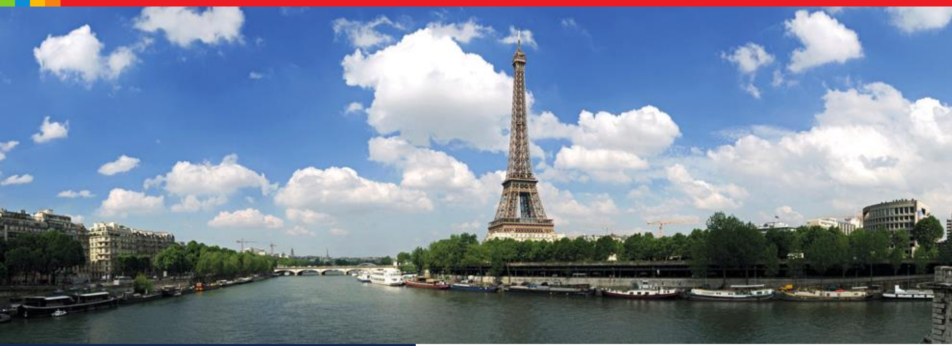
2012-2015 Triennium Work Reports



WORKING COMMITTEE 2

UNDERGROUND GAS STORAGE

LADISLAV GORYL

June 2015

WGCPARIS2015
WORLD GAS CONFERENCE

IGU
INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

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Ladislav Goryl (chair of WOC2) and Nikita Barsuk (Vice-chair of WOC2) like to thank all the WOC2 members and contributors for this report, especially: Vladimir Lorenc (leader of SG2.1 “UGS Database”), Fabien Favret (leader of SG2.2 “Techniques and New Opportunities”), Jacques Grappe (co-leader SG2.2), Nikita Barsuk (leader of SG2.3 “Attracting students to storage activities”), and Hélène Giouse.

We would like specially acknowledge contributions from respective storage companies which provided data mainly for SG 2.1 and SG 2.3. Without them this report would hardly be possible.

Executive summary

Underground gas storage represents unique assets of gas value chain combining geological reservoir with subsurface and surface infrastructure. This year 100th anniversary of the first UGS storage in Welland County, Ontario in Canada has been honoured. Originally, UGS was built as gas accumulation element covering imbalances in gas consumption markets. Since its early **beginnings, UGS has developed into a complex gas infrastructure providing physical flexibility to gas markets as it contains substantial volumes of gas close to customers and flexibility to deliver gas at a short notice according to market needs.** The basic roles of UGS are the following:

- Seasonal, monthly, daily and even hourly balancing of gas consumption variations
- Transmission and distribution gas grids optimization and balancing
- Security of gas supply
- Gas production optimization
- Gas trading and arbitration

Each UGS is characterized by storage capacity consisting of working gas volume, withdrawal and injection rate. Due to the fact that the basic role of UGS is to moderate gas consumption fluctuations, interconnections to gas grids are important. The classification of UGS types is as follows:

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.

Usually due to their characteristics, caverns provide flexible storage with relatively smaller volumes and higher rates and porous storages fit to seasonal storages where larger volumes are smaller rates in relative terms. However, this is general classification and also very deliverable porous storages might be found.

In this triennium, WOC2 have had three study groups dedicated to:

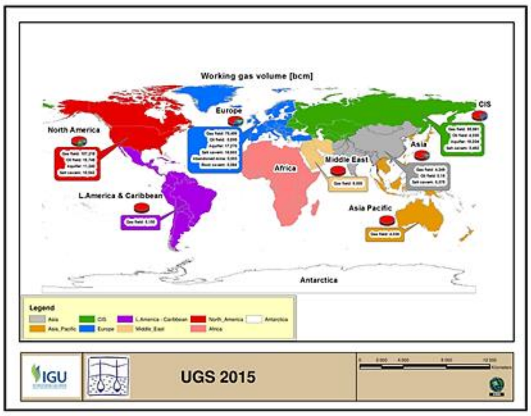
- SG 2.1 UGS database
- SG 2.2 Techniques and new opportunities
- SG 2.3 Human resources: attracting students to storage activities

SG 2.1

This group has been working for 5 trienniums providing a valuable summary of UGS activities worldwide. Total WGV is 393 bcm without taking into account long term strategic reserves, operated in about 715 storage facilities all over the world with the withdrawal rate of some 6 656 mcm/d. Most storages are developed in former gas fields.

During this triennium a special web based application was developed summarizing SG's deliverables as follows:

- UGS Data viewer
- UGS facts in Charts & Tables
- UGS interactive map
- UGS vocabulary in fourteen languages
- Studies from previous triennium



and is accessible at http://ugs.igu.org/ after registration. Moreover, a general definition of trends in established and emerging gas regions is given.

<u>SG 2.2</u>

The main orientation was on UGS techniques, new opportunities and best practices. As operators of underground gas storage facilities have to react quickly to changing market demands for gas while raising safety standards and reducing environmental impacts. The first part looks at subsurface integrity management and the second at the reduction of the environmental footprint of UGS operations and the enhancement of their energy efficiency. UGS operators are taking advantage of sophisticated and advanced technologies which were mainly developed by and for oil and gas majors or engineering service companies. But UGS operators are also investing in R&D to adapt these technologies to their specific needs in order to continuously improve their practices.

Furthermore, information **to which extent UGS technology may contribute to energy storage** generated from intermittent renewable energy sources is given. This part focuses on the identification of solutions UGS applications might contribute, on the related technology gaps together with the R&D effort needed to overcome them, and on current market uncertainties, opportunities and constraints likely to impact the deployment of these UGS.

<u>SG 2.3</u>

The main goal of SG was to find the key factors affecting talent attraction to the underground storage sector and develop strategic approaches to HR development. The results based on questionnaire survey are reported in a comprehensive report.

The most important part of SG 2.3 was development of **"Program of competition in honour of 100th anniversary of UGS".**

The programme was destined for the students and young specialists (younger than 30 years old) working with or willing to work in UGS industry. Finally authors of the four best theses were awarded with participation in the world gas conference in Paris 2015.

- **Damien Lavergne**, Storengy, France, Topic: Innovative technology for monitoring an Underground Gas Storage
- **Yila Dudnikova,** Gazprom VNIIGAZ, Russia, Topic: Active Methods to Control process of Forming the Gas bubble in aquifer UGS
- **Rafał Mrzygłód,** Operator Systemu Magazynowania Sp. z o.o., Poland, Topic: Optimization Model Filling the Cavern Gas Storage Mogilno
- **Roman Zavada**, NAFTA, Slovakia, Topic: Utilizing waste heat in a gas reservoir environment

Topics of theses correspond with "gold" and "green" strategic pillars of French presidency.

Storage provides general benefits to the entire gas infrastructure but not only for balancing of gas grids. In other words **storages help the final customers to get their gas in efficient, reliable and secured way**.

2012-2015 Triennium Work Report
June 2015

REPORT OF STUDY GROUP 2.1

UGS Database

produced by:
International Gas Union

www.igu.org

http://ugs.igu.org/

1 Report of Study Group 2.1

1.1 Introduction

The UGS Database SG has been established for the first time as a part of the International Gas Union Triennium work programme 2000 – 2003 as Basic Activity and since then, it provides valuable summary of UGS activities worldwide. The study has been constantly improved over trienniums and is complemented by below mentioned additional deliverables posted at IGU server and available at http://ugs.igu.org/ after registration:

- UGS Data viewer
- UGS facts in Charts & Tables
- UGS interactive map
- UGS vocabulary in fourteen languages
- Studies from previous triennium

The results are to be presented during the World Gas Conference 2015 in Paris.

The Study Group Members are listed in Appendix 6.

The Study Group leader: Vladimír Lorenc (Slovakia)

The main contributors:
Joachim Wallbrecht, Marije Wagter, Kimberly Denbow, Philippe Meynard, Emmanuelle Wicquart, Andreas Böhmer, Ladislav Goryl, Mária Poláková, Ligen Tang, Ali Teymouri, Michael Kreuz,

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

1.2 Aims

The aim of the Study is promoting UGS and its importance as a unique infrastructure of its kind in gas value chain. The Study summarizes actual status of UGS capacities and related activities via its collection worldwide which makes it out of ordinary contribution. Furthermore the data are plotted in a variety of figures and tables in order to indicate trends and perspectives wherever it is useful and feasible.

The objectives of the Study were to carry out the activities as follows:

- Statistical survey of UGS in operation and UGS projects worldwide
- Analysis of gained data
- Summary of general trends
- Update of the UGS World Map
- Extension of the UGS Glossary by additional languages

- Development of application for data collection and their availability at IGU server in order to preserve data of IGU over trienniums

The study covers the following types of UGS 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.

1.3 Methods

1.3.1 IGU UGS web application

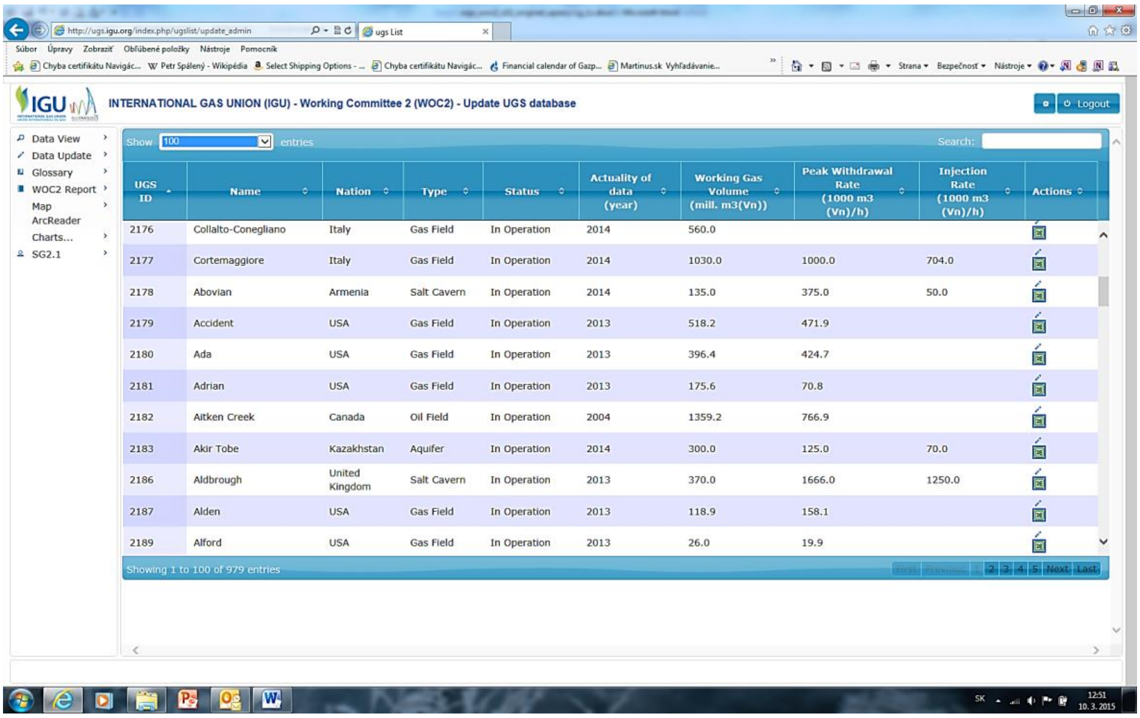
During the triennium, a special application has been developed and it is accessible at IGU website http://ugs.igu.org/ with the following structure:

I. UGS World Data Bank in IGU	UGS in operation, planned and abandoned (status: 2013/2014) in Metric Unit and in English Units (only for WOC2 members and contributors)
II. UGS Charts& tables	The main general and technical figures from the report e.g. http://ugs.igu.org/index.php/figure/load/world_trend
III. UGS World Map	Geo-referenced visualisation[1] of UGS data in Metric Unit and in English Units
IV. UGS Glossary	Glossary of relevant technical UGS terms
V. WOC2 Report	Current and last triennium reports on:

Table 1 IGU Website structure

The application (Figure 1) is based on programmable language PHP5 and database server MySQL. The application has its own small security system, which accepts the following roles: Administrator, Contributor & IGU User and Public User.

[1] *UGS World map is activated only in case of installing a special free GIS SW:* ***ArcReader10.2****. Further explanations and details for its installation are accessible in set up guide (Appendix 8)*



UGS ID	Name	Nation	Type	Status	Actuality of data (year)	Working Gas Volume (mill. m3(Vn))	Peak Withdrawal Rate (1000 m3 (Vn)/h)	Injection Rate (1000 m3 (Vn)/h)	Actions
2176	Collalto-Conegliano	Italy	Gas Field	In Operation	2014	560.0			
2177	Cortemaggiore	Italy	Gas Field	In Operation	2014	1030.0	1000.0	704.0	
2178	Abovian	Armenia	Salt Cavern	In Operation	2014	135.0	375.0	50.0	
2179	Accident	USA	Gas Field	In Operation	2013	518.2	471.9		
2180	Ada	USA	Gas Field	In Operation	2013	396.4	424.7		
2181	Adrian	USA	Gas Field	In Operation	2013	175.6	70.8		
2182	Aitken Creek	Canada	Oil Field	In Operation	2004	1359.2	766.9		
2183	Akir Tobe	Kazakhstan	Aquifer	In Operation	2014	300.0	125.0	70.0	
2186	Aldbrough	United Kingdom	Salt Cavern	In Operation	2013	370.0	1666.0	1250.0	
2187	Alden	USA	Gas Field	In Operation	2013	118.9	158.1		
2189	Alford	USA	Gas Field	In Operation	2013	26.0	19.9		

Figure 1 IGU UGS Website

The main goal of the application is updating the existing database via Web form which is similar to previous excel questionnaire. The workflow application described in Figure 2.

1. If user is logged in as an Administrator, he or she is able to **C**reate, **R**ead, **U**pdate and **D**elete each UGS facility in database.
2. If user is logged in as a Contributor or WOC2 member, he or she is able to read data of all UGS facilities in detail, but only a Contributor can update data of his UGS facilities.
3. Public User can read the basic data from database only.

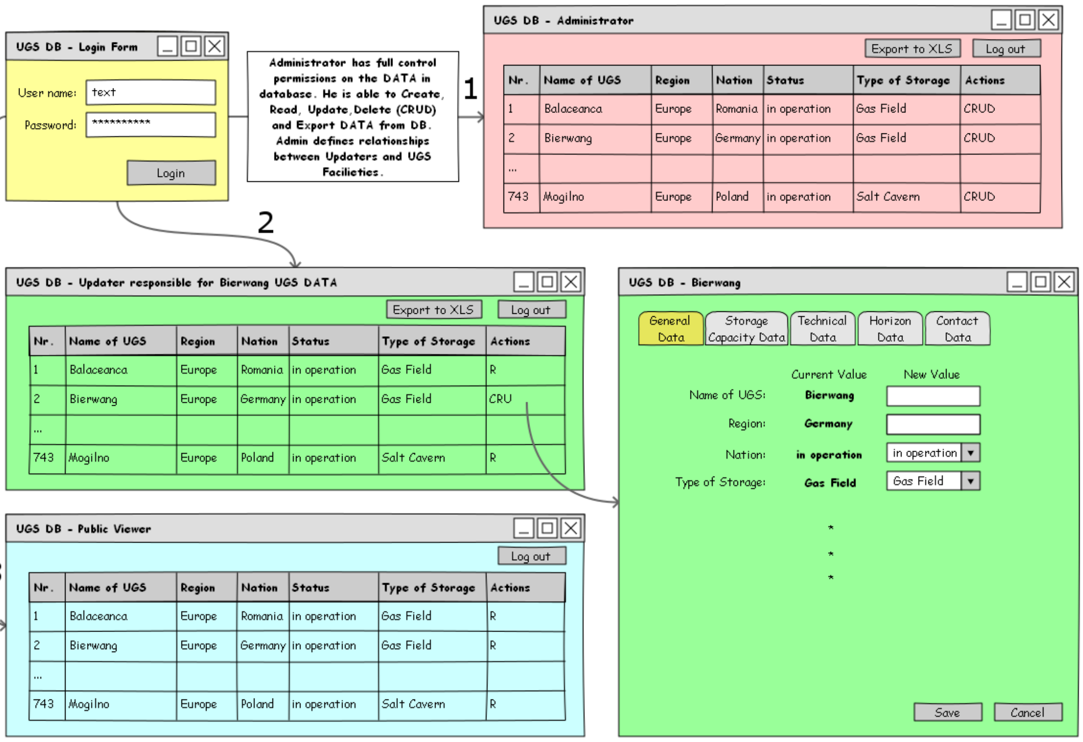


Figure 2 Workflow Application

The data are divided into 4 groups:

- General
- Capacity
- Technical
- Horizon

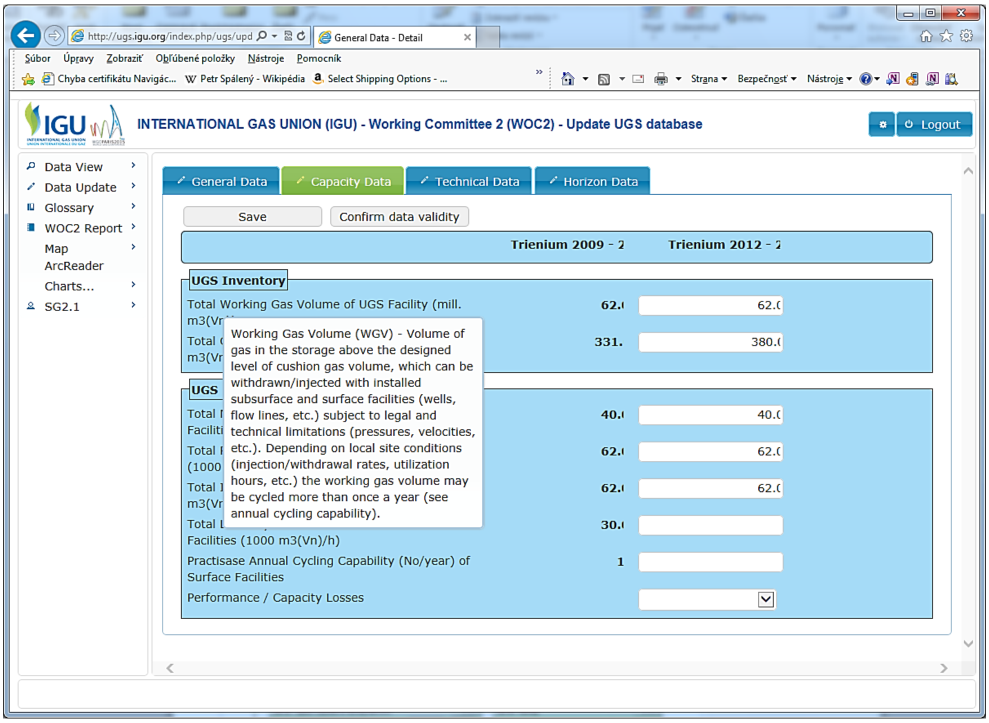


Figure 3 Detail of UGS Capacity data

1.3.2 UGS World Map

The geo-referenced presentation within the UGS World Map is available in Metric and English units. Key data of UGS in the world are available as 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. However, UGS World map is activated only in case of installing a special free GIS SW: **ArcReader10.2** which can be downloaded from UGS Web application [http://ugs.igu.org/.](http://ugs.igu.org/) Further explanations and details for its installation are accessible in set up guide (Appendix 8).

