGS facilities in Germany that directly serve the Dutch market. The first three mentioned UGS have been constructed in depleted gas fields, whereas the latter are salt cavern storages.

The three depleted field UGS facilities (Grijpskerk, Norg and Alkmaar) on Dutch territory were built in the mid 90’s and can provide a total send out (end of winter capacity) of 5.8 mcm/h and currently provide a total working volume of 5.0 bcm. The fourth mentioned UGS facility (Zuidwending) was started in 2011 and can provide an additional WGV of 0.2 cm/h.

The UGS’s in Grijpskerk, Norg, and Alkmaar 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 GasTerra. Expansion plans are being considered to meet future capacity and work-volume demands.

The UGS Zuidwending was been designed to act as high frequency multi cycling cavern storage, with high production and injection capacity. The storages erected by Essent, Nuon, Dong and Eneco are cavern storages too. The Eneco UGS is expected to be available in 2012, while Nuon has expanded its facilities in 2011.

Another major development is the intention of TAQA to build an UGS in the depleted gas field of Bergermeer. According to current planning this should have a working gas volume of 3.3 bcm or more, and an associated delivery rate of 57 mcm/day, which is typical for a seasonal storage of this size. The existing production facilities will be extended with 14 additional wells, gastreament, compression and pipelines. Local resistance has risen in particularly because:

- Inconvenience during construction works
- Possible earth tremor during gas storage operation
- Safety and environmental impact during construction and operations

A decision of the Council of State, the highest administrative court in the Netherlands is expected early 2012, which will be the final step in the decision process.

A Memorandum of Understanding (MoU) between TAQA and Gazprom is put into effect. The MoU entails the delivery of cushion gas in the four summers from 2009 onwards by Gazprom. This storage will double the existing seasonal storage capacity in the Netherlands, but it might also serve the UK market provided that sufficient capacity on the BBL becomes available.

Liberalisation & security of supply
There is a continued political interest in the legal framework for the gas industry in the Netherlands. There has been a strong drive towards liberalisation in the last decade, starting in 1998. However, the last years there has been growing concern over the influence that government has on companies in a free market. Especially securing supplies and promoting investments in storages seems to be a difficult task.

As a step in the liberalisation of the market, the integrated transport and trading company Gasunie has been split up in a gas infrastructure company which inherited the Gasunie name, and a trade and supply company now under the name GasTerra. The Dutch government has chosen to retain a strong influence in the trading company GasTerra, thus allowing it to inherit some of the social responsibilities that were of concern in the market prior to the unbundling. For one, there are the concerns for the long-term security of supply for the Netherlands. These were at the basis of the constraint on the average volume offtake from the Groningen Field over a number of years. This constraint currently stands at 425 G m3 for the period 2006-2015. It furthermore is the instrument for continuance of the successful small-field policy.

Another issue is the role of GasTerra in the balancing system, in particular in view of the important role that the Groningen Field currently has in balancing the Dutch network. During 2008 the transport system operator GTS (100% subsidiary of state-owned Gasunie) has been asked by the Dutch ministry of Economic Affairs, Agriculture and Innovation to redesign the balancing system such that the Dutch transmission network will be prepared for a situation where the Groningen Field no longer balances the transmission network. The new balancing system aims at creating price signals for new investments in flexibility instruments through a more market-oriented system. In 2011 the new balancing system was put in place.
The new balancing system is expected to create price signals for new investments in flexibility instruments through a more market-oriented system. This is expected to have an impact particularly for the high-end of the LDC.

The Dutch government has decided on full unbundling of all energy companies, as a preparatory step towards greater European integration. In a reaction, the two major Dutch utilities Essent and Nuon have looked for international alliances. So far, this has resulted in a take-over by RWE for the commercial parts of Essent, whereas Nuon was merged with the

Swedish company Vattenfall. The result of such take-overs will be a further integration of the North-West European markets. For the gas market this will have implications for the capacity market.

Regulation

As part of the ongoing European liberalisation efforts the Dutch regulator (formerly DTe, now Energy chamber of the competition authority NMa) has indicated already during the previous triennium that a larger part of the Dutch UGS's should be made available for Third Party Access (TPA) than the current 11%. 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 Energiekamer has issued guidelines, which the storage owner should adhere to when offering storage services to the market. 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 the Energy Chamber. However, NAM together with GasTerra, has decided to make part of the capacity available to the third parties (the 11% mentioned above) as NAM and GasTerra wish to co-operate with the overall EU liberalisation efforts.

In view of the recent development of new storage capacities in the Netherlands, one might conclude that the actions of the regulator have been partially successful. However, various parties are calling for more investments, particularly in view of the Dutch ambition to become the gas roundabout for Northwest Europe.

Environmental/social

With the European 20/20/20 ambition, the existing trend to increase energy efficiency and to limit the environmental impact of operations as much as reasonably possible (zero impact if possible) is enhanced.

Beyond the existing policies such as "no flaring", and further minimization of CO_2 emissions imply the use of lowcarbon technologies as much as possible, e.g. opting for electrical rather than for gas-fired compressors.

It furthermore implies enhanced importance of planning procedures for extensions, or construction of new facilities. More than ever this requires involvement in an early stage of all stakeholders (i.e. neighbouring communities, local government, and 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 mcm/d. In the UGS Zuidwending state-of-the-art technology has been applied, with for example remote control enabling fully unmanned operations.