The IGU regions referred to throughout the report are defined by colour coded areas as depicted in the map in Figure 4. The visualisation is created in 4 layers depicting different regions, nations and storages with a present scope of UGS data.

Individual layers are accessible by zooming in the map and UGS data can be accessed by pointing to identify-mode at UGS location. Further zooming provides the information of WGV split according to storage types by countries as depicted in Figure 5.

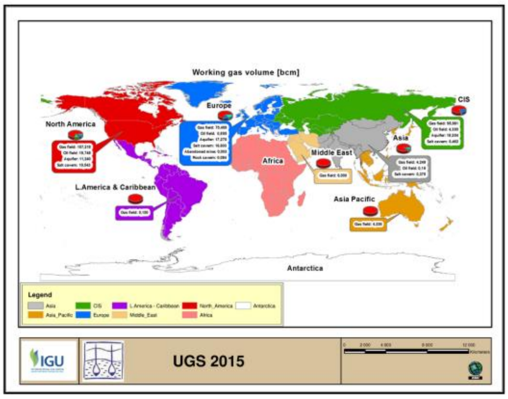


Figure 4 Layer visualisation of WGV by regions

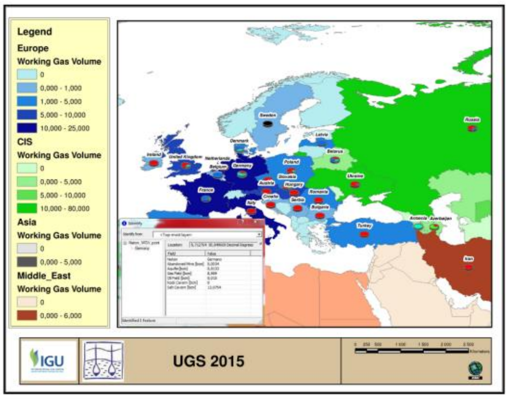


Figure 5 Layer visualisation of WGV by countries

Additional zooming provides location of individual UGS. Its type and size is marked by different symbols with basic technical data as depicted in Figure 6 and Figure 7.

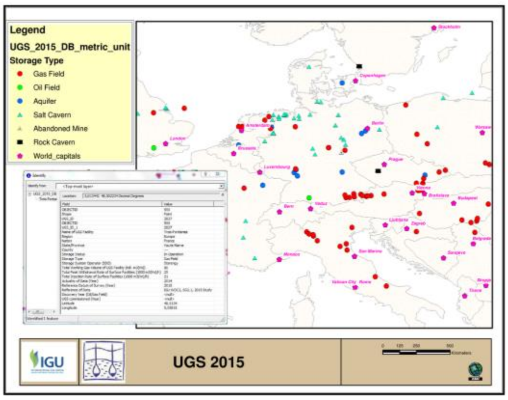


Figure 6 Layer visualisation of WGV by storage types

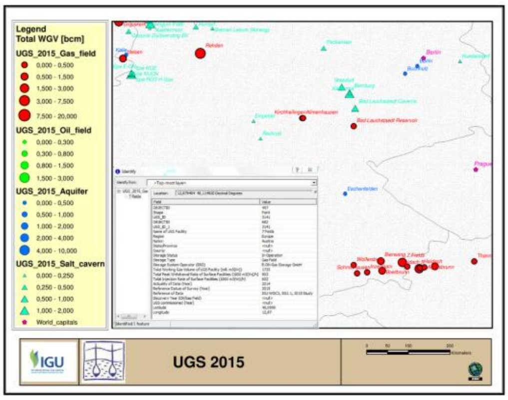


Figure 7 Layer visualisation of UGS by name

1.3.3 UGS Glossary

As there are too many different storage related definitions available, mainly exploration and production and marketing related consolidated glossary of the relevant technical terminology related to the storage of natural gas in underground gas storage facilities has been developed. As the technology is similar, the terminology can be applied for the storage of hydrogen, Carbon Dioxide, Air and other gases. The glossary covers the following terms depicted in Figure 8.

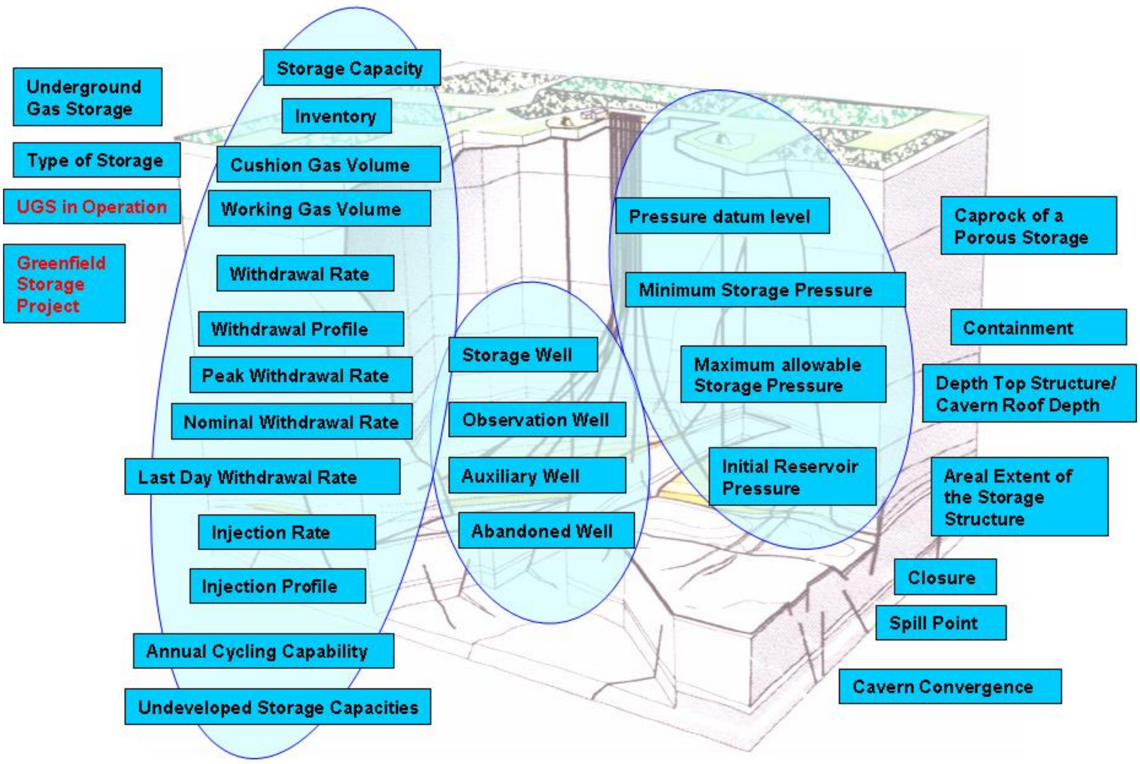


Figure 8 The Glossary

The English glossary is included in Appendix 9. The enclosed glossary has been translated in other languages (Russian, Italian, Ukrainian, French, German, Japanese, Danish, Serbian, Portuguese, Slovak, Czech, Croatian and Chinese) and are also available directly at UGS Web application http://ugs.igu.org/

1.3.4 Data collection

The countries were grouped into the following regions respecting IGU classification:

- North America
- Latin America & Caribbean
- Europe
- Commonwealth of Independent States
- Middle East
- Asia
- Asia Pacific
- Africa

The data are representing the status of 2013; however, significant effort was dedicated by SG members to update them to 2014 status. They are included, apart from some adjustments, as received. The database is still incomplete for some categories and regions especially without participation in SG 2.1 so the study does not claim to be complete. Applied units are defined in the Appendix 5. As SG2.1 will continue in the next triennium, the existing database will be broadened and updated further.

Storage facility data were received from companies via the application at IGU website. 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 (People's Republic of China) and Middle East (Iran) due to participation of Chinese and Iranian representatives. Direct replies from Latin America (Argentina) and Asia Pacific (Australia and Japan) have also been received.

Taking into account a huge number of storage operators in North America, different approach was applied. Those data were gathered and delivered by a representative of AGA from their 2013 Storage survey and were complemented by data from public sources. Taking into account commercial nature of AGA data collection, those data are used only in aggregate form and they are available only in limited details.

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 public sources (e.g. Gas Storage Europe investment database for Europe).

1.4 Results

1.4.1 Underground Gas Storage in the World

Total WGV is 393 bcm [2] without taking into account long term strategic reserves[3], operated in about 715 storage facilities all over the world with the peak withdrawal rate of some 6 656 mcm/d[4]. WGV has been developed steadily over years as depicted in Figure 9. From original needs to optimally design transmission pipelines and their load factor for transporting gas from production fields to consumption centres, UGS have expanded substantially.

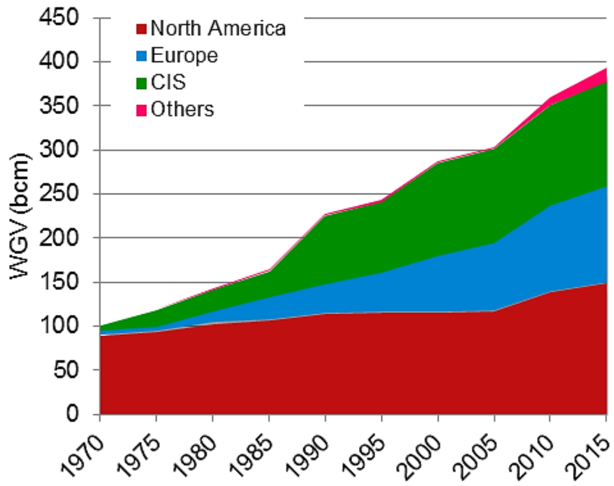


Figure 9 Trends WGV World

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[2] *the term WGV in the study represents capacity and not its utilization so WGV and actually booked and utilized volumes may differ*

[3] *Russia declares 38,12 bcm long term strategic reserves which represents gas which might be used under special circumstances with existing infrastructure*

[4] *This number is approximate as some data were missing at the time of study preparation for smaller storage facilities representing ca 10 bcm especially in North America*

Nowadays, UGS fulfils the following roles:

- Balancing seasonal, weekly, daily, hourly fluctuations in gas consumption
- Provision of Security of supply
- Transmission and distribution grids balancing&optimization
- Optimization gas production

Since gas market liberalization UGS has been recognized as a tool for:
- Trading and arbitration
- Insurance against gas price movement.

1.4.2 WGV as per storage type

WGV of respective storage types as of 2015 is depicted in Figure 10. Storage type distribution as per WGV from the previous triennium 2012 is depicted in Figure 11 for comparison.

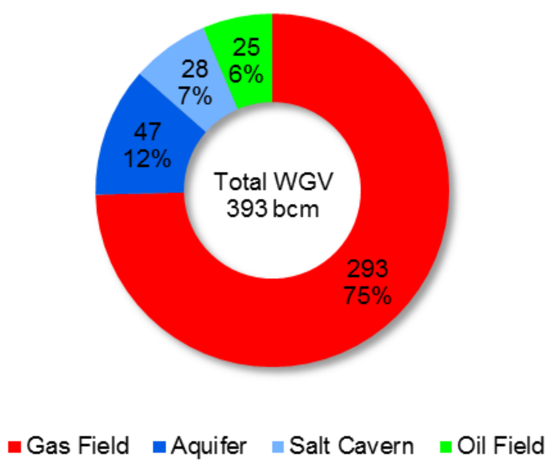

Figure 10 WGV by storage types 2015

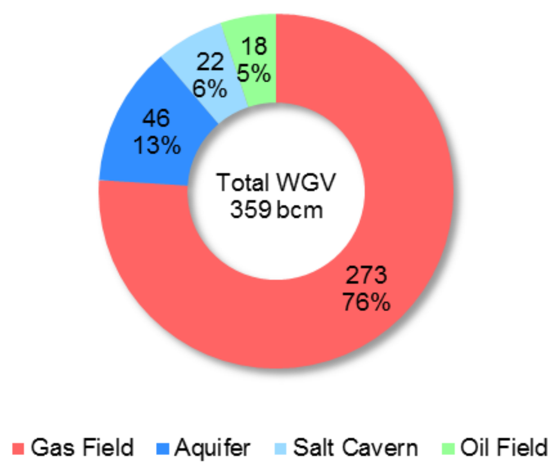

Figure 11 WGV by storage types 2012

Moreover, PWR distribution per storage type over trienniums is depicted in Figure 12 and Figure 13.

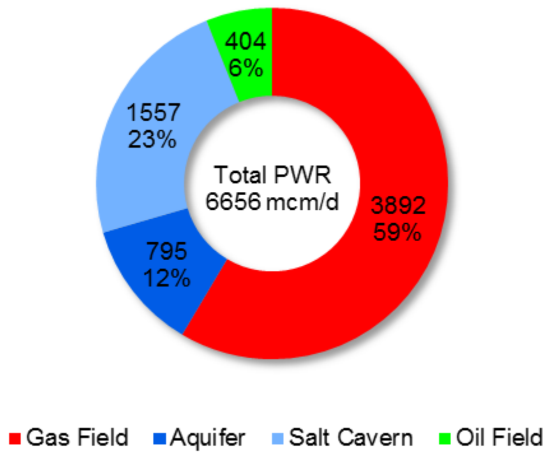

Figure 12 PWR by storage types 2015

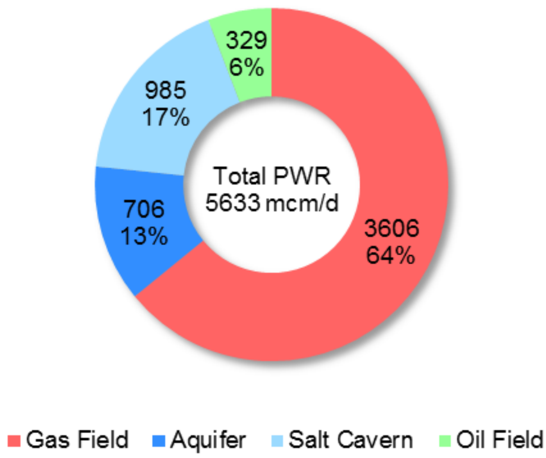

Figure 13 PWR by storage types 2012

The most WGV is developed **in gas fields representing 75% part (293 bcm) but gas fields take only 59% if PWR is considered**, followed by aquifers 12% (47 bcm). This corresponds with their lower deliverability thus predetermining them mostly for seasonal balancing. **Salt caverns have 7% (28 bcm) share per WGV but 23 % per PWR which demonstrates their high deliverability** and their utilization for flexible storage. Oil fields have the same 6% (25 bcm) share of WGV and PWR.

Other types as rock caverns and abandoned mines represent negligible WGV are just demonstrating that progress in technology enables building storages also in geologically unfavourable site. There are only two reported rock caverns worldwide used for storing of gas in gaseous state (Haje in Czech Republic operated by RWE Gas storage, s.r.o. with WGV 75 mcm and lined rock cavern Skallen in Sweden operated by E.ON Swergie with WGV 9 mcm) .Concerning abandoned mine there is only one reported: Burggraf-Bernsdorf in Germany operated by ONTRAS Gastransport GmbH with WGV 3,4 mcm.

There was no significant change in storage type distribution per WGV reported over trienniums as differences represent only 1-2 % changes per some storage types. In absolute terms WGV increased (+34 bcm) over trienniums with the most substantial increase in gas fields (+20 bcm), oil fields (+7 bcm) and salt caverns (+6 bcm). This fact is illustrated in Figure 14

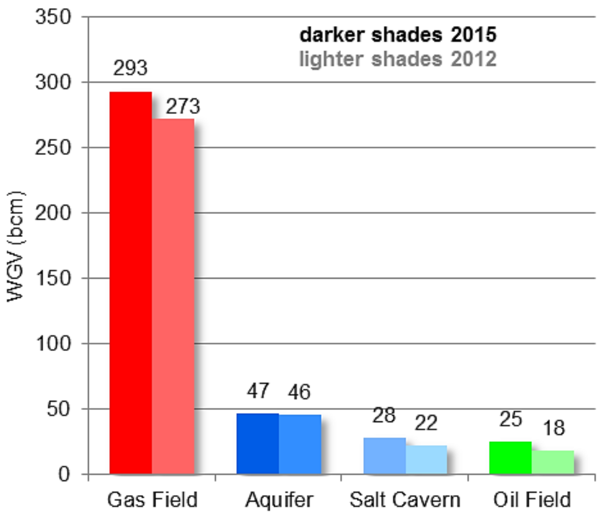

Figure 14 Comparison of WGV by storage types 2015 vs 2012

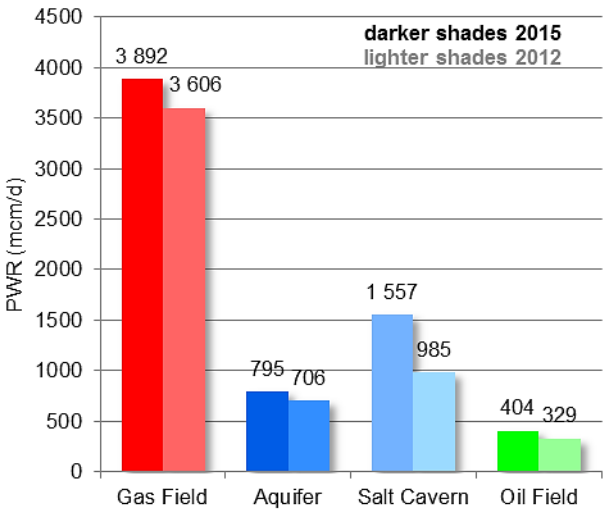

Figure 15 Comparison of PWR by storage types 2015 vs 2012

However, if PWR development is considered, there is a clear evidence that PWR of salt caverns has grown at the fastest pace (+572 mcm/d), followed by gas fields (+284 mcm/d). This furthermore underlines a growing importance of flexibility triggering demand for higher deliverability which salt caverns fit due to its natural characteristics.

Different storage types have different natural characteristics which can be illustrated in Figure 16. Porous storages have large WGV but lower deliverability while salt caverns correspond for smaller portion of WGV but with higher deliverability.

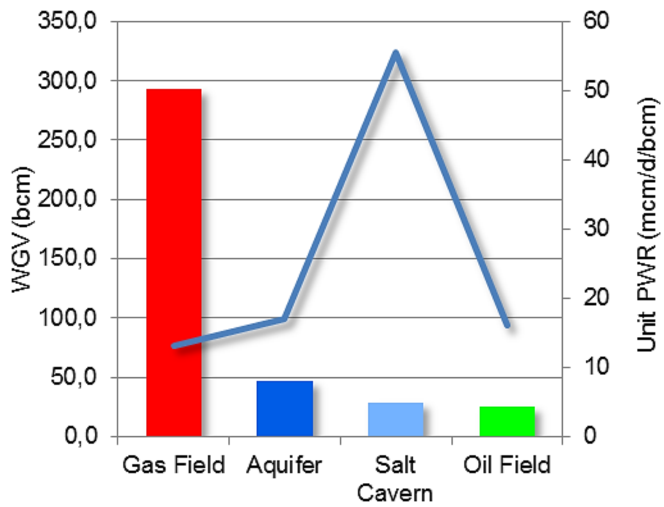

Figure 16 Unit PWR by storage type

However, if Unit PWR is considered the differences are more visible in deliverability of different storage types: on average 13 mcm/d/bcm stands for gas fields while acquirers and oil fields have 17 and 16 mcm/d/bcm respectively. On the other hand salt caverns show on average 55 mcm/d/bcm.

1.4.3 WGV as per IGU regions

Development of WGV as of 2015 according to IGU regions is depicted in Figure 17 broken down into respective IGU regions. The previous triennium 2012 is depicted in Figure 18 Total increase of WGV of 34 bcm is reported over trienniums from 359 bcm up to 393 bcm representing 9% growth.

The most growth in absolute terms comes from Europe and North America (11 bcm). Both regions are gas developed markets where new capacity comes on stream rather as a result of decisions made in past than demand for new WGV. Significant contribution is reported also from CIS (5,3 bcm) with main contributor Russia and Middle East (4,6 bcm) with Iran as a single representative developing gas flexibility for its main consuming regions.

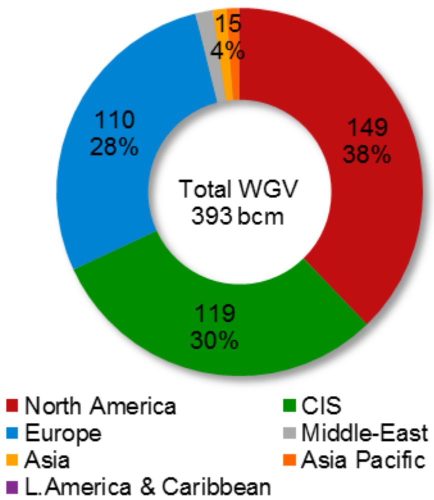

Figure 17 WGV by regions 2015

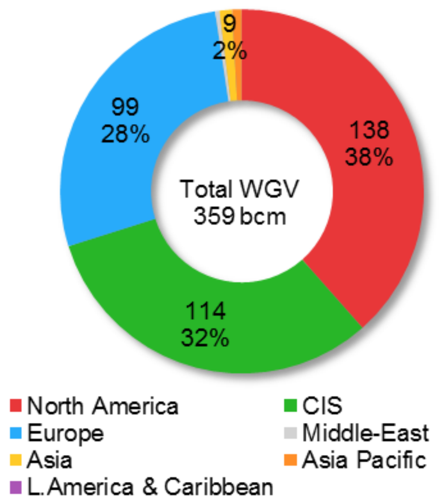

Figure 18 WGV by regions 2012

1.4.4 PWR and Unit PWR as per IGU regions

Corresponding increases of PWR and its distribution over regions are depicted in Figure 19 for 2015 triennium and Figure 20 for 2012 respectively.

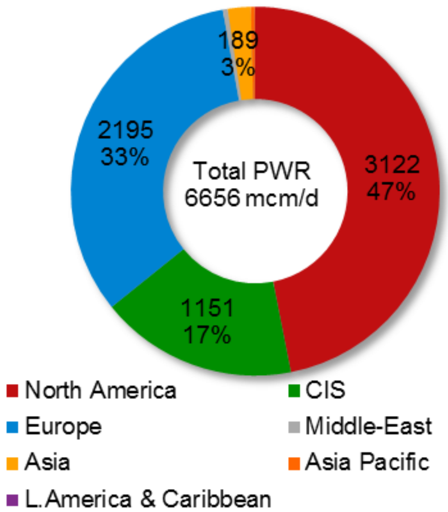

Figure 19 PWR by regions 2015

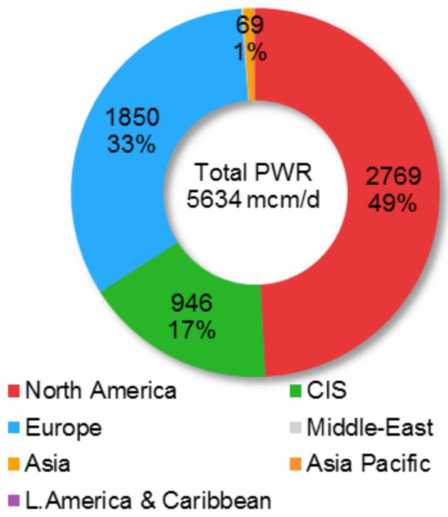

Figure 20 PWR by regions 2012

Total increase of PWR of 1022 mcm/d is reported over trienniums from 5634 mcm/d up to 6656 mcm/d representing 18% growth. The most increases are related to North America (353 mcm/d), followed by Europe (345 mcm/d), CIS (205 mcm/d), Asia (95 mcm/d) and Middle-East (20 mcm/d). Comparing 9% growth in WGV to 18% in PWR demonstrates progressive trends toward importance of deliverability of storages; however its significance differs in respective regions.

Analysing deliverability requires data going beyond scope of this study so a simple assessment was carried out using term Unit PWR which represents ratio of PWR to WGV in mcm/day/bcm: the higher figure means the higher deliverability of storages and vice versa. Analysis of Unit PWR per IGU regions is depicted in Figure 21. Based on this, we might differentiate among more deliverable regions (ca 20 mcm/day/bcm) represented by North America and Europe and[5] less deliverable regions (ca 10 mcm/day/bcm and less) represented by CIS, Asia and others.

Comparing change of Unit PWR over trienniums shows that in more deliverable regions an investment in new capacity slightly increases deliverability further (North America and Europe adding ca additional 1 mcm/day/bcm) while other regions concentrate so far more on development of WGV which means in certain case also decrease of Unit PWR but on the other hand it might be temporary due to phases of investments.

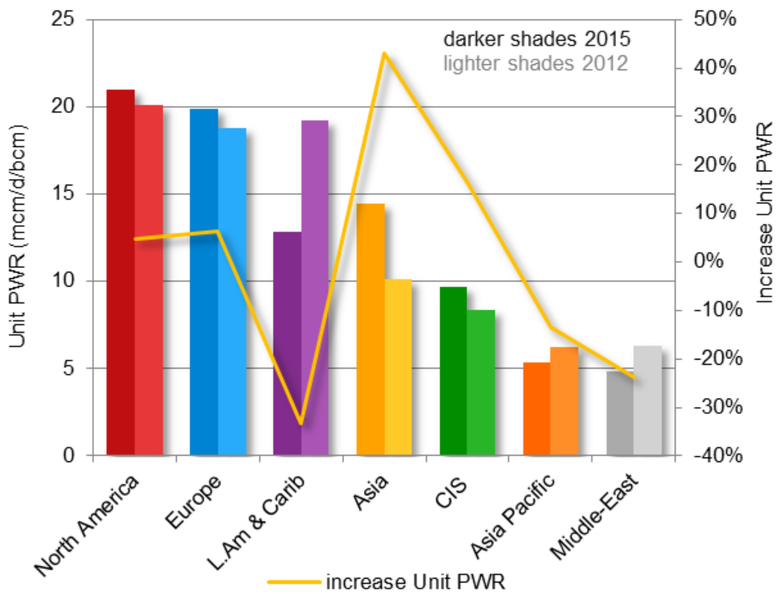

Figure 21 Unit PWR by regions

Increase of Unit PWR in relative terms shows growth in People's Republic of China (> 40%) and CIS (ca 15% mainly Russia). However, looking at overall figures there is still a gap in absolute Unit PWR (e.g. CIS 9,6 vs Europe 19,8 mcm/day/bcm) as depicted in Figure 21. Concerning Latin America's drop in Unit PWR, this was caused by increase of WGV by 50 mcm without increase of PWR in only one existing storage facility Diadema in Argentina.

1.4.5 Projects as per IGU regions

Projects summary in respective regions are summarized in Appendix 10. Totally there were reported plans for 60,7 bcm of WGV in various stage of planning. Greenfield development still represents significant part amounting to 67% while expansion of existing facilities represents approx. 33%. Based on their volatile nature there is presented only general information. Level of details is varying and this part needs further work in next triennium.

1.4.6 WGV by nations

WGV of countries with known underground gas storage facilities in operation is summarized in Table 2 which gives the WGV status in current and previous trienniums. No new country has expanded the list.

---

[5] *Latin America is not a significant one as there is only one UGS with limited WGV 150 mcm*

Nation	No. of UGS Facilities	WGV (bcm)	PWR (mcm/d)
USA	419	128,10	2891
Russia[6]	23	70,40	741
Ukraine	13	32,18	264
Germany	51	22,90	663
Canada	61	20,65	231
Italy	11	17,11	331
Netherlands	5	12,81	263
France	16	12,78	274
Austria	9	8,20	94
Iran	2	6,00	29
Hungary	6	6,49	80
Uzbekistan	3	6,20	56
United Kingdom	8	5,27	152
People's Republic of China	21	4,78	135
Kazakhstan	3	4,65	34
Azerbaijan	3	4,20	14
Czech Republic	8	3,53	67
Spain	4	3,37	31
Slovakia	3	3,32	39
Romania	8	3,11	34
Australia	6	2,91	17
Poland	9	2,75	45
Turkey	1	2,66	20
Latvia	1	2,30	30
Japan	5	1,15	5
Belarus	3	1,12	31
Denmark	2	1,02	25
Belgium	1	0,70	15
Croatia	1	0,56	6
Bulgaria	1	0,55	4
Serbia	1	0,45	10
New Zealand	1	0,27	1
Portugal	1	0,24	7
Ireland	1	0,23	3
Argentina	1	0,15	2
Armenia	1	0,14	9
Kyrgyzstan	1	0,06	1
Sweden	1	0,01	1
Total	715	393	6 656

Table 2 WGV by nations

[6] *Russia declares 38,12 bcm long term strategic reserves which represents gas which might be used under special circumstances with existing infrastructure*

It is obvious that US operates the highest WGV followed by Russia, Ukraine and Germany. WGV by countries is visualized in Figure 22 and Figure 23. Each country has a different driver for WGV development. For US and Canada it is mostly completion of past projects. Significant growths in relative terms was reported from Iran where storage development continuous further.

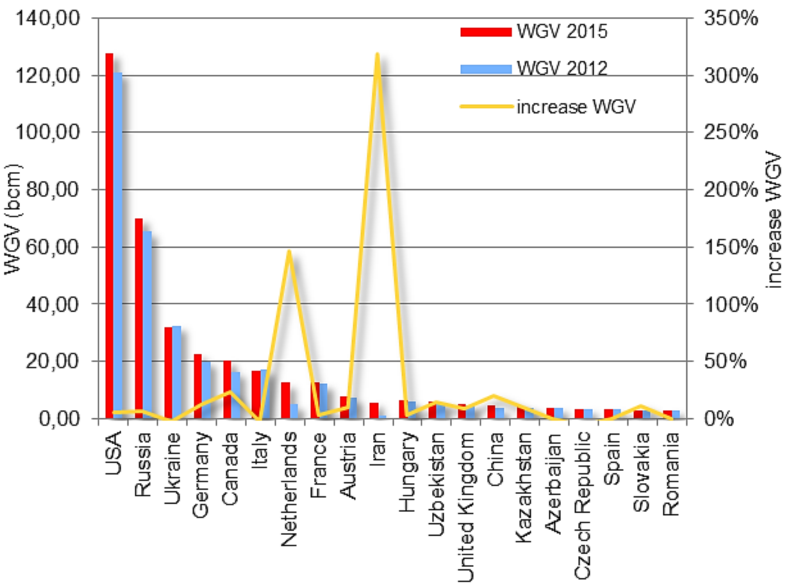

Figure 22 WGV by nations > 3 bcm

Developments in Netherlands are linked with UGS Bergermer which has been coming on stream right now. A part of its WGV was contracted by Gazprom in exchange of cushion gas as GAZPROM's previous strategy to keep 5% of WGV of imported gas in the territory of Europe. In Germany growth is associated with caverns and its believed role in supporting flexibility for growing renewables.

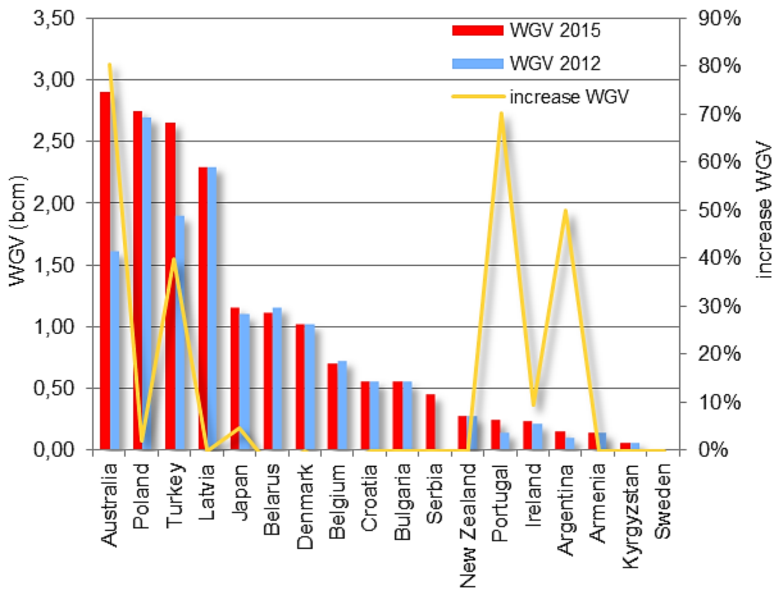

Figure 23 WGV by nations < 3 bcm

Simplified WGV distribution by storage type per porous and caverns are given in Figure 24 and Figure 25. Germany has striking share of caverns over its WGV which demonstrates also increased Unit PWR. Usually nations with caverns have higher Unit PWR than others. It is obvious nations with only caverns in their storage portfolio reach the highest Unit PWR but only for a limited volume.