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, the market is quite active, with the activities at the Epe location by a number of Dutch utilities, as well as the development of the Zuidwending site by Gasunie. These activities entail sizeable investments that not only deliver peak capacities when required, but also serve as a physical backbone for enhanced trading activities.

Much higher capital investments are however required to accommodate seasonal modulation of relatively large working volumes at the low-end of the LDC (figure below). This type of investment requires long planning and engineering lead times, before such large UGS's can be taken into operation.

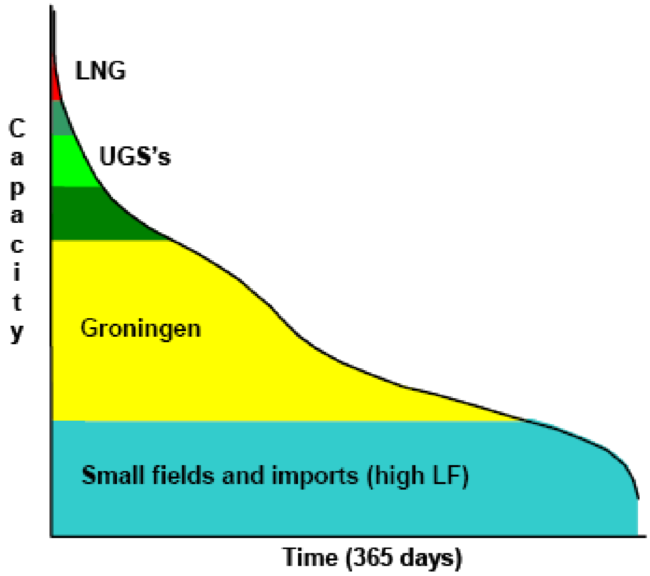

Figure 68 The Netherlands - Load Duration Curve in

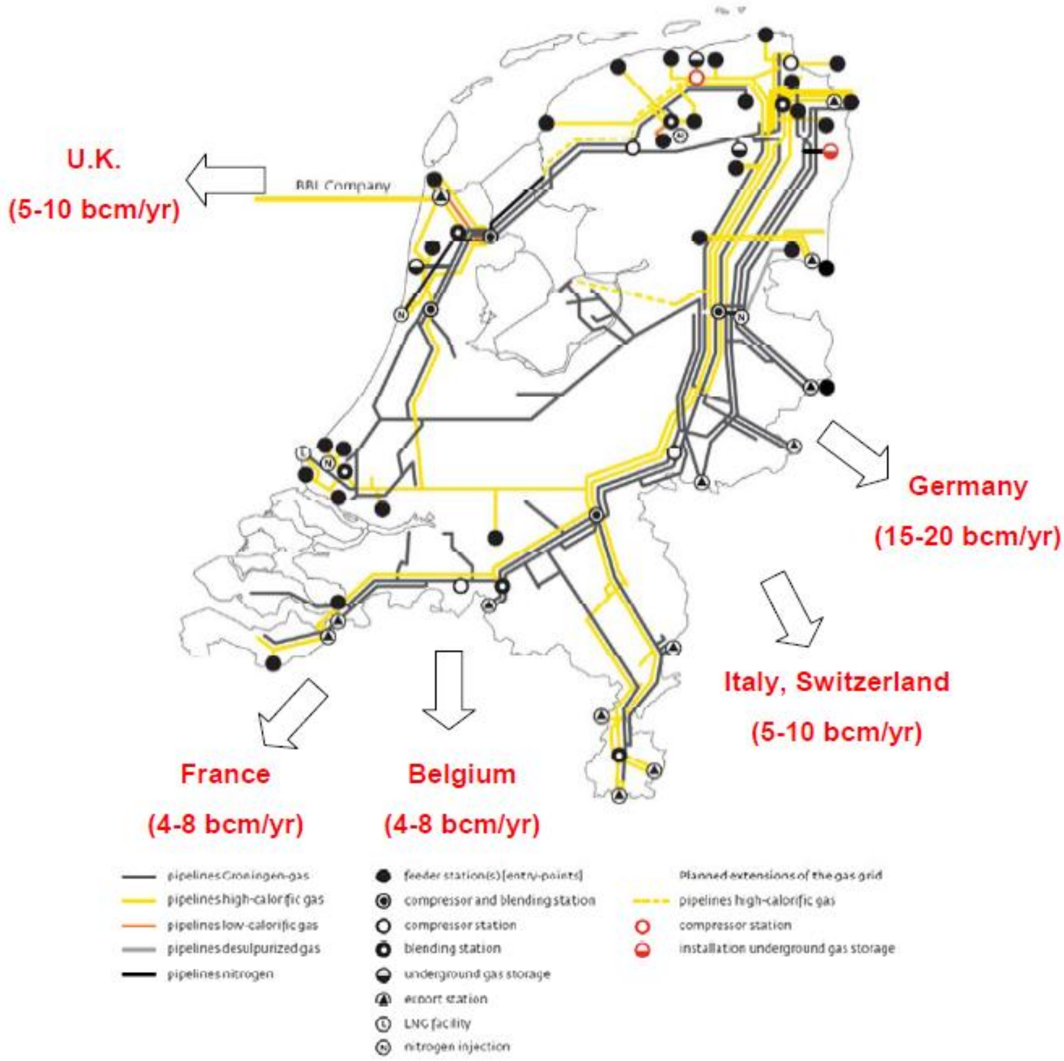

Figure 69 Overview of Dutch Gas Distribution system

6.17 Appendix SG2.1_12 Slovakia

General

Natural gas is an important energy source for Slovakia representing approx. 30% share in energy consumption. Yearly consumption amounted to 5.7 bcm in 2010. The major part of gas is supplied from Russia via transmission system transporting Russian gas to EU. Slovakia has extensive gas infrastructure used also internationally:

- Transmission system operated by Eustream with capacity 90 bcm/y
- UGS Lab complex operated by NAFTA and POZAGAS with total WGV 3 bcm (and it is still expanding) which represents more than 50% of annual gas consumption of Slovakia

On top of that, one of the most developed distribution network in Europe is operated by SPP distribution. UGS Lab complex is located only in the south-western part of Slovakia near Slovak-Austrian borders in close vicinity of Eustream's transmission system and offers a unique interconnection to all main gas grids as depicted in Figure 70

- distribution system
- transmission system
- direct connection to Central European gas hub at Baumgarten (CEGH)

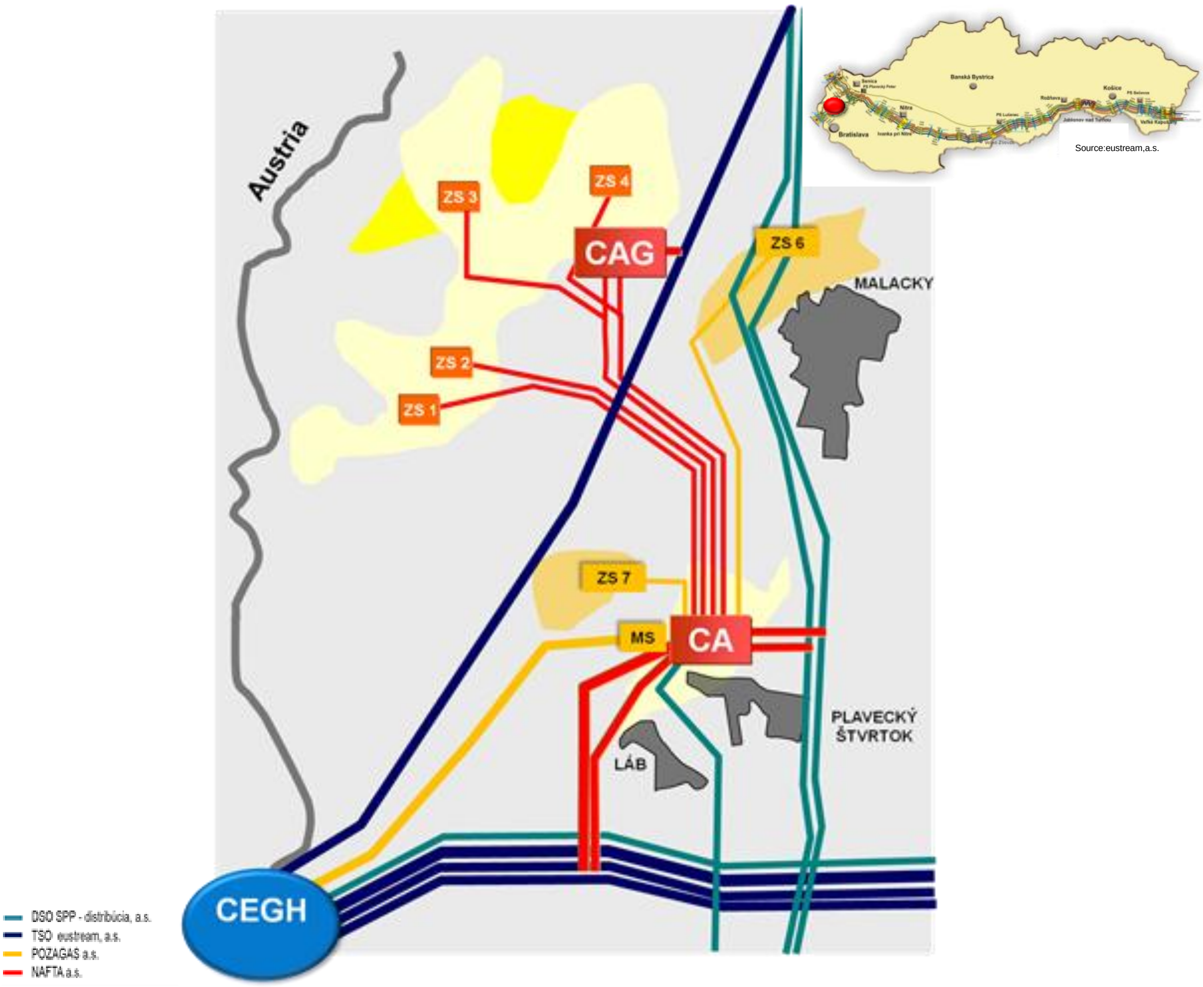

Figure 70 Interconnections of UGS Lab complex to gas grids

Thanks to favourable geological conditions (depleted gas/oil reservoir) of the northern part of the Vienna basin and variety on the side of interconnection, existing UGS provide sufficient, reliable and flexible storage capacity not only for Slovakia but also for other European customers. The UGS complex Lab has a solid track record of 40 years reliable operation as it was demonstrated during the last years when gas supply cuts occasionally happened.

Further expansion of storage capacity is under way. Project Gajary baden with WGV 0.5 bcm, developed as a part of UGS Lab complex, has been successfully commissioned on time and within budget and its build up started. Within the scope of the project, new interconnections to transmission system and to UGS Lab complex were also built. The latter was also recognized and financially supported by European Commission and evaluated as one of the best project supporting reverse flows in case of supply disruptions. State of the art technology with high safety standards ensures high reliability and efficiency of storage operation. Modular design of compressor station enables flexible usage compressors either for injection into Gajary baden or for injection and /or injection into other reservoir of UGS Gajary baden thus increasing internal diversification and flexibility of the entire UGS complex Lab.