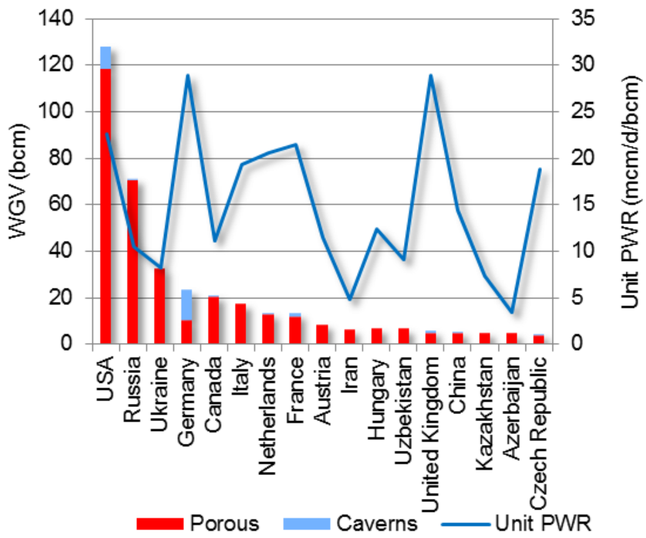

Figure 24 WGV vs Unit PWR by nations >3,5 bcm

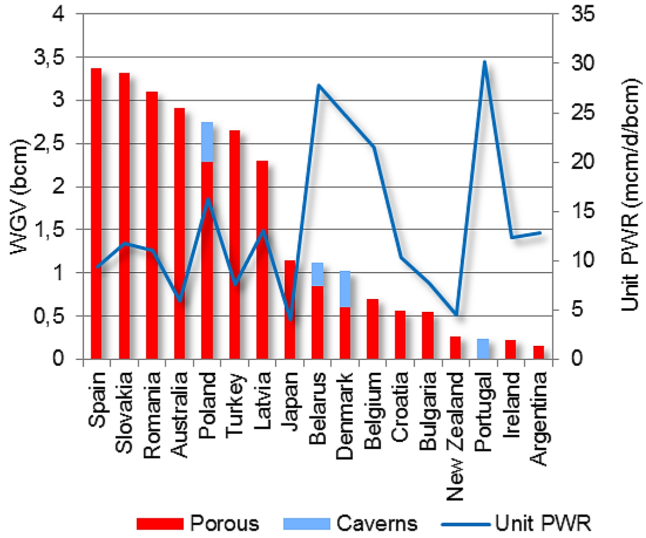

Figure 25 WGV vs Unit PWR by nations <3,5 bcm

The ranking looks different if withdrawal rates are taken into consideration in absolute terms. The leader is US followed closely by Russia and Germany, later by Italy and France. Details are given in Figure 26.

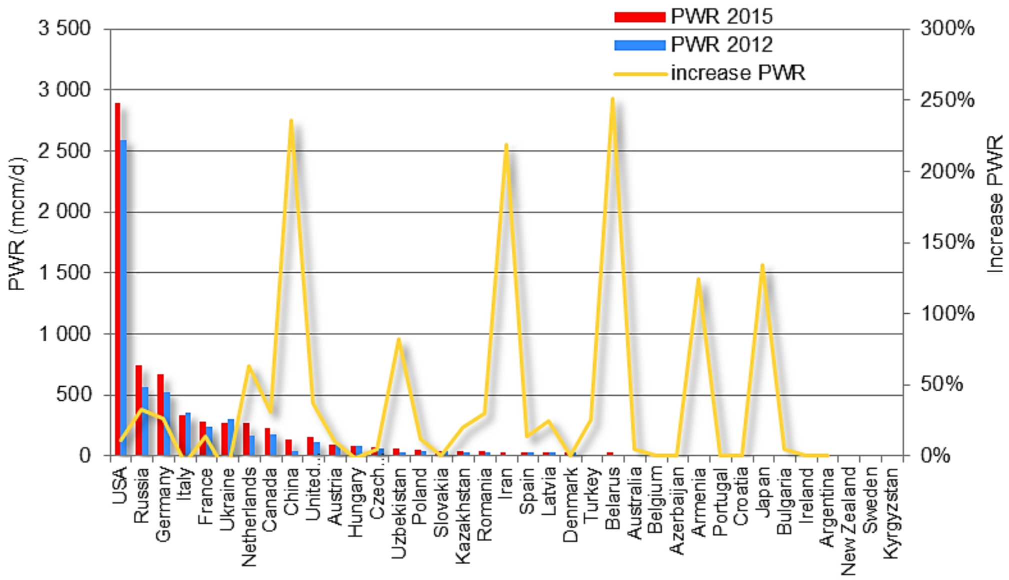

Figure 26 PWR by nations

Figure 27 offers interesting comparison of specific WGV which is WGV per number of storage facilities in given countries over trienniums. High specific WGV is typical for countries with large WGV and small numbers of storage facilities as Russia, Iran, Netherlands, Ukraine, Turkey and Latvia are an example of country with one storage facility with relatively high WGV.

On the other hand there are countries with small WGV fragmented in plenty of storage facilities as US and People's Republic of China or countries with one storage facility with a limited size as Sweden, Kyrgyzstan, Armenia, Argentina, Ireland, Portugal, New Zeeland etc.

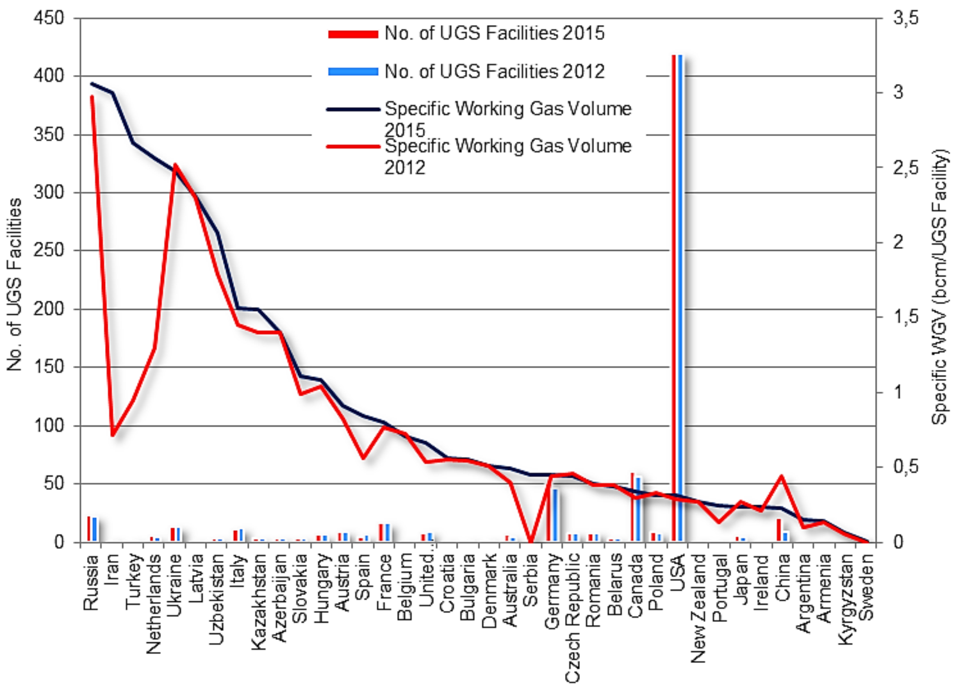

Figure 27 Specific WGV and No. of UGS by nations

For comparison there are depicted also data from the previous triennium showing addition of new projects to Specific Working Gas Volume of a given country.

1.5 Regional trends in UGS

1.5.1 Gas Storage Europe

1.5.1.1 Current storage market situation Europe

Europe is the 3rd biggest region concerning WGC after North America and CIS. Together with North America it is a region with the highest Unit PWR ca 20 mcm/d/bcm of WGV as high flexibility is demanded by liberalized gas markets. Storages in Europe are distributed across the whole continent as illustrated in Figure 28.

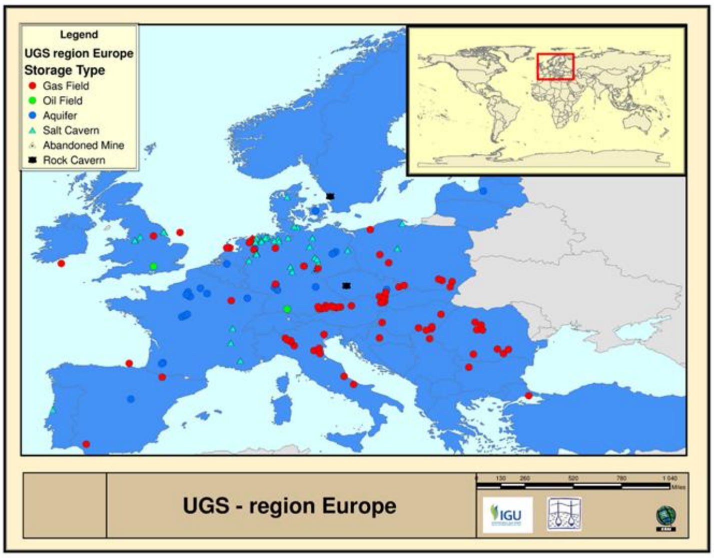

Figure 28 Location of storages - Europe

1.5.1.2 WGV

WGV increase over years is depicted in Figure 29 which is about 22% of European gas consumption.

Despite the economic crisis WGV has increased since 2010 (+10bcm) but pace of increase has slowed down compared to period 2005 – 2010 (+ 20 bcm). There are several reasons behind on demand side as stagnation of gas consumption, investment into insulations of R&C sector which due to high seasonality is one of the biggest gas consumer, decline of gas power generations just to name a few. Increased infrastructure development and its interconnectivity supported by public funding did not help either.

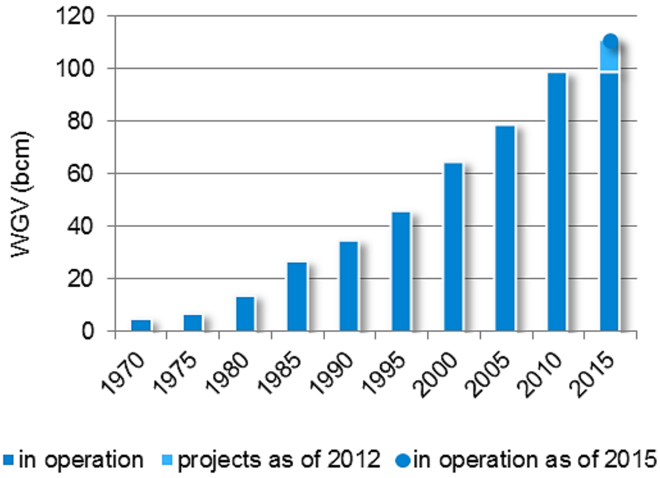

Figure 29 Trends WGV Europe

Moreover, addition of new infrastructure and the same time decrease of consumption caused lower average load factor. Compared to previous time storages experienced growing competitiveness on flexibility market

Overall increase of WGV (+11 bcm) over trienniums as per storage type is depicted in Figure 30 and Figure 31 respectively.

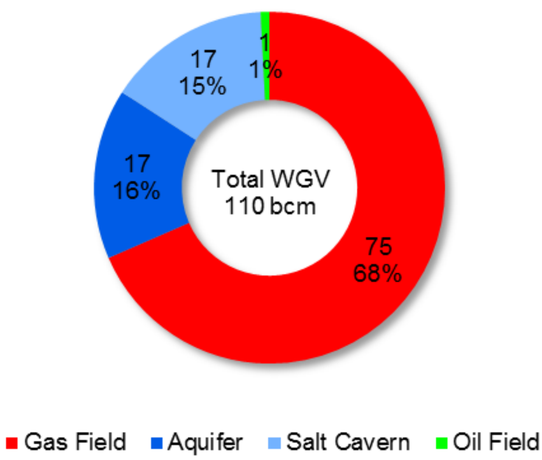

Figure 30 WGV by storage types - Europe 2015

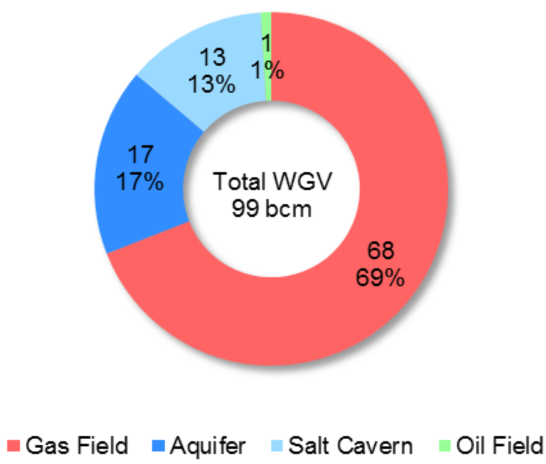

Figure 31 WGV by storage types - Europe 2012

The most of WGV increase comes from porous reservoir (+7 bcm) followed by salt caverns (+4 bcm).

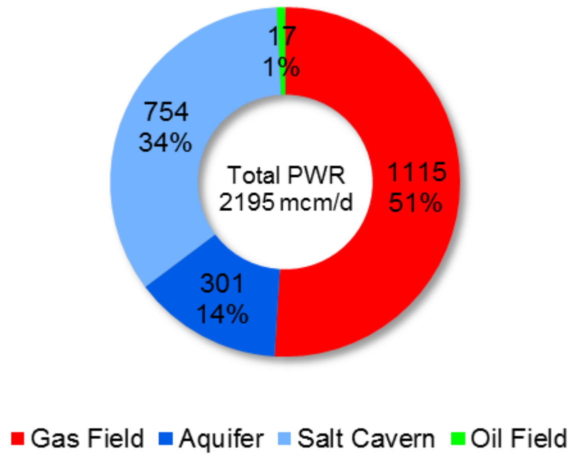

Figure 32 PWR by storage types - Europe 2015

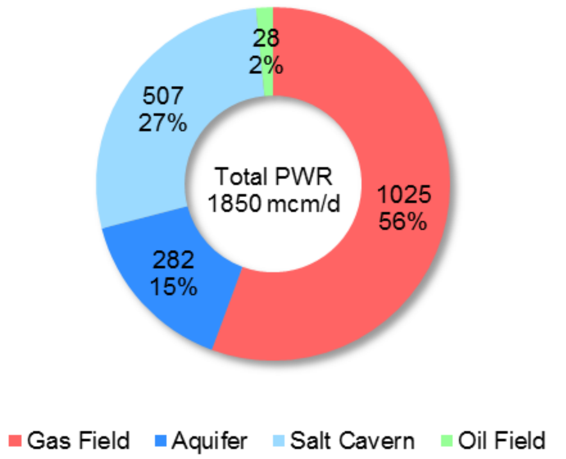

Figure 33 PWR by storage types - Europe 2012

PWR over trienniums grew by 345 mcm/d which represents 19% increase. However, PWR of salt caverns has grown by 248 mcm/d and currently deliver 34 % (754 mcm/d) of overall PWR at 15% share on overall WGV (17 bcm). Those increases are results of previous investment decisions and due to longer lead time this capacity is coming on stream. Furthermore, investments in expansion aimed at enhancement of deliverability are experienced.

1.5.1.3 Current storage market situation Europe

1.5.1.3.1 Short term trends

In the next few years we can see several trends impacting storage demand. These trends show a decline in storage demand in short term in contrary to increasing import dependence and decreasing production swing. If current market conditions continue it is more likely that there will be more divestments and mothballing of low performance storages with parameters not reflecting current demand from market. But situation differs among regions as for example South-eastern Europe still shows very low storage capacity.

1.5.1.3.2 Gas Supply

Indigenous production in Europe is declining.

The imports will be both through pipeline and LNG. The increased import dependence of the European gas market will have implications for security of supply. The decline in domestic production is associated with a decline in swing production. This decline in swing production is expected to stimulate the demand for (seasonal) storage.

The effect of growing LNG imports on storage needs is two-fold. On the one hand supply of flexible LNG reduces the need for storage. But on the other hand the supply of LNG is not guaranteed. When the global LNG market gets tighter, the risk of non-delivery gets higher. This could increase the need for storage for security of supply purposes. For illustration LNG and UGS supply & supply share during winter time for 5 years is given in Figure 34[7].

[7] *Based on ENTSOG Winter supply outlook 2014/15*

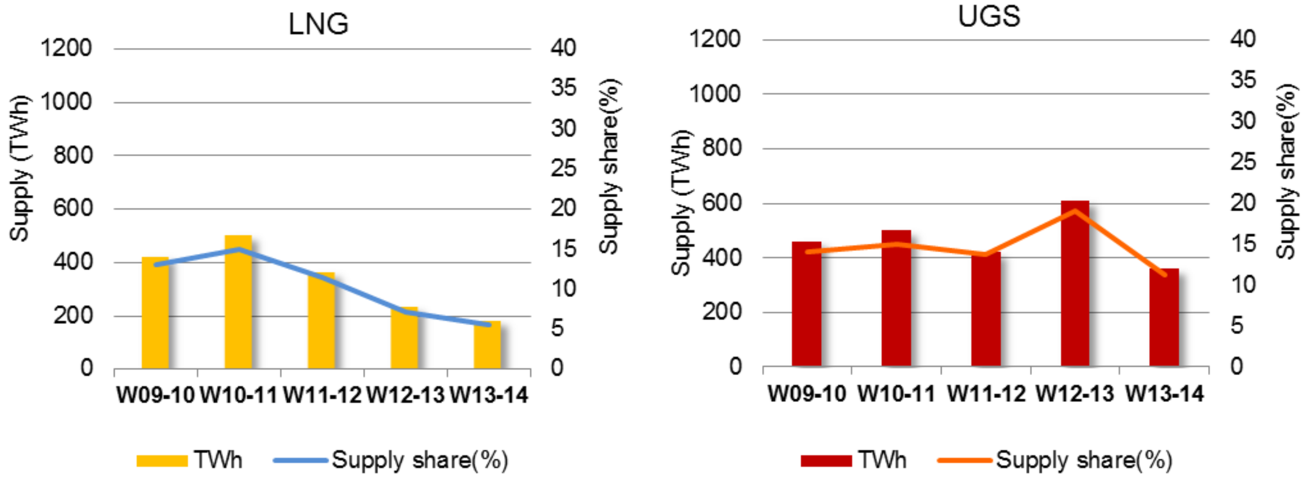

Figure 34 LNG and UGS supply in winter

Looking at W12-13 were extended cold snap hit Europe in February and March supply share of LNG was only 5% compare to 20% share of UGS. This demonstrates less LNG flexibility on unpredictable demand. On contrary UGS supplied gas on demand flexibly ramping up its withdrawals.