Legal and marketing

Slovak energy legislation respects European Energy Directives. The framework of storage business is laid down mainly in two Acts: the Energy Act and Act on Regulation in the network industries. Implementation of 3rd Energy package into Slovak legislation is under way. GGPSSO are in place and are observed by storage operators enabling transparent and non-discriminatory conditions for 3rd parties.

The access to storage services is regulated on the basis of maximum prices. This means that regulated price cannot be exceeded in the tenders organized by storage operators.

All storage capacity is sold to 3rd parties via open and transparent tenders' procedures. At the moment, demand for short term products is visible. Standard bundled services are offered to the market with an option to customize deliverability and/or injectability with unbundled injection or withdrawal rates either on firm or interruptible basis. The storage products might be also modified by applying to day-ahead rates. Storage services are either flexible enabling change of flows from injection into withdrawal and vice versa intra-day or seasonal respecting standard seasonal pattern of injection and withdrawal. Being interconnected to various grids, clients frequently use switching of entry/exit points between the grids. Storage products are continually improved in order to add value to storage clients and very soon will be complemented by products from financial markets.

Environmental

At the moment, strengthening environmental criteria for construction or operation of UGS have been adopted. Environment impact assessment for construction of new storages or storage's expansion 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.

Technical trends

Concerning subsurface, 3D seismic, new methodologies and software tools are applied to depict as precisely as possible geological reality i.e. geological structure, its extension and tightness of reservoir trap. Complex reservoir models are applied to provide a tool to optimize storage processes and forecast different scenarios of its development and operation.

Further effort is focused on increased automatisation and safety of storage operations. Control system is being split into safety and process control systems.

Safety valve systems, including subsurface valves, are deployed in the completion of the storage wells meeting European standards. Surface facilities of UGS have been revamped ensuring their compliance with the latest environmental and safety standards and regulations thus being able to provide reliable storage services. New projects use state of the art technology which is consequently deployed also to existing facilities.

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6.20 YEEP partners (SG 2.3)

<u>Czech Gas Association</u>

Gazprom

Gazprom is one of the world's largest energy companies. Its major business lines are geological exploration, production, transportation, storage, processing and marketing of hydrocarbons as well as generation and marketing of heat and electric power. OAO Gazprom's mission is to ensure a safe, efficient, and balanced supply of natural gas, other types of energy resources, and refined products to consumers.

Gubkin Russian State University of oil and gas

Gubkin Russian State University of Oil and Gas – the leader in the Russian professional education system that assimilated the best traditions of domestic higher education institutions.

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RWE Gas Storage

Technical University of Liberec

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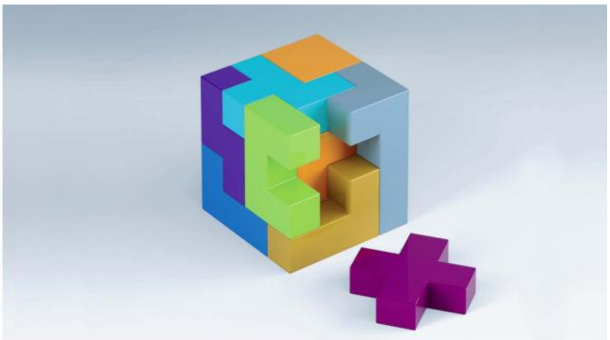

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6.21 YEEP students

<u>List of the participants</u>

	Surname	Name	Country	Company	Position	Specialty
1	BODNÁR	Jozef	Czech Republic	RWE Gas Storage, s.r.o.	Specialist, Asset Operation	UGS operation
2	Kolarovič	Peter	Czech Republic	Euro-Geologic	Geologist	Geological models
3	Kovaleva	Iana	Russia	LLC "Gazprom UGS"	Chief engineer	Development and operation of oil and gas fields
4	Li	Chun	China	China National Petroleum Corporation	Engineer	Reservoir engineering
5	Mihočová	Mariana	Czech Republic	MND a. s., Hodonín	Reservoir Engineer	Numerical simulation of flow (Petrel+Eclipse), analyses of reserves and duration of their viability
6	MÖBIUS	Christian	Germany	E.ON Gas Storage	Project Manager	Geoscience
7	Motov	Eugeniy	Russia	LLC "Gazprom UGS"	Oil-gas production operator	Technology and equipment for exploration of mineral deposit
8	NIKITIN	Maxim	Russia	Gazpromenergodiagnostika	Specialist in Petroleum Engineering	
9	Oreshina	Natalia	Russia	LLC "Gazprom UGS"	Engineer on new technology and equipment implementation	Geology and geochemistry of fossil fuel
10	POLAK-OSINIAK	Dorota	Poland	Polish Oil and Gas Company (PGNiG SA)	Specialist	Underground Gas Storage
11	Pylev	Eugeniy	Russia	LLC "Gazprom VNIIGAZ"	Scientist of laboratory of technologies of construction and work over of wells at UGS	Exploration of underground water
12	Ran	lina	China	China National Petroleum Corporation	Engineer	Geotechnical engineering
13	SALZWEDEL	Alexander	Germany	E.ON Gas Storage	Project Engineer	Reservoir & Production Engineering
14	Sorokin	Sergey	Russia	LLC "Gazprom VNIIGAZ"	Scientist of laboratory of UGS technical designing	Chemistry
15	Wanyan	Qiqi	China	China National Petroleum Corporation	Engineer	Geological engineering

<u>The three best students</u> which are selected to participate in the IGU Youth programme organized during the WGC2012.