1.5.1.3.3 Infrastructure

In the past there was a lack of interconnectivity and reversibility in the European network. There were also congestion issues on several points. These issues greatly contributed to the gas crisis of 2006 and 2009. Since then numerous interconnections have been build or are planned. The greater connectivity with flexible storages improves security of supply for the European market and enhances liquidity of gas market.

1.5.1.3.4 Storage Usage

Spot markets show low volatility and seasonal spreads. This greatly reduces the value of storage from a trader’s perspective. However, valuation of storage is more complex as traders are not sole users of storage capacity. Furthermore, spreads are just market estimates on future gas prices at given time. They do not take into account an overall gas system efficiency due to having storage right at consumption centres and do not value storage security of supply role. As it was several times confirmed gas storage is one of the best tools for physical flexibility even in case of gas crisis.

Moreover, transmission tariffs to and from storage do not always recognize the role of storage in supporting the transmission network. Though lower transmission tariffs for storage are supported by framework guidelines they are not always recognized by regulators. High tariffs to and from storage reduces the incentive for storage usage.

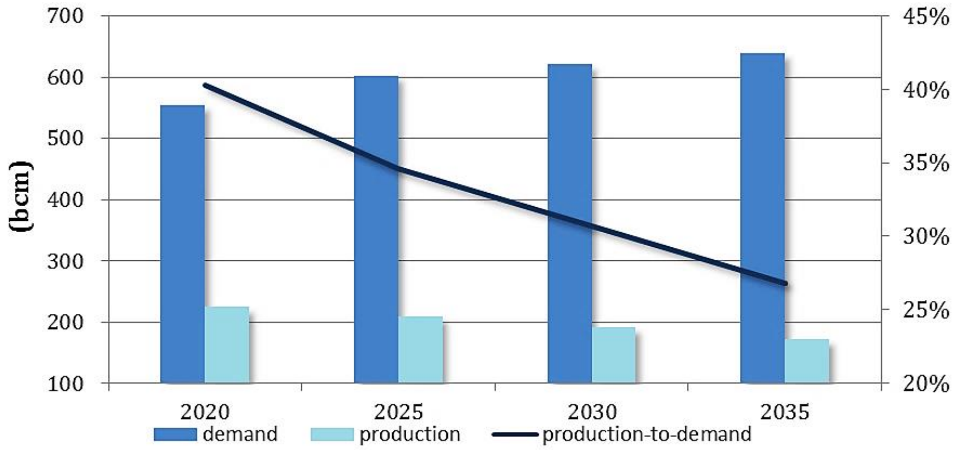

Figure 35 Gas demand and production

1.5.1.3.5 Investment Climate

There are also some factors hindering the investment in new storage capacity. The current economic conditions are poor and not favourable to investment in storage. The low volatility and seasonal spreads do not support investments on economic grounds. Permitting is often also a hurdle to investment. As permitting is often a long and difficult process for new storage projects, this may hinder the development of new storages even where they may be needed and potentially create lack of storages in the future.

1.5.1.3.6 Long term trends

The long term trends show some upward potential for storage demand, even though the size and timing are uncertain. Part of this potential is on the basis of security of supply as gap between indigenous productions and consumption tends to further expand in the future. In the current market we see very little incentive to actually pay for storage to cope with security of supply issues. The market signs will have to become much clearer before we can expect any sizable investments in storage. Due to the long lead times in storage development this could lead to a period of shortage in storage capacity before new developments come online.

According to IGU analysis there is assumed only 27% share of indigenous production in 2035. The development of shale gas and biogas may reduce decline somewhat but not significantly. Imports are therefore expected to increase to compensate for the decline in production. Increasing gap between indigenous production and demand for next 30 years is illustrated in Figure 35.

1.5.1.3.7 Gas demand

For the medium to long term there could be some growth in gas consumption but it is expected to be much slower than in the past. Two main drivers for future growth that can be identified are gas fired power generation and the development of the gas market in southeast Europe. Although gas fired power generation is currently under pressure there are some developments supporting growth in the future. The phase-out of nuclear power plants, for example in Germany, could increase the demand for gas fired power generation. Environmental constraints on coal through EC regulation, such as the LPCD (large combustion plant directive) forcing closure of aging coal plant will decrease the share of coal in the generation mix, leaving room for gas fired generation to grow. The growth of renewable energy can also be an opportunity. Flexible gas fired power plants can act as back up for intermittent energy sources. Gas consumption in southeast Europe, including Turkey, is expected to increase because of the development of the gas market in this area through new production and import pipelines.

Overall these factors and end up to an outlook of modest growth in total demand driven by the needs of the power sector. In the residential sector consumption is expected to remain flat, with decreases in mature markets and rising demand in new regions. The demand for the industrial sector is also expected to remain flat.

1.5.1.3.8 Storage Demand

There are some positive trends for the future that could boost storage demand. In trends for gas demand we saw that there is a trend for more gas fired power generation in the future. This would entail mostly peak demand and flexible power generation. This would therefore trigger a higher demand for peak storage as well.

Security of supply is a growing issue as the import dependence of Europe increases. Although storage is not the only tool available to secure supply it proved to have the highest contribution in case of interruption or reduction of supply. The N-1 standard of Regulation 994/210/EC has driven several countries to invest in new storage capacity as they cannot cope with an interruption of their largest source of supply. There are several reasons behind security of supply issue:

- Decline in indigenous production in Europe
- Modest growth in gas consumption in the future
- Import from distant regions

For illustration in Figure 36, coverage of gas demand from different sources in average and the peak day during season 2012/2013 is depicted therein. It shows that on average in winter season UGS in Europe are covering ca 18% of gas demand and increasing it up to 31% in Peak day. Share of LNG was just 7% in season and 9% on Peak day. Summing up storage is a unique source of physical flexibility having flexibility and gas commodity at the time of high gas demand in given region provided storage capacity is utilized by market players.

This vital role of storages was demonstrated during all gas crisis or harsh winters time which Europe faced in the last decade.

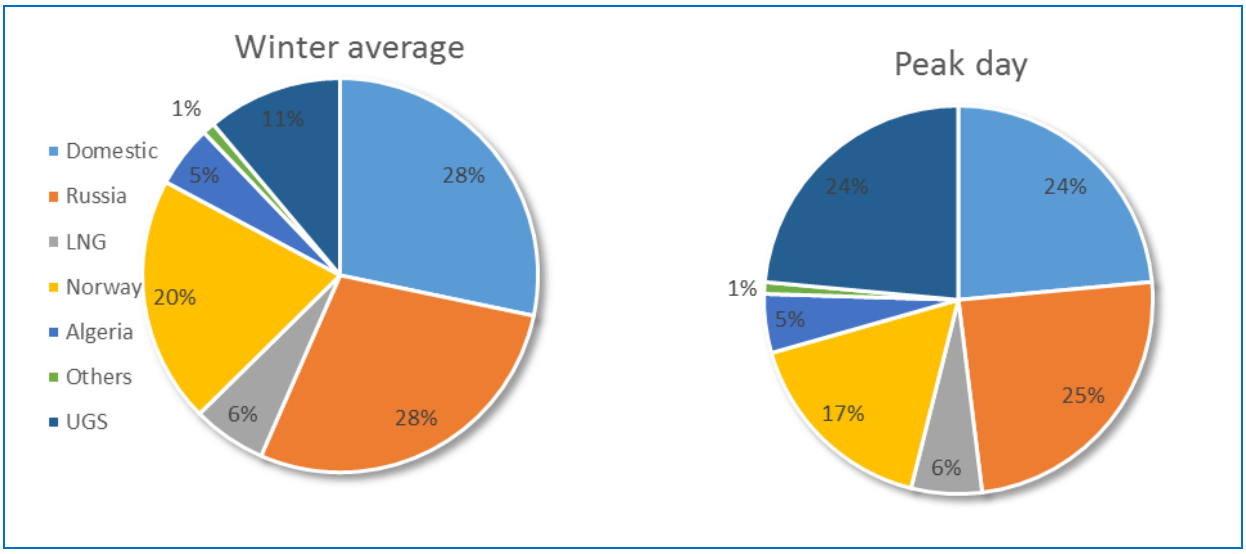

Figure 36 Gas demand from different sources

1.5.2 Gas Storage CIS

Nations of CIS are using gas significantly and they have a long tradition of the storages usage mainly for gas grid operation and seasonal balancing. Based on favourable geological characteristic storages show relatively high representation of porous storages with high WGV but limited PWR. Deliverability stays its major challenge though there is a gradual improvement. Storages and their distribution are given in Figure 37.

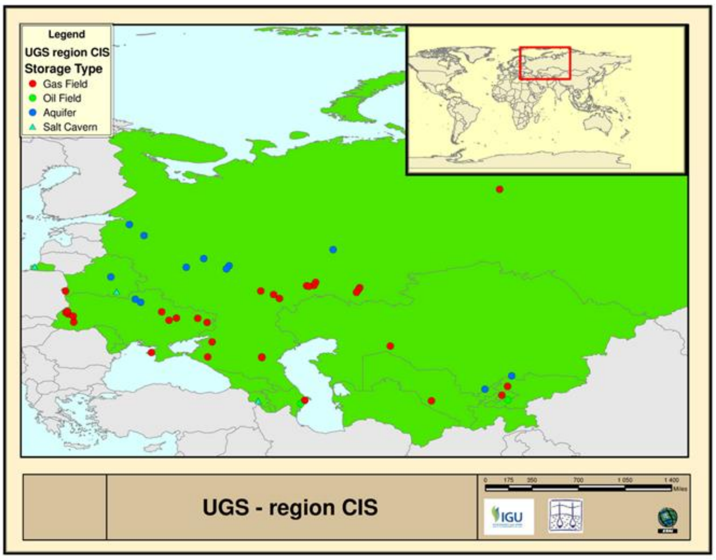

Figure 37 Location of storages - CIS

WGV has been developed steadily but with slowing rate. As there is no reward for capacity market, storage development is in hands of national gas vertically oriented gas companies or ministries which supervise their activities.

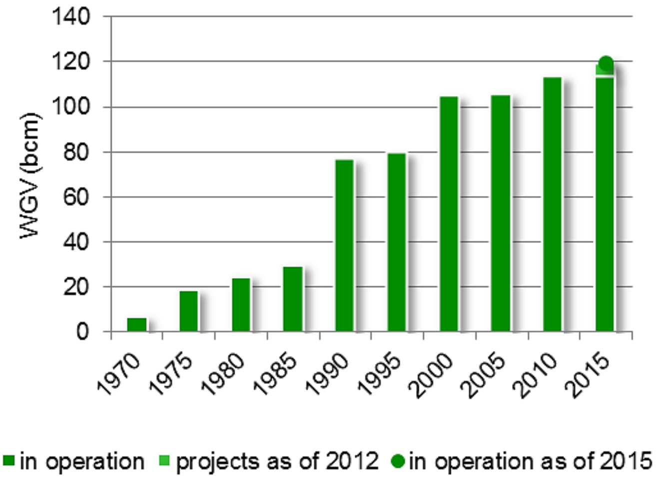

Figure 38 Trends WGV CIS

Most of storages especially in Russia were built in order to support the largest grid of pipeline network Unified Gas Supply System of Russia. Moreover, storages in Ukraine and Belarus were designed in order to support gas export to Europe.

1.5.2.1 Storage capacity

Overall increase of WGV (+5 bcm) over trienniums as per storage type is depicted in Figure 39 and Figure 40 respectively.

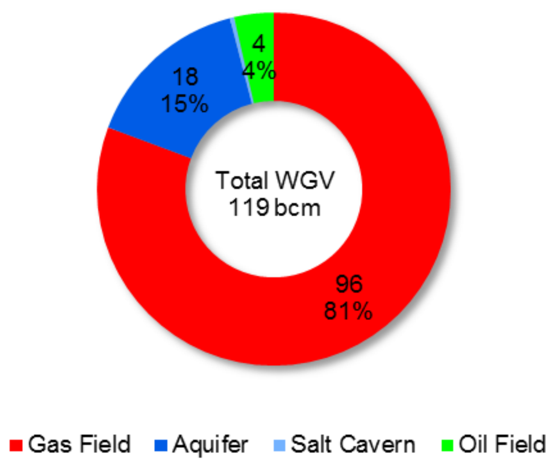

Figure 39 WGV by storage types CIS 2015

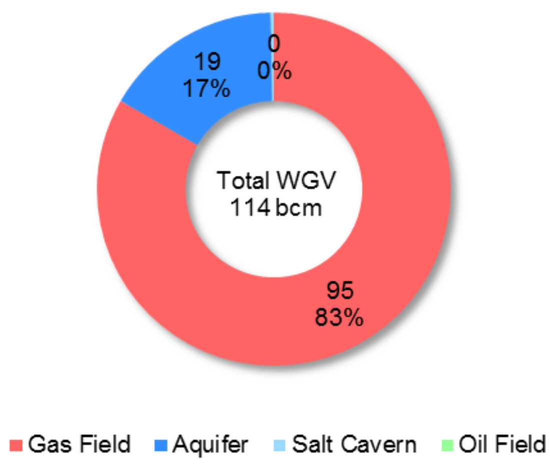

Figure 40 WGV by storage types CIS 2012

Nearly all WGV increase comes from porous reservoir. Concerning salt caverns, a new storage have been added in Kaliningrad enclave belonging to Russia. Together with Mozyrskoe in Belarus and Abovskoe in Armenia there are currently ca 460 mcm of WGV with nearly 34 mcm/d of PWR developed in salt caverns.

PWR over trienniums grew by 206 mcm/d which represents 22% increase. A substantial part of growth was associated with gas fields and aquifers (+153 mcm/d) followed by salt caverns (+30 mcm/d). Comparing growth of WGV (+5%) to PWR (+22%) over trienniums illustrates focus on increased importance of deliverability known for its relatively low deliverability compared to WGV.

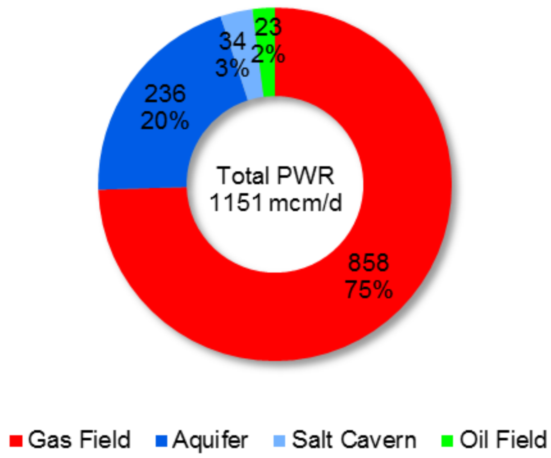

Figure 41 PWR by storage types CIS 2015

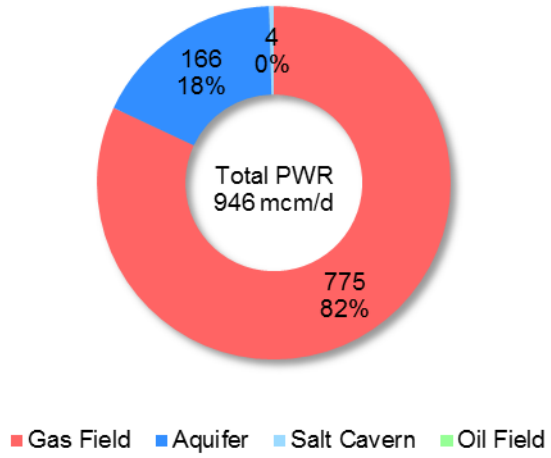

Figure 42 PWR by storage types CIS 2012

1.5.2.2 Future trend

CIS gas markets are not liberalized so state owned vertically oriented gas companies usually are in charge of gas supply and gas infrastructure operation. As there is no real gas market, demand on future storage needs is defined by state companies and/ or governments. As several winters with cold snaps showed there is still a need for deliverability rather than WGV in order to meet peak residential demand

While WGV is comparable with other big markets as North America and Europe, Unit PWR is still lagging behind reaching only a half value of 20 mcm/d/bcm.

New projects which are supposed to come on stream mostly in Russia till 2020 will bring additional ca 12 bcm WGV with above average deliverability. Interestingly, ca 20% of WGV will come from salt caverns.

1.5.3 Gas Storage North America

North America (as represented by Canada and the US) represents the region with the highest amount of WGV worldwide amounting to 149 bcm. At the same time, this is also the most developed gas market where storage has had more than 100 years of tradition. The US and Canada are relatively large countries with well-developed storage which covers and serves the demands of their markets. Due to geological characteristics and geographic and historical conditions, WGV is distributed across 419 storage facilities with relatively small WGV per facility as compared to storage facilities in some other countries. Most of them

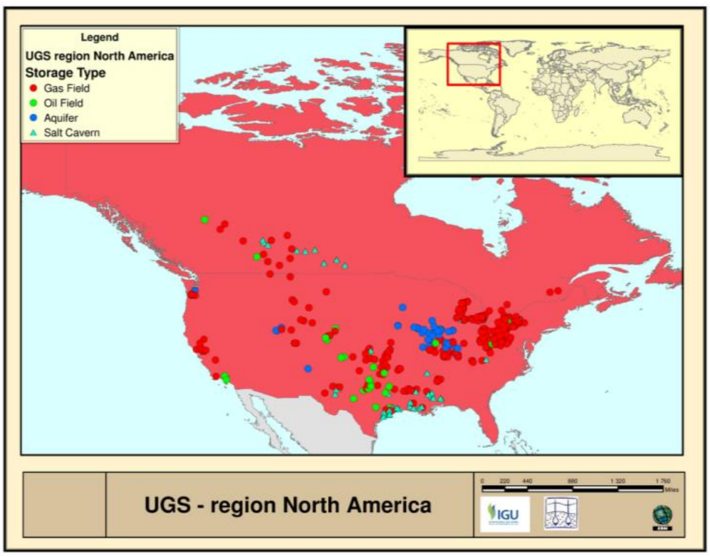

Figure 43 Location of storages - NA

(64 bcm) are concentrated in Eastern regions which is the greatest consumption centre in US (Figure 43).

1.5.3.1 Storage capacity

Overall increase of WGV (+11 bcm) over trienniums as per storage type is depicted in Figure 44 and Figure 45 respectively.

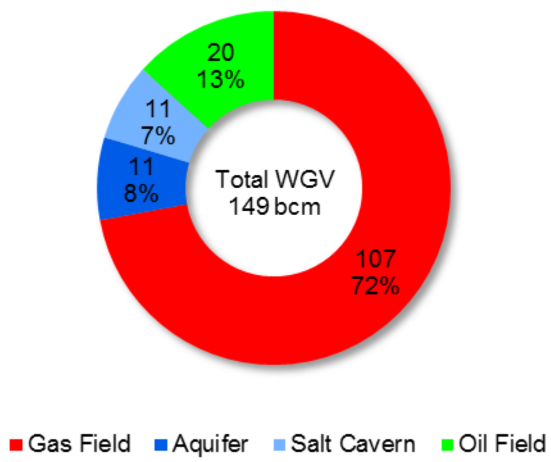

Figure 44 WGV by storage types NA 2015

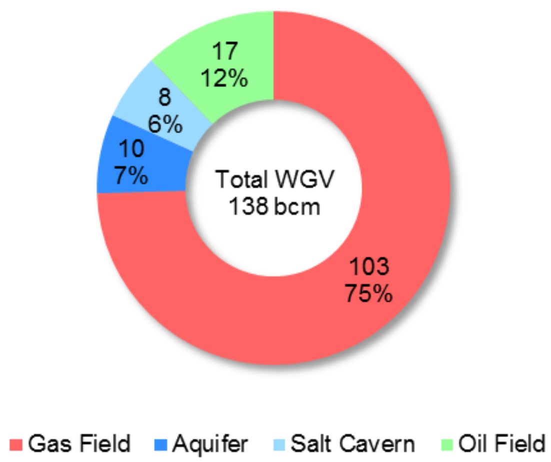

Figure 45 WGV by storage types NA 2012

The most of WGV increase comes from porous reservoir (+9 bcm) followed by salt caverns (+2 bcm). Salt caverns provide 24 % (756 mcm/d) of overall PWR even though they have only 7% share on overall WGV (11bcm). PWR over trienniums grew by 353 mcm/d which represents13% increase. A substantial part of growth was associated with salt cavern (+282 mcm/d) which emphasizes an increased role of deliverability. As the North American market has well-developed storage, the facilities are spread widely across that continent, these figures require further data collection and its consolidation.

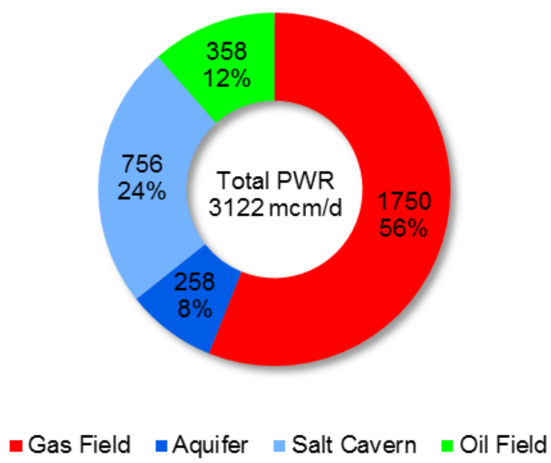

Figure 46 PWR by storage types NA 2015

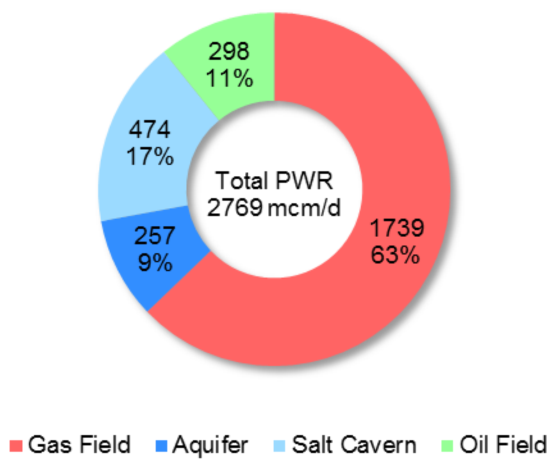

Figure 47 PWR by storage types NA 2012

1.5.3.2 Current storage market situation

The North American market has been going through a fundamental technological expansion introducing new gas production regions as a result of shale gas innovations. The shale gas development augments the existing infrastructure and impacts the way in which North America uses natural gas. Shale gas production, continually coming on-stream, (more than 1,1 bcm/d in January 2015) created a gas glut which substantially levelled seasonal spreads and changed gas storage utilization. The majority of working gas is still owned and operated to meet long-term customer contracts. Therefore, much remains cost-based service based on gas supply demand dynamics. Anyway, demand on seasonal gas storage is not declining as it is demonstrated by gas stocks movement in existing storages.

Due to mild winter 2012/2013 and plenty of gas, low withdrawals from storages meant high stock levels at the end of withdrawal season. However, importance of flexibility was demonstrated during winter 2013/14 where high withdrawals were recorded due to several cold snaps hitting US consumption centres. Spiking gas demand spurred increases in gas price thus stimulating additional withdrawals. Such record withdrawals led to consequent high injections in summer 2014. The winter season 2014/15 has also been showing higher withdrawals even gas prices collapsed significantly compared to the previous winter.

On the other hand, development of gas storage capacity has reacted by slowing down a pace of its development compared to previous 5 years period as illustrated in Figure 48. This slowdown was also forecasted in the study from the previous trienniums

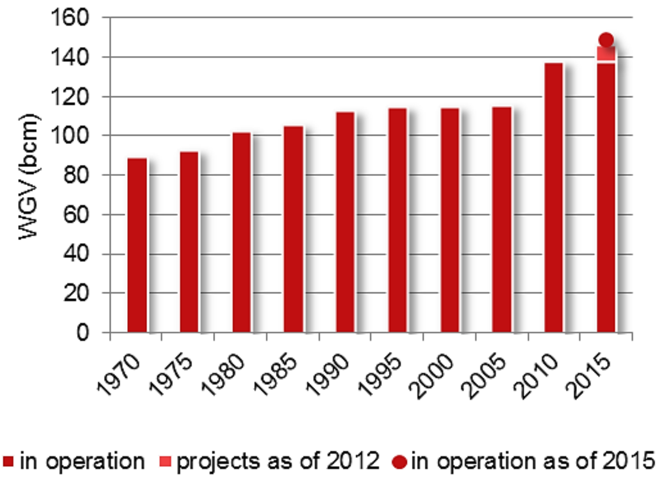

Figure 48 Trends WGV NA

1.5.3.3 Future trends

Thanks partially to technological advancements expanding natural gas production into shale gas formations; it is possible that North America will become a gas exporter in the near future. The North American infrastructure should be planned with a value of flexibility in mind including import/export, power generation and home and industrial use, vehicular fuel, and more. As indigenous production grows, utilization of storages differs significantly. Security of supply is not an issue any longer. With decrease of gas prices, gas becomes more competitive. Apart from heating gas power generation has gained share at the expense of other fuels. So power generation might be one of future drivers of flexibility. Despite the fact that the most demand still comes from heating, there is evidence that gas storage is used also during summer for covering peaks in power generation.

Concerning demand for storage capacity, there is not envisaged a substantial increase of storage capacity at least in the short term future. On the other hand, there is not a trend of abandonment of existing storages. “Abandonment” is rather related do storage projects which are cancelled or postponed. Many operators are rigorously looking at re-engineering or enhancement of existing storage to create inherent flexibility in parameters such as working-to-base, max deliverability, injection capability, cyclability, and other value drivers.

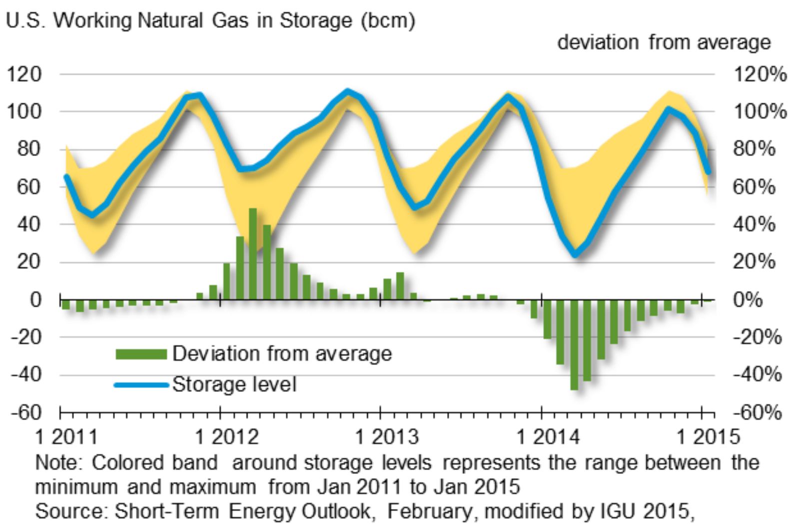

Figure 49 Storage utilization US

One of the values of the North American storage system is that there is an inherent flexibility and an inherent value of potential in the re-engineering and enhancement of individual facilities. North America's long history in storage provides an operational basis to inform us as we adjust to various market conditions over the years.

Storage utilization depicting those contradictory trends is given in Figure 49

The momentum is and will be in deliverability rather than in volume. This trend has been partially materialized as the study shows that growth of PWR (+13%) has overtaken growth of WGV (+8%) over trienniums and most growth of this PWR is tied to salt caverns development. Moreover, future projects indicate also this trend as 2,6 bcm out of 5,2 bcm from projected WGV in the years 2015-2017 may come from salt cavern. This is even more striking if PWR is considered as 217 mcm/d from overall 264 mcm/d will come from salt caverns[8].

LNG development is occurring at a slow, steady pace across the North America. While facilities across the North America have approvals, and some construction elements are starting, the Sabine Pass LNG Terminal (Cheniere Energy) along the Gulf of Mexico is the only facility scheduled for operations in the near future (projected date of 2015). Cavern storage development is occurring at a slower degree as the focus of underground storage growth is seen primarily through economic expansion and re-engineering of existing facilities rather than in green field development. From a conservative perspective, there is not enough trend data to make absolute predictions regarding the near-term role of underground gas storage usage in domestic LNG operations. The role of underground gas storage for LNG will continue to depend on multiple variables, including but not limited to, market demands, financial risk-tolerance, and trusted relationships among potential partnering companies. However, a site specific gas storage usage for liquefaction plants operation may be introduced as in case of a newly developed 13,5 mtpa LNG plant Corpus Christi[9]

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[8] *Source: "Upcoming U.S. Natural Gas Storage Facilities" EIA 2015, http://www.eia.gov/naturalgas/data.cfm*

[9] *(Source: Yahoo Finance; Kinder Morgan and Cheniere Announce Long-Term Transportation and Storage Agreements; 10 December, 2014;* http://finance.yahoo.com/news/kinder-morgan-cheniere-announce-long-210500478.html?.tsrc=applewf)

1.5.4 Gas Storage Asia

Asia is represented solely by People's Republic of China. Even current WGV does not represent extremely high figure a massive gas development which has already started might change it quite quickly.

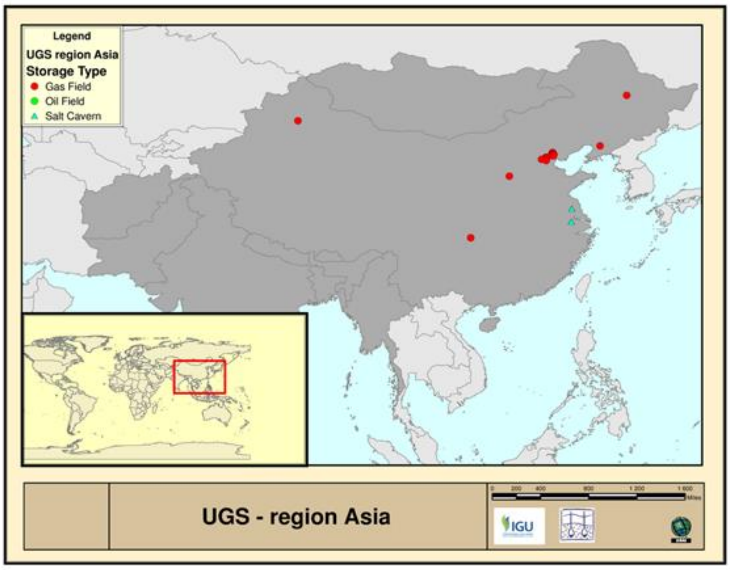

Figure 50 Location of storages – Asia – People's Republic of China

1.5.4.1 Storage capacity

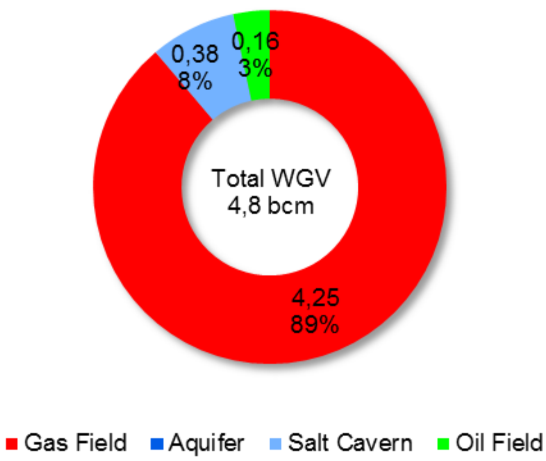

Figure 51 WGV by storage types Asia 2015

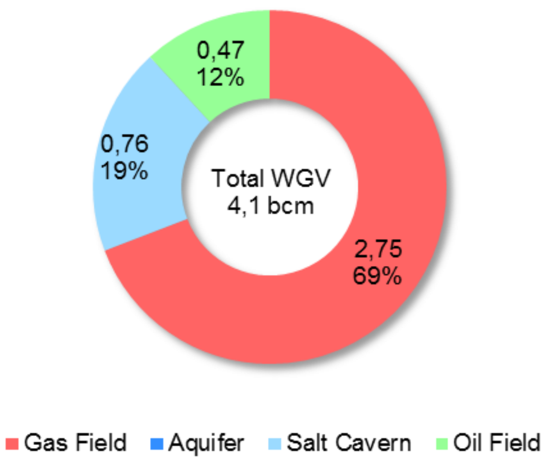

Figure 52 WGV by storage types Asia 2012

Current and previous WGV distribution by storage type is depicted in Figure 51 and Figure 52. Most WGV 4,2 bcm is concentrated in gas fields while small volumes are in salt caverns and oil fields. At the time being there are no aquifers.

1.5.4.2 Future trend

As People's Republic of China replaces coal by gas for heating and power generation there is a strong demand for gas storages development. With current ca 200 bcm of gas consumption annually which should be more than doubled by 2030, import dependency is to be increased up to 50%.

Furthermore, production fields in central and western part of People's Republic of China are distant several thousand kilometres from consumption centres in the east which underlines demand on flexibility and balancing of variations in consumption patter. Taking that into account ca 32 bcm of WGV is to be developed by 2025 if geological conditions allow it. Due to unfavourable geologic characteristics related to deep gas reservoir up to 5 000 m, low permeability and porosity or bedded salt layers with insoluble components developing such a huge storage capacity represents the greatest challenge in storage development worldwide.

Currently there are 12 projects under construction with WGV of 12 bcm which should come on stream in 2016 so total WGV will reach 16 bcm. All of them are gas field's conversion whereas most of them represent expansion of existing facilities. Assuming demand 450 bcm by 2030 and 10% WGV-to-consumption ratio People's Republic of China needs storage capacity of 45 bcm. Storage projects till 2025 plan represents 32 bcm so balance must be filled by LNG.

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Concluding 30-year supply contract delivering 38 bcm of Russian gas annually to People's Republic of China Gazprom decided to embark on its gas sales diversification. On top of that, a memorandum on another 30 bcm/y was signed via western "Altaj" route. Those contracts need construction of huge pipeline infrastructure which will be probably accompanied by development of further storages for provision of flexibility of gas supplies. Assuming challenging geological conditions in People's Republic of China we may expect that a part of those storages will be developed also on Russian territory.

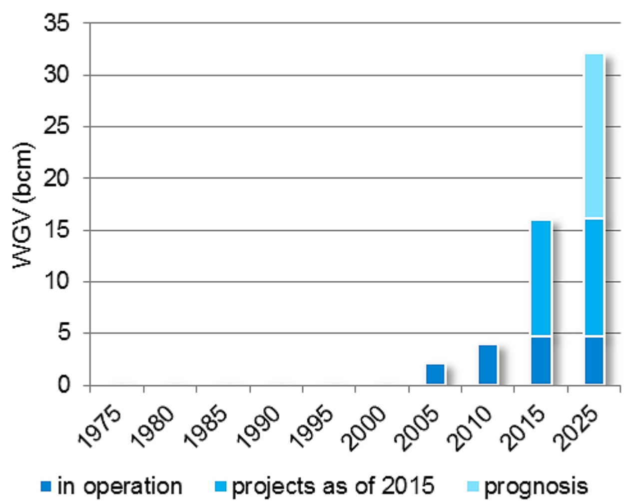

Figure 53 UGS Trends - Asia (People's Republic of China)

1.5.5 Gas Storage Middle-East (Iran)

Iran is the first country in Middle-East which has built and operates underground gas storages. With first storage Sarajeh located near Quom which came on stream in 2011 Iran has started its UGS development programme. In 2014 Shurijeh a new storage located near Turkmenistan was added. Location of storages is given in Figure 54.