Surname	Name	Year of birth	Company	Country	Position	Specialty
SALZWEDEL	Alexander	1985	E.ON Gas Storage	Germany	Project Engineer	Reservoir & Production Engineering
VORONOV	Svyatoslav	1989	LLC "Gazprom VNIIGAZ"	Russian Federation	Research officer of UGS Department	Underground gas and liquid storage
MÖBIUS	Christian	1983	E.ON Gas Storage	Germany	Project Manager	Geoscience

6.22 YEEP entry test

<u>PART 1 - Geosciences</u>

1. Select points which are not among main goals of UGS creations.

a) compensation of seasonal, monthly, daily and etc. gas demand variation because of powerstation, industry, and municipal heating gas consumption changes;

b) reducing of capital investments in pipeline network and compressor stations;
c) creation of state gas reserves for extremely cold winter or emergency;
d) store of petroleum gas in a new developed oil provinces;
e) increasing of oil recovery degree at the exhausted oil fields;
f) improving of gas quality to be delivered to social important consumers;
g) creation of feedstock and produced goods reserves at the petrochemical plants;
h) reducing of risk of caprock caving at the depleted oil-gas fields.

2. What does it mean «working (active) gas»?
a) gas annually extracted and injected without negative consequences for reservoir environment;
b) gas sock to cover annual demand of contracted consumers;
c) gas annually extracted and injected for compensation of demand variation.

3. What kind of UGS doesn't exist?
a) in depleted oil and gas fields;
b) in aquifers;
c) in abandoned mines;
d) in fractured coal stratus;
e) in salt rock caverns.

4. Does wells drilled for field development could be conversed for applying at the UGS?
a) yes;
b) no.

5. What does it mean «cushion gas»?
a) gas remaining in reservoir after working gas withdrawal and secure optimal technological and economical characteristics of UGS;
b) gas stock dedicated for extremely cold weather or emergency situation;
c) technological gas remaining in reservoir after working gas withdrawal and secure reservoir pressure.

6. What intermediate casing string dedicated for?
a) creation of optimal condition for reservoir tapping and wellhead equipment connection;
b) well testing;
c) direction for further drilling.

7. «Total UGS volume capacity» means:
a) total gas volume at the beginning of extraction;
b) technologically available volume of effective pore space of reservoir in the explored limits of structural trap;
c) initial gas volume in reservoir at the beginning of gas field development.

8. After drilling well have to be examine by:
a) hydrodynamic research;
b) log survey;
c) chemical analyses.

9. What is the main evidence of possibility of UGS creation in depleted oil field?
a) presence of gas cup;
b) good permeability of reservoir rocks;
c) low concentration of water in extracted oil.

10. What are the main advantages of horizontal wells compeering with traditional vertical?
a) reducing of capital investments into drilling;
b) significant increasing of well productivity;
c) reducing of casing string and tubing diameters;
d) reducing of cushion gas volume.

11. What is permeability for different phases depend from?
a) degree of oil, gas, water saturation of reservoir pore space;
b) reservoir pressure;
c) reservoir gas saturation.

12. What kind of measures could be applied for improving of drainage of reservoir?
a) deviated-directional well;
b) well cluster;
c) advanced technologies of well completion;
d) new types of well filters;
e) modern methods of geophysical survey.

13. Technological characteristics of UGS in depleted gas field are includes:
a) maximum permitted reservoir pressure;
b) minimum necessary reservoir pressure at the end of gas extraction;
c) reservoir permeability;
d) quantity of production wells including conversed existing wells;
e) diameter and length of internal pipeline network;
f) volume of working and cushion gas;
g) total UGS daily rate of gas withdrawal and injection.

14. Main reasons of UGS unintegrity:
a) zones of rocks deconsolidation and disjunctive disturbances;
b) fluid untightness of casing strings, tubing strings, packers and couplings;
c) extreme drop of atmospheric pressure;
d) non-proper technology of formation segregation;
e) nonconformity of chemical compounds of gas and brine water;
f) fluid untightness of well-head equipment;
g) unintegrity of cementing annulus.

15. Reservoir relative productivity could be evaluated at the base of following researches:
a) log survey;
b) in-well hydrodynamic research;
c) reservoir rock's core samples laboratory analyses and tests.

16. Increasing of cushion gas resulting in:
a) increasing of reservoir pressure and some wells productivity;
b) increasing of compression degree at the compressor station;
c) increasing of well quantity.

17. UGS exploration includes:
a) structural and deep exploration drilling;
b) calculation of technological capacities of UGS;
c) investigation of geological (stratigraphical and lithological) construction of structural trap.

18. Does methane fit the rule of «perfect gases»?
a) yes;

b) no.

19. What does it mean «unified gas supply system»?
a) complex of main pipelines, UGS, and gas distribution facilities unified by common regime of gas transportation, store and distribution;
b) complex of main pipelines and gas distribution facilities unified by common regime of gas transportation and distribution;
c) complex of gas fields, main pipelines, UGS, and gas distribution facilities unified by common hydrodynamic regime of gas production, transportation, store and distribution.