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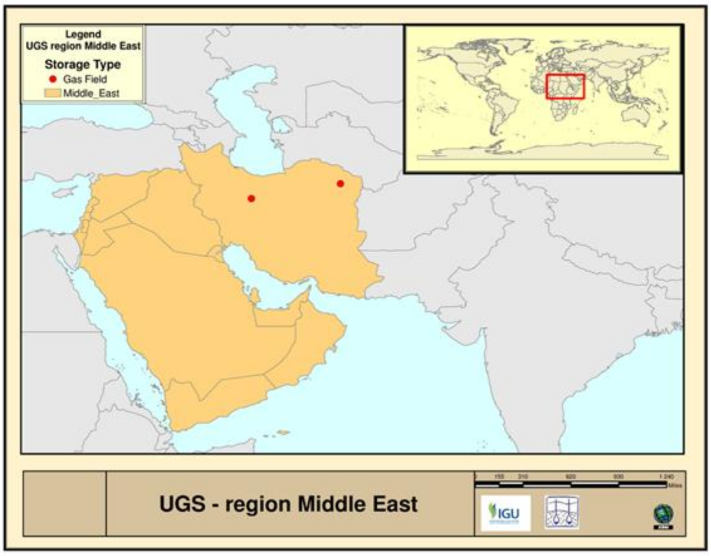

Figure 54 Location of storages – Middle East (Iran)

1.5.5.1 Storage capacity

Currently WGV in 2 storages reaches 6 bcm with PWR 29 mcm/d and there are further plans for their development. Both storages are developed in former gas fields

1.5.5.2 Future Trends

The needs for storage are driven by growing consumption of natural gas in residential sector for heating. Especially this tendency is visible at large consumption centres close to large cities. Even Iran holds vast natural gas reserves their production increased yearly, is still lagging behind consumption especially in winter time. Iran needs to cover its flexibility needs via importing gas during winter time in order to tackle seasonal swing. The last year there were[10] some press releases that talks with Azerbaijan officials have been led in order to use underground gas storages in Azerbaijan.

On the other hand it needs to be said that over years infrastructure with neighbouring countries (Azerbaijan, Turkmenistan, Armenia) was developed in the way enabling bi –directional gas flows or supply of gas for receiving electricity.

The construction of UGS adopted by NGSC is a part of National strategic plan. The main role of NGFC is to establish storage facilities near the main consumption centres which guarantee security of supply and ensure gas for enhanced oil recovery.

However, current storages in operation help to reduce pressure only partially. Having WGV of 6 bcm compared to ca 160 bcm/y annual consumption on stream there is a need for further development of storages. Other types as oil fields, salt caverns and aquifers are also possible. The demand for winter peak shaving is even more urgent as daily consumption record set new highs in 2014 exceeding 624 mcm/d with more than 2/3rds coming from a booming residential and commercial sector[11]. More than 220 reservoirs across the country have been screened, out of which 40 potential gas storage sites were selected for furthers detailed studies. More advanced exploratory phase for projects as Nasr-Abad Kashan Salt Dome, Yurt-e-Shah

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[10] *source: "http://interfaxenergy.com/gasdaily/article/12472/iran-to-access-to-azerbaijans-underground-gas-storage Iran to access to Azerbaijan's underground gas storage"*

[11] *Source: http://en.trend.az/business/energy/2367164.html*

Aquifer, Ahmadi Structure and Ghezel -Tappeh Structure12. Even Iran is rich of large oil and gas reservoir, they are still producing and large reserves are contained there. Moreover, their size is also significant which makes storage development not economic. Taking those facts into account provides clue why Iran is trying to develop also other types of storages and not to hinder its gas production.

1.5.6 New opportunities for storage

Detailed information about new opportunities for storage can be found in SG 2.2 report.

1.5.7 Database analysis

Some analyses from UGS database have been carried out providing interesting comparison.

1.5.7.1 Maximum allowable pressures

Based on the existing data base, analysis was carried out on the maximum allowable storage pressure of pore storage facilities and the maximum allowable pressure of salt caverns.

Just for the facilities with complete set of data of depth and pressures, these data for UGS in operation were converted to pressure gradients for cavern storage facilities Figure 55 and to the ratio of max. allowable pressure vs. initial reservoir pressure for storage facilities in oil/gas fields (Figure 56, Figure 57) and aquifer structures Figure 58.

Reported depths and pressures are average values, especially for caverns, and are sometimes not used consistently. Thus the content of the graphs cannot be used for all UGS as absolute figures, but indicates the order of magnitude and should be used as relative trends, highlighting the relevance of capacity enhancements by increasing the maximum allowable storage pressure as a cost-effective measure.

It is state of the art technology to increase the storage pressure above initial pressure for UGS in oil and gas fields and also to apply respective higher gradients in caverns.

The level of maximum allowable pressure is in general an indication of the utilization of the upside potential of storage capacities.

Due to specific conditions (fault system, juxtaposition), technical reasons (e.g. poorly cemented old wells) and governmental/mining law regulations, as e.g. Italy and Austria, lower maximum allowable storage pressures may be applied only in some nations and UGS.

The gap between the applied pressures and commonly applied higher pressure gradients, e.g. 1,2, Figure 55 is theoretically equivalent to additional storage capacities.

Previous studies indicated, for UGS in oil and gas fields that significant capacities may be developed in a cost-effective manner worldwide.

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[12] *Source: presentation of NGSC during WOC2 meeting in Tehran, October, 2013*

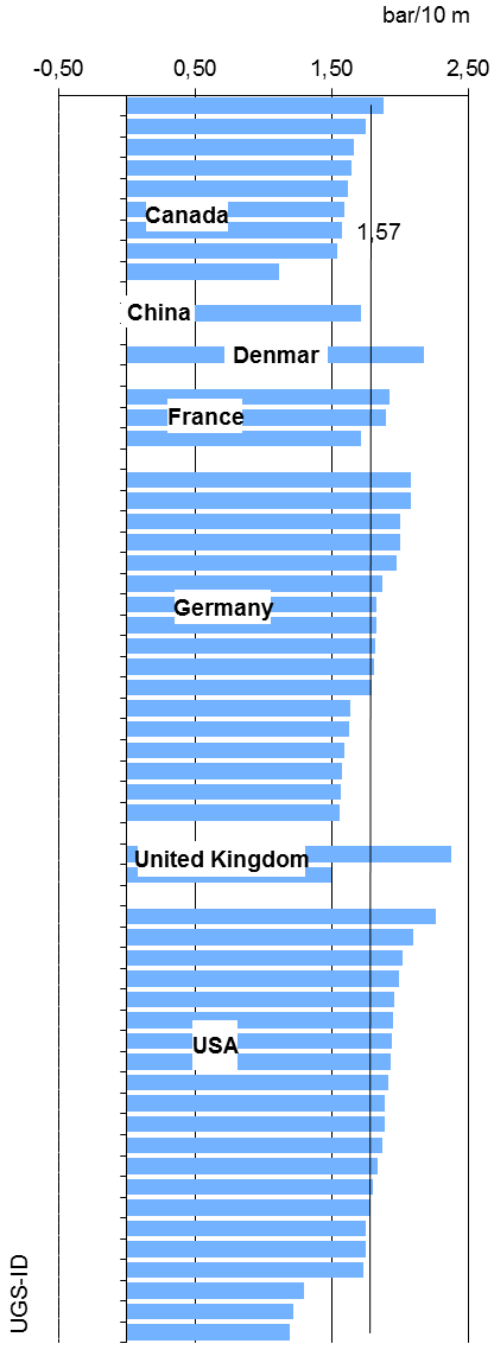


Figure 55 Max. storage pressure gradients - salt caverns

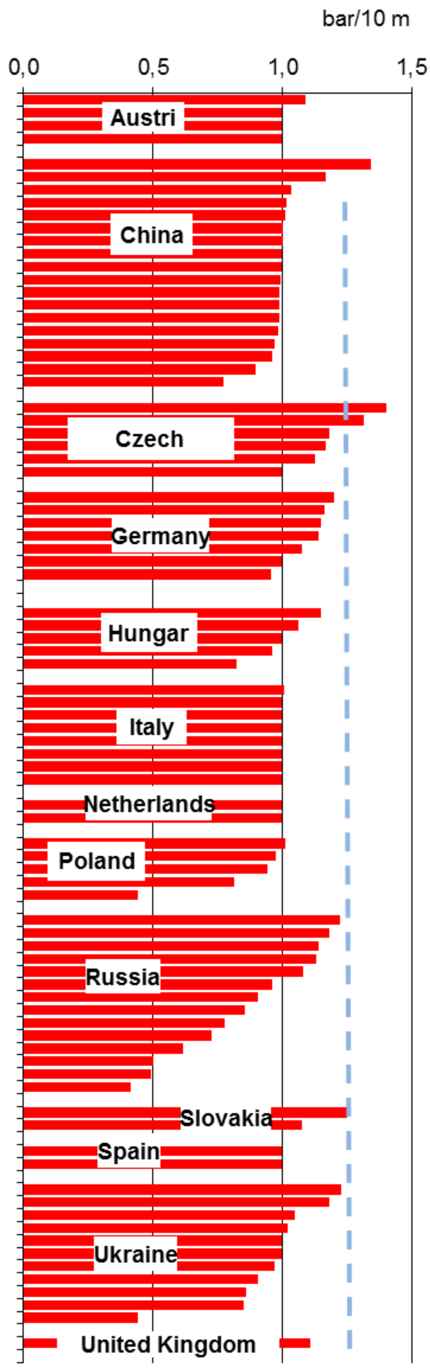


Figure 56 Ratio of max storage pressure vs initial pressure – Oil&Gas Fields World excl. America

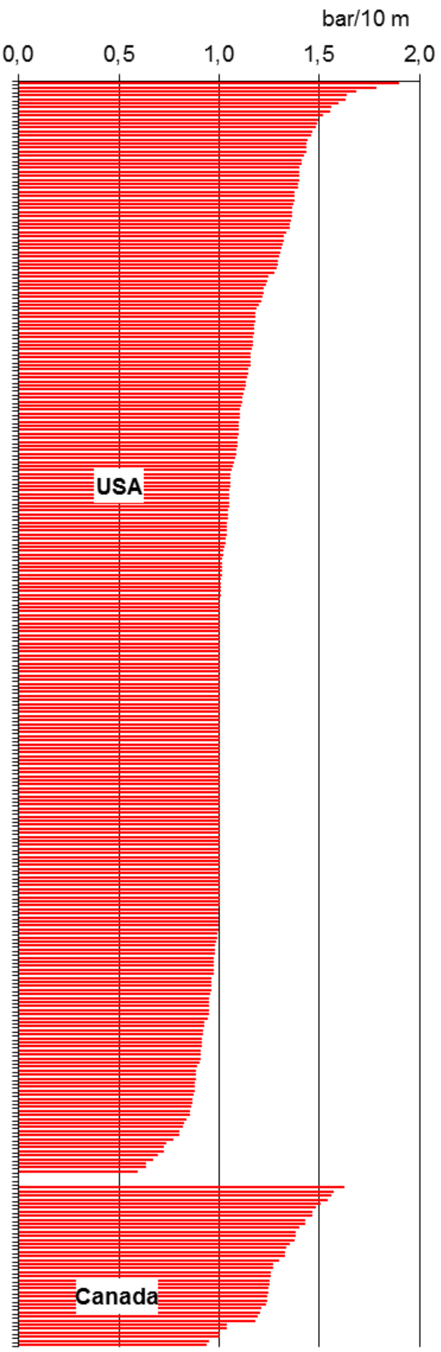


Figure 57 Ratio of max storage pressure vs initial pressure - Oil&Gas Fields incl America

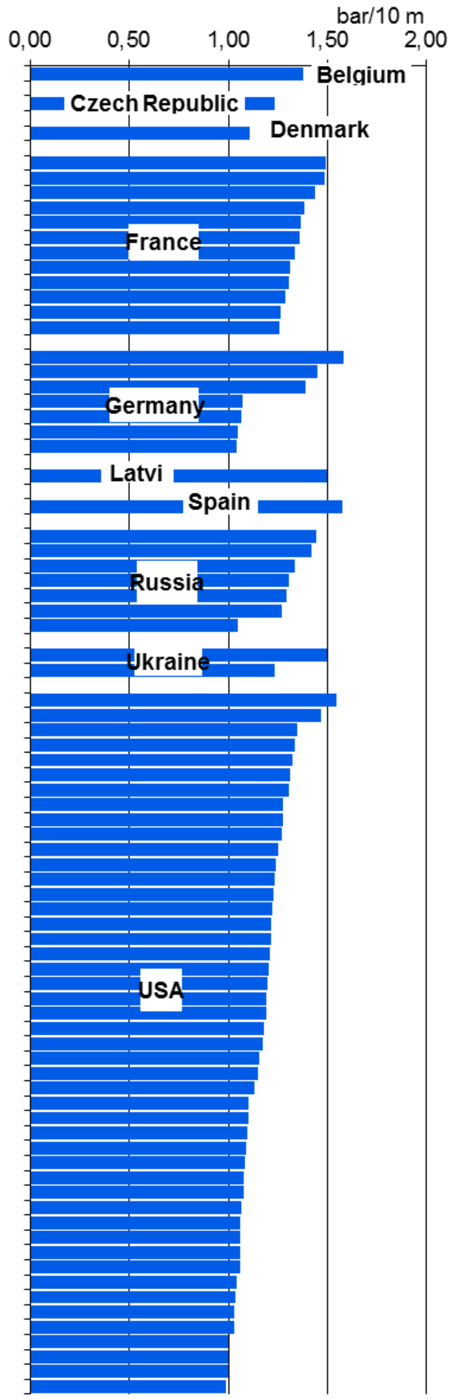


Figure 58 Ratio of max. storage pressure vs initial pressure - aquifer

1.5.7.2 Development of UGS facilities

We will celebrate the 100th anniversary of creation of the first UGS facility in the near future. This was in the United States in 1915, in depleted gas field. The first commercial natural gas storage facility in the U.S. was constructed at the Zoar field near Buffalo, N.Y. in 1916 – still in operation. The first underground natural gas storage was a depleted natural gas reservoir in Welland County, Ontario, Canada, converted to the natural gas storage in 1915.

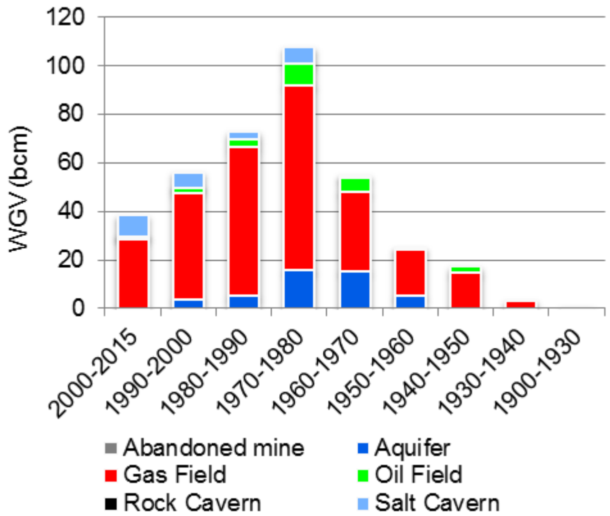
Underground gas storages see a relatively slow development from then to the years 1950s, mainly in depleted gas fields and afterwards in depleted oil fields.

Creation of facilities in aquifers took place in the 50´s, the most important period of development being between the 60s and 80s. The first aquifer used as gas storage was built in Kentucky in 1946. Since the year 2000, the development in aquifer is almost equal to zero.

The UGS in salt cavities appear in the 1960s and are still being constructed nowadays. The first cavern used as gas storage was built in Michigan in 1961. Their biggest development is in 1990-2000.

For all types of storages, there is a maximum of development in the period from 1970 to 2000. Between 1960 and 1980, more than 200 UGS facilities were built, which represent around one third of the total worldwide facilities. The peak is from 1970 to 1980, for all types of facilities, but also due to depleted gas fields. But it was in the period of ten years 1970-1980 that a maximum number of 120 facilities is reached.

UGS in gas fields are predominant amongst all types of storages and are still developed.
As is depicted in the Figure 59 the huge development of storages was from 1970 to 1980 decade related to number of storages and volume as well. From 1980th the development of WGV is decreasing in comparison with PWR holds the same level.



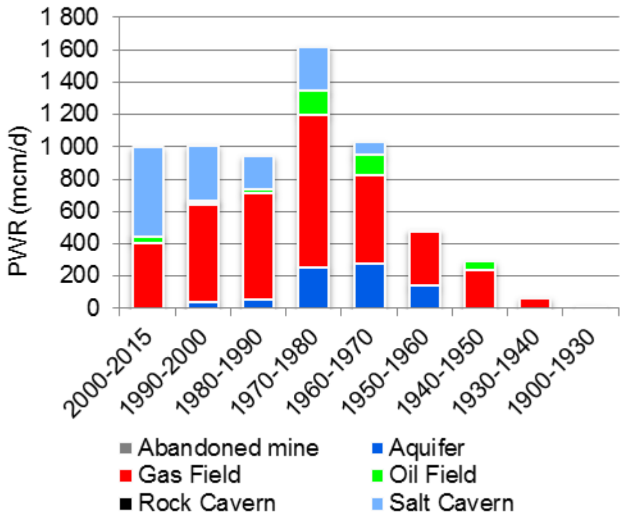


Figure 59 Development of WGV and PWR

Increasing volume of storages of different types, ratio of CGV to WGV is decreasing. The most substantial decrease is related to aquifer storages while other types show less striking figures. The smallest differences are in salt caverns, followed by oil&gas fields. Simply said development of storages of smaller size is less efficient and more costly as per stored cm compared to larger ones. Moreover small storages have problems to reach economy scale especially under current market dynamics.