20. Is it necessary to treat gas before delivery to consumer if it was already treated before injection?
a) yes;
b) no.

PART 2 – Reservoir Engineering

21. The minimal allowed depth for the UGS is approx.
a) 100 m;
b) 300 m;
c) 1000 m;
d) 1500 m.

22. What is approx. the maximal reservoir pressure for safe operation of the UGS?
a) 1.05 times the hydrostatic pressure;
b) 1.7 times the hydrostatic pressure;
c) 2.5 times the hydrostatic pressure;
d) 5 times the hydrostatic pressure.

23. The cushion recovery could be the highest in
a) aquifer UGS;
b) salt cavern;
c) low permeable depleted gas with a strong water drive.

24. The fluid flow in porous media is governed by
a) Bernoulli equation;
b) Archimedes law;
c) Darcy's law.

25. The fluid in porous media is described by
a) specific weight;
b) PVT characteristics;
c) degree of dissociation.

26. The principal purpose of the welltesting is
a) to determine corrosion of the casing;
b) to determine the parameters of well and the reservoir;
c) to determine cement bonding behind casing.

27. The k.h calculation based on the welltest results is done by:
a) Early Time Rate;
b) Middle Time Rate;
c) Late Time Rate.

28. The material balance calculation of the UGS is a correlation between gas volume and
a) reservoir pressure;
b) reservoir pressure corrected by z-factor (compressibility factor);
c) reservoir pressure corrected by gas viscosity.

29. The equation of state (EOS) for ideal gas is
a) P . V = n R . T
b) ρ . V = n R. T
c) (P . V)² = n R . T

30. The real gas EOS, compared to ideal gas EOS, contains an extra term, which is
a) viscosity;
b) density;
c) compressibility factor.

31. The gas volume formation factor is a ratio
a) of gas volume in reservoir conditions to gas volume in standard conditions;
b) of gas volume to water volume;
c) of gas compressibility to rock compressibility.

$$= \frac{p_{sc}}{T_{sc}} \frac{zT}{p}$$

32. The gas volume formation factor Bg =
a) is ok;
b) is not ok, the viscosity is missing;
c) is not ok, the density is missing.

33.

$$v = -\frac{k}{\mu} \frac{dp}{dL}$$

where v = apparent fluid flowing velocity, cm/sec
k = proportionality constant, or permeability, Darcys
μ = viscosity of the flowing fluid, cp
dp/dL = pressure drop per unit length, atm/cm

is an equation of:
a) flow;
b) action and reaction;
c) material balance.

34. The radial homogenous flow regime is typical for
a) sedimentary porous rock;
b) fractured rock (carbonate reservoirs etc.);
c) a combination of porous and fractured rocks.

35. The relative permeability (of reservoir fluids)
a) is the same for all reservoir fluids;
b) depends on saturation of fluids;
c) for gas is always higher than the relative permeability for water.

36. Gradient of pressure
a) points in direction of isoline in given point;
b) points in direction of highest increase of the pressure in given point;
c) is a scalar quantity therefore has no direction.

37. The Darcy's law u = -K grad(p) is a partial differential equation of
a) elliptic type;

b) parabolic type;
c) hyperbolic type.

38. Hydraulic permeability of anisotropic porous media is
a) scalar quantity;
b) vector quantity;
c) tensor quantity.

39. The standard finite difference method uses
a) structured rectangular grid;
b) unstructured grid of triangles;
c) any type of grid.

40. The local grid refinement is used for
a) better accuracy of the calculation;
b) decreasing the memory used for the calculation;
c) speeding up the calculation.

PART 3 – Treatment of Natural Gas

41. Natural gas of type H contains, as compared with the type L:
a) higher concentration of methane and nitrogen;
b) lower concentration of incombustible components and higher concentration of methane;
c) the gases are interchangeable.

42. The basic measure of the gas interchangeability is the Wobe number, defined as
a) ratio of low heat value and square root of density;
b) ratio of low heat value and squared density;
c) ratio of high heat value and square root of relative density.

43. The natural gas and town gas are mutually
a) totally interchangeable;
b) partially interchangeable;
c) not interchangeable.

44. The warning odor level should be at
a) 20 % of lower explosion limit;
b) 20 % of upper explosion limit;
c) 10 % of lower explosion limit.

45. High and low heat values
a) do not differ;
b) do not have anything in common;
c) High heat value is higher than or equal to the low heat value.

46. High heat value of the fuel gases is usually determined
a) by the calorimeter;

b) by calculation from the gas chemical composition;
c) by calculation from the low heat value.

47. Most parts of the gas well are installed underground. Above ground could be seen
a) sand filter;
b) packer;
c) christmas tree.

48. Propane-butane gas belongs to
a) low heat value fuel gases;
b) medium heat value fuel gases;
c) very high heat value fuel gases.

49. The preventer is:
a) the device for preventative removal of impurities from the mud before its repeated use;
b) the device enabling the fast shutdown of the well and so preventing the blow-out;
c) the device enabling the shutting of the pipeline to prevent the infiltration of dirt.

50. Underground gas storage serves to:
a) store the surplus gas;
b) matching the deliveries with consumption in particular year seasons;
c) the smoothing out the consumption peaks.

51. Removal of H2S from the gas by the ferric oxide is based on the reaction
a) 2 NaHCO3 + H2S = Na2S + 2 H2O + 2 CO2
b) Fe2O3 . 3 H2O + 3 H2S = 2 FeS + S + 6 H2O
c) 2 NH4OH + H2S = (NH4)2S + 2 H2O

52. The gas well consists of several concentric casings. The casing having the largest diameter is
a) intermediate casing;
b) surface casing;
c) production casing.

53. What process is used to dehydrate the gas from Czech underground storages?
a) none - it is not necessary to dehydrate the storage gas;
b) process based on the Joule-Thomson effect;
c) absorption by di- or triethyleneglycol.

54. Which of the listed groups of gases consists completely from the fuel gases?
a) nitrogen, oxygen, hydrogen;
b) helium, propane-butane gas, blast furnace gas;
c) natural gas, coke oven gas, propane-butane gas.

55. PSA method is based on
a) reversible adsorption of contaminants on the solid sorbent;
b) chemisorption of contaminants into special solutions (e.g. MEA);
c) absorption of contaminants into suitable solvent.

56. The high pressure water scrubbing is used for:
a) separation of methane from biogas, based on its higher solubility under pressure;
b) separation of CO2 from biogas, based on its higher solubility under pressure;
c) separation of CO2 and H2S from biogas, based on their higher solubility under pressure.

57. The coke oven gas belongs to:

a) low heat value fuel gases;
b) medium heat value fuel gases;
c) very high heat value fuel gases.

58. The salt cavern gas storage is usually created by
a) using explosives;
b) leaching of cavern by water;
c) by conventional underground mining technology.

59. Lower flammability limit is:
a) lowest temperature to support combustion;
b) lowest volume concentration of the gas in the air which, after heating to the ignition temperature, ignites and sustains further complete combustion;
c) highest volume concentration of the air in the gas/air mixture which, after heating to the ignition temperature, ignites and sustains further complete combustion.

60. Lower and upper flammability limits of methane in the air are:
a) 5 and 15 % vol.;
b) 4 and 72,4 % vol.;
c) 7 and 22 % vol.

6.23 YEEP time schedule

Arrivals to Moscow	**18 - 19 June 2011**
Course **Geosciences**, Gubkin Russian State University of Oil and Gas	**20 June – 1 July**
Arrivals to the Ruzyne airport in Prague from Moscow	**2 July 2011**
Transport by the bus to Liberec	**2 July 2011**
Kick-off of the course **Reservoir Engineering** in Liberec	**4 July 2011**
Course **Reservoir Engineering** , Technical University in Liberec	**4 – 15 July 2011**
Leaving test of the course **Reservoir Engineering** in Liberec	**15 July 2011**
Transport by the bus (arranged by CGA) from Liberec to Prague	**16 July 2011**
Kick-off of the course **Treatment of Natural Gas** in Prague	**18 July 2011**
Course **Treatment of Natural Gas**, Institute of Chemical Technology in Prague	**18 – 29 July**
Leaving test of the course **Treatment of Natural Gas** in Prague	**29 July 2011**
Departure back to home	**29 - 30 July 2011**

6.24 YEEP Programme

Course I

20 June	Official course opening ***Khan S.A. -*** ***Arutynov A.E. –*** ***Zubarev A.P. –*** ***Cibulskiy P.G. –*** ***Ruban G.N. -*** ***Zolotukhin A. B.***	Role of UGS in gas supply system, main characteristics, world location according to geological conditions. ***Khan S.A.***	Role of scientific organizations for UGS creation **Cibulskiy P.G. -**	Role of UGS in gas supply system of Russia, European states and all over the world. **Arutynov A.E.**	Challenges and perspectives of oil and gas exploration with optimization of development process and rational UGS location. ***Gavrilov V.P.***
21 June	The Russian Federation's natural gas storage facilities and guarantee of supply security (Europe and APR) ***Lugay D.V.***	Geological aspects and vindication of UGS creation ***Bondarev V.L.***	Specificities of exploration for UGS creation (stages, evaluation of filtration-volumetric properties and trap size). ***Reznik B.A.***		
22 June	Specificities of UGS designing ***Buzinov S.N.***	Differences in gas field development and UGS operation. ***Perepilichenko V.F.***	Specificities of UGS creation in aquifer ***Garaishin A.S***	Creation and operation of UGS in complicate geological conditions ***Soldatkin S.G.***	
23 June	Environmental Challenges and environmental monitoring at UGS ***Akopova T.S.***	Geodynamic monitoring at UGS ***Nikonov A.I.***	Specificities of designing and construction of wells at UGS (including horizontal and deviated-directional). ***Engibarian A.A.***		
24 June	Chemical influence at the reservoir to increase period of well's dry operation. ***Karimov M.F.***	Modern methodology of diagnostic of well's integrity at UGS ***Zubarev A.P.***	Modern methodology of diagnostic of well's integrity at UGS ***Danilenko V.N.***	Remote monitoring of reservoir characteristics through observation wells at UGS ***Sidorov A.P.***	

25 June	Tutorial *Specialists of LLC «Gazprom UGS» and Gubkin RSU of oil and gas*			
26 June	Excursion to Moscow **Volostnyh E.V.**			
27 June	Technical visit to UGS			
28 June	Technology of well completion and process of formation exposing ***Shamshin V.I.***	Specificities of well's work over at UGS ***Kazarian V.P.***	State-of-the-art well productivity enhancement ***Kazarian V.P.***	
29 June	Geophysical and geochemical monitoring of UGS operation ***Zubarev A.P.** - Candidate of geo-mineralogical sciense*	Up-to-date requirements to hydrodynamic well test at UGS in framework of gas injection-store-extraction monitoring ***Markov D.A.,*** ***Kotliarova E.M.***		
30 June	Possible gas immobilisation in reservoir ***Soldatkin S.G.***	Surface geophysical survey for UGS integrity monitoring ***Iskhakov A.Y***	Geophysical and Geological monitoring of UGS creation and operation ***Ruban G.N.***	Share of mining and geological inspection of UGS in common process of UGS operational monitoring ***Ruban G.N.***
1 July	Attestation	Final round table (sizing up, discussion of exit tests and abstracts)		

Course II

	8:30-10:00	10:30-12:00	13:00-14:30	15:00-16:30
4.7.2011	Reservoir Engineering, introduction *Vladimir Onderka*	Petroleum Geology, introduction *Vladimir Onderka*	Mathematical background Otto Severýn	Modeling and simulation - introduction Jan Šembera
5.7.2011	Geochemistry of gases *Josef Zeman*	Applied geochemistry *Tomáš Pačes*	Modeling and simulation - introduction Jan Šembera	Mathematical background *Otto Severýn*
6.7.2011	Reservoir Engineering and simulation *Leonhard Ganzer*	Reservoir Engineering and simulation *Leonhard Ganzer*	Reservoir Engineering and simulation *Leonhard Ganzer*	Mathematical background *Otto Severýn*
7.7.2011	Reservoir Engineering and simulation *Leonhard Ganzer*	Reservoir Engineering and simulation *Leonhard Ganzer*	Reservoir Engineering and simulation *Leonhard Ganzer*	Numerical methods *Milan Hokr*
8.7.2011	Reservoir Engineering and simulation *Leonhard Ganzer*	Reservoir Engineering and simulation *Leonhard Ganzer*	Model calibration *Jan Šembera*	Model calibration *Jan Šembera*

	8:30-10:00	10:30-12:00	13:00-14:30	15:00-16:30
11.7.2011	Thermodynamics of gases *Vladimír Onderka*	Introduction to logging *Petra Valentová*	Well completions *Lukáš Svozil*	Welltesting *Vladimír Onderka*
12.7.2011	Numerical methods *Jan Šembera*	Numerical methods *Jan Šembera*	Welltesting *Vladimír Onderka*	Eclipse *Miroslav Dressler*
13.7.2011	Reservoir simulation - gridding *Miroslav Dressler*	Reservoir simulation *Miroslav Dressler*	Welltesting *Vladimír Onderka*	Welltesting *Vladimír Onderka*
14.7.2011	Reservoir simulation *Otto Severýn*	FEM models *Milan Hokr*	FEM models *Milan Hokr*	Eclipse *Otto Severýn*
15.7.2011	Leaving test of the course **Reservoir Engineering**	Fractured rocks *Milan Hokr*	THMC processes *Milan Hokr*	Discussions, various topics

Course III

	8:30-10:00	**10:30-12:00**	**13:00-14:30**	**15:00-16:30**
18.7.2011	Basic terms and properties *Růžička, Voňka*	State behaviour of ideal gas *Růžička, Voňka*	Properties of natural gases *Čapla*	Properties of natural gases *Čapla*
19.7.2011	The first law of thermodynamics *Růžička, Voňka*	The second law of thermodynamics *Růžička, Voňka*	Surface technology for the gas injection and withdrawal *Koza*	Surface technology for the gas injection and withdrawal *Koza*
20.7.2011	Equations of state (EOS) *Růžička, Voňka*	Thermodynamic quantities and state behaviour of real gas *Růžička, Voňka*	Properties of natural gases *Čapla*	Properties of natural gases *Čapla*
21.7.2011	Calculation of heat and work *Růžička, Voňka*	Vapour-liquid equilibrium *Růžička, Voňka*	Properties of natural gases *Čapla*	Properties of natural gases *Čapla*
22.7.2011	Surface technology for the gas injection and withdrawal *Koza*	Surface technology for the gas injection and withdrawal *Koza*	Properties of natural gases *Čapla*	Properties of natural gases *Čapla*

	8:30-10:00	10:30-12:00	13:00-14:30	15:00-16:30
25.7.2011	Surface technology for the gas injection and withdrawal *Koza*	Surface technology for the gas injection and withdrawal *Koza*	Natural Gas Treatment Technologies *Tenkrát*	Natural Gas Treatment Technologies *Tenkrát*
26.7.2011	Surface technology for the gas injection and withdrawal *Koza*	Surface technology for the gas injection and withdrawal *Koza*	Natural Gas Treatment Technologies *Tenkrát*	Natural Gas Treatment Technologies *Tenkrát*
27.7.2011	Aspen Hysys simulation (lecture room – nr. of the door : 156 a, first floor) *Polák*	Aspen Hysys simulation (lecture room – nr. of the door : 156 a, first floor) *Polák*	Natural Gas Treatment Technologies *Tenkrát*	Natural Gas Treatment Technologies *Tenkrát*
28.7.2011	Aspen Hysys simulation (lecture room – nr. of the door : 156 a, first floor) *Polák*	Aspen Hysys simulation (lecture room – nr. of the door : 156 a, first floor) *Polák*	Aspen Hysys simulation (lecture room – nr. of the door : 156 a, first floor) *Polák*	Aspen Hysys simulation (lecture room – nr. of the door : 156 a, first floor) *Polák*
29.7.2011	Final Exam of the course **Treatment of Natural Gas**	Aspen Hysys simulation (lecture room – nr. of the door : 156 a, first floor) *Polák*	Aspen Hysys simulation (lecture room – nr. of the door : 156 a, first floor) *Polák*	YEEP Evaluation + Closing Ceremony *Onderka*