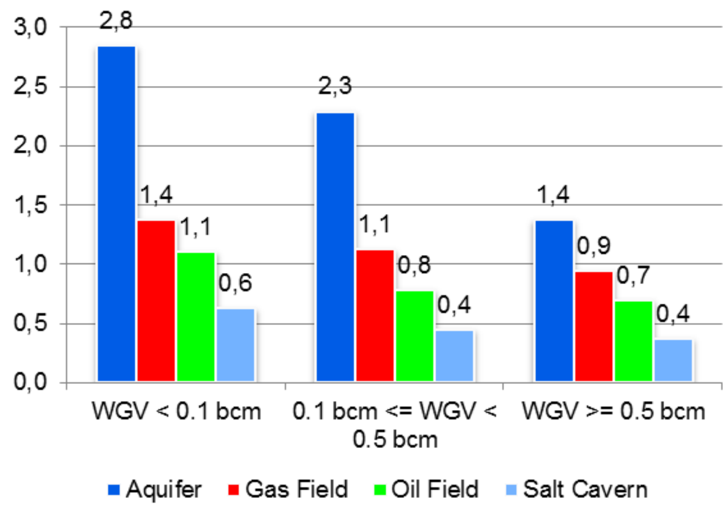


Figure 60 CGV vs WGV

The most deliverable storages are salt caverns especially of smaller size if Unit PWR is considered. It is understandable as in relative terms this figure is high but in absolute terms real WR is small so not so much investment in infrastructure is needed (wells, compressor, flowlines, dehydration plants, metering). The larger the WGV the more capital intensive storage development is.

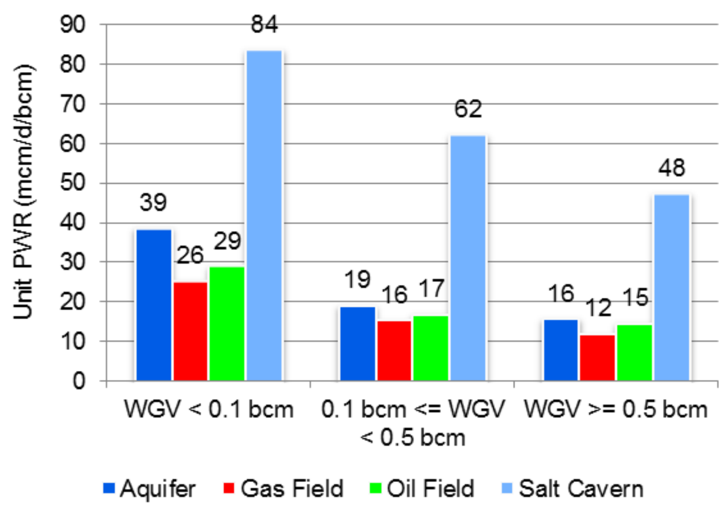


Figure 61 PWR to WGV

2012-2015 Triennium Work Report
June 2015

REPORT OF STUDY GROUP 2.2

TECHNIQUES AND NEW OPPORTUNITIES

2 Report of Study Group SG2.2

2.1 Introduction

The Study Group leader: Fabien Favret (France)

The main Contributors:
Jacques Grappe, Andreas Böhmer, Gaetano Annunziata, Lionel Thomas, Marie-Claire Chiodaroli

2.2 Aims

Two major topics have been investigated during this 2012-2015 Triennium by IGU's Working Committee 2 under the responsibility of Study Group 2.2 dedicated to "Techniques and New Opportunities". These are:

- **UGS techniques, new opportunities and best practices:**

Operators of underground gas storage (UGS) facilities have to react quickly to changing market demands for gas while raising safety standards and reducing environmental impacts. In this context, latest developments and recent findings are presented. The first part looks at subsurface integrity management and the second at the reduction of the environmental footprint of UGS operations and the enhancement of their energy efficiency. UGS operators are taking advantage of sophisticated and advanced technologies which were mainly developed by and for oil and gas majors or engineering service companies. But UGS operators are also investing in R&D to adapt these technologies to their specific needs in order to continuously improve their practices. The aim is to limit as much as possible the risks and the environmental impacts of their facilities in a changing worldwide gas market.

- **To which extent UGS technology may contribute to energy storage:**

The aim of this section is to provide information on the ways and the extent to which (UGS) techniques might contribute to storing excess electricity generated from intermittent renewable energy sources and respond to some of the new challenges posed by the changes currently experienced in the energy sector. The contribution does not intend to be comprehensive. It focuses on the identification of solutions UGS applications might contribute, on the related technology gaps together with the R&D effort needed to overcome them, and on current market uncertainties, opportunities and constraints likely to impact the deployment of these UGS solutions.

2.3 Results

2.3.1 UGS techniques and new opportunities & Best Practices

2.3.1.1 Subsurface integrity management

Integrity management involves taking a risk based rather than a uniform approach to safety and was pioneered by pipeline operators. Asset integrity is the ability of an asset to perform its required function effectively and efficiently whilst safeguarding life and the environment. It ensures 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. As regards the subsurface integrity of UGS, there have been some interesting developments.

2.3.1.1.1 *Well integrity management*

Wells are key assets for storage operators and their integrity has to be controlled not only during their ageing phase but starting from their drilling or building phase (some UGS wells have been in operation for more than 50 years Figure 62).

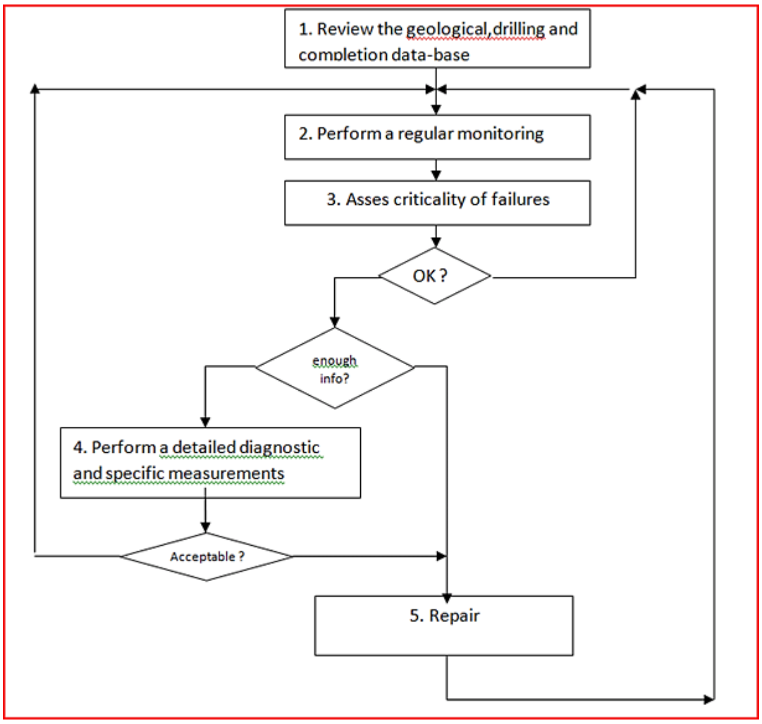


Figure 62 Well integrity management process

Well integrity management (WIM) involves a six-stage process:

- An initial collection and review of all the data sets available, such as geological, drilling and completion data, to create an "identity card" or database entry for each well;
- Regular monitoring should be carried out during normal operation or maintenance. The parameters (such as tubing/wellhead pressure, annulus pressures, productivity) to be measured (every day, or every week or every year, according to the expected evolution of the parameters) depend on many factors: operator's needs, national regulations and availability of those data;
- Then, every change or abnormal evolution of the parameters should be analysed. These failures could be more or less negative in their consequences according to the specific environment (on surface and at subsurface) of the well. The assessment of the criticality of the risk has to be adapted according to the concern (safety, environmental protection, performance). In any case, a multicriteria analysis, similar to risk assessment methods used in different industrial sectors and project management, has to be applied;
- In this case, detailed diagnostic and specific measurements (such as logging, gas analysis, borehole video, flow logging) have to be implemented. In most cases the detailed diagnostic cannot be based on a single measurement. Several logs and measures are needed for a better understanding of the situation;
- Afterwards and if necessary, a repair has to be done. Methods which can be performed without work-over (repair using a drilling rig) are preferred, taking into account that a work-over is expensive and possibly risky and also not always successful;

- Once the repair job is completed the well's database entry is updated and the WIM process continues.

2.3.1.1.2 Integrity management of reservoirs and caverns

Passive microseismic can be used to monitor the integrity of UGS facilities such as mined rock caverns, salt caverns, natural gas storage reservoirs and more recently CO_2 sequestration projects. It consists of tracking microseismic events resulting from stress release within the subsurface rock mass via a network of geophones connected to a continuous recording device. The technique is increasingly being implemented by UGS operators in naturally seismically active areas or whenever a risk of occurrence of sizeable induced seismic events with potential consequences on stability and/or containment is identified.

The sensitivity of the monitoring network is set to detect and localise even minor seismic events with sufficient accuracy to demonstrate that the operation does not induce any failure process within the rock mass, which is likely to impair the storage stability or containment.

Continuous recording of minor events and analysis of spatial and historic evolution of their characteristics provide a reference for establishing an advanced warning and traffic light system, based on pre-validated criteria.

A traffic light system is usually defined as follows:

- Green: no risk, operations proceed as planned;
- Amber: alertness, be prepared to alter plans. Operations proceed with caution, possibly at reduced rates, and monitoring is intensified;
- Red: warning, operations are suspended immediately.

We will focus on two types of seismic events here, micro and abnormal. Micro events can occur as a normal response to the storage cycles and to pressure changes in the storage space. Such induced microseismic events are inherent to UGS operation and reflect minor readjustments of the stress field within the rock mass. The events are extremely small (typically with negative magnitude) and require very sensitive monitoring equipment to be detected.

Abnormal events can be related to reactivation of existing geological features such as discontinuities, triggered or induced by storage operation. This class of events whose magnitude is usually positive and which may sometimes be felt at surface level, is linked to processes involving large amplitude injection/production cycles of gas or fluids into the storage space. Occurrence of such events can often be forecasted, by interpreting fore-runner signals detected by the microseismic monitoring network (such as e.g. a sudden increase of the number and/or the magnitude of micro-events or a change in their location). In such events, the monitoring records provide a reliable basis for:

2.3.1.1.3 Analysis and characterisation of the events and of their triggering mechanisms

Prevention of further occurrence, by proper adjustment of the operating parameters, based on the results of relevant modelling and simulation studies.
Additionally, the microseismic monitoring system helps to demonstrate the absence of adverse impacts resulting from a natural earthquake in the storage vicinity, or conversely in the case of hard rock or salt storage caverns, to identify potentially unstable areas and block falls triggered by earthquakes.

The key concern is to define anomalous behaviour based on geomechanical modelling and/or knowledge gained from case studies and similar projects and/or historical seismic records of the zone before the UGS development. Instances of man-made induced seismic activity have been documented and the level of potentially induced seismicity is available from case studies. The table hereafter gives a scale of seismic events.

Magnitude range	Class	Length Scale	Displacement Scale
8 – 10	Great	100-1000km	4-40m
6 – 8	Large	10-100km	0.4-4m
4 – 6	Moderate	1-10km	4-40cm
2 – 4	Small	0.1-1km	4-40mm
0 – 2	Micro**	10-100m	0.4-4mm
-2 – 0	Nano	1-10m	40-400µm
-4 – -2	Pico	0.1-1m	4-40µm
-6 – -4	Femto	1-10cm	0.4-4µm
-8 – -6	Atto	1-10mm	0.04-0.4µm

Earthquake Seismic Hazard Domain (8 – 10 to 2 – 4)
Watch & Warning (0 – 2 to -2 – 0)
Imaging (-2 – 0 to -4 – -2)
AE Lab Test Domain (-6 – -4 to -8 – -6)
Induced Seismicity Microseismic Domain (0 – 2 to -4 – -2)

Bohnhoff et al., ILP, 2010 - Length and displacement approx.

Table 3 Seismic event scaled[13]

Microseismic monitoring systems in operation include:

- Geosel/Geomethane salt sites (France) for discriminating micro-seismicity vs Durance valley seismicity;
- CO_2 sequestration in Rousse (France) for identifying micro-seismicity vs Pyrenees mountains' seismicity;
- Collato UGS (Edison, Italy) for a depleted gas field survey;
- Bayou Corne (Texas Brine, USA) for survey of salt caverns.

2.3.1.2 Reducing the environmental footprint of UGS operations

2.3.1.2.1 Reducing natural gas emissions

Methane is an extremely potent greenhouse gas and although UGS is a very low methane emitting activity, efforts have been made in recent years to reduce emissions. More and more UGS operators are reducing the venting of gas during maintenance and emergency sequences. These efforts are mainly voluntary since regulations in the field of methane emissions have yet to be widely implemented.

Three countries have methane emission regulations: Germany, Russia and the UK.
From various sources it is possible to estimate the average ratio of methane emissions compared to working gas volume to be approximately 500 m^3(n) per million m^3(n) of working gas, i.e. 0.05%. This has decreased by a factor 2 in around 10 years( ).

Best practices are mainly the following:

- Control of compressor (dry) seal emissions by either a gathering system for re-injecting in pipes or the installation of an encapsulated compressor (no methane emissions during normal operation);
- Replacement of natural gas driven process or safety valves by electrical, mechanical (spring), air or hydraulic driven valves;

[13] *rupture length/displacement ranges are approximate with apparent stress drop of 3MPa*

- Recovery of gas during planned venting, including well testing, by re-injection in pipes;
- Reduced blow-down gas volumes during emergency sequences by the segmentation of gas facilities allowing areas to be vented independently depending on the location of related alarms.

Figure 63 UGS facilities

2.3.1.2.2 Reducing methanol/glycol consumption

Methanol/glycol consumption may be reduced by the adoption of operational practices or facilities such as:

- Suppression of methanol/glycol injections at wellhead or in gas lines before and after withdrawal period;
- Strict follow-up of related methanol/glycol consumption during operation;
- Optimisation of injection of methanol/glycol by automated monitoring procedures linked to the pressure and temperature of the gas in facilities.

As an example, Storengy reports to have significantly decreased the ratio of methanol consumed to produce gas by a factor of 2 to 3 between 1993 and 2013.

2.3.1.2.3 Compressor technology

Efficiency of compressors has been improved in the last decade by the development of:

- Encapsulated high-speed power-driven compressors with a rigid or flexible motor/ compressor rotor levitated on magnetic bearings which provide a very high flexibility but also a high energy efficiency (no gear box means no lubricant and a reduction in energy consumption);
- High efficiency gas turbine-driven compressors with very low NOx and CO emissions and reduced CO_2 emissions.

2.3.1.2.4 Ejectors

Ejectors (also known as jet pumps or Venturi pumps) are the most efficient way to pump or to move many types of liquids and gases in the petrochemical, process and power industries. Ejectors utilise the kinetic energy of one liquid or gas to cause the flow of another.

They consist of a converging nozzle, a body and a diffuser, and resemble siphons in appearance. In operation, the pressure energy of the motive liquid/gas is converted to velocity energy by the converging nozzle.

The high velocity liquid/gas flow then entrains the suction liquid/gas. Complete mixing of the motive and suction liquids/gases is performed in the body and diffuser section. The mixture of liquids/gases is then converted back to an intermediate pressure after passing through the diffuser.

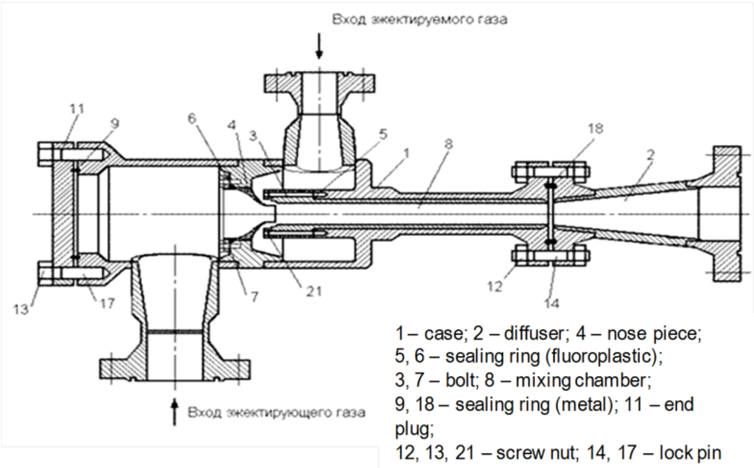


Figure 64 Cross-section of a typical ejector

Ejectors may be used in UGS facilities to:

- Increase the compressor gas injection rate above the total power of gas compressor units;
- Reduce energy consumption (fuel gas, electric energy, motor oil, etc.);
- Regulate the injection rate;
- Increase compressor mean time before repair;
- Recover the products of gas combustion in the boiler stacks and igneous vaporisers;
- Increase the performance of individual low-pressure wells by reducing the backpressure;
- Enhance gas recovery from the storage in the presence of high-pressure gas sources;
- Reduce negative environmental impacts on inhabited areas near the UGS site (less compressor units).

Figure 65 Ejectors at Peschano-Umetskoye UGS in 2000 (left) & at Bernburg UGS in 2011 (right)

Examples of the successful implementation of ejector technology include:

- UGS developed in a depleted gas field – Peschano-Umetskoye (Gazprom, Russia) where there is a centrifugal power-driven compressor station and 10 identical supersonic gas ejectors have been installed. This modification has led to an increase in the daily injection rate of 27.3% and a reduction in power consumption of 11%;
- UGS in salt cavities at Bernburg (Verbundnetz Gaz AG, Germany) which has a piston power-driven compressor station. Injection performance has been improved by an average of 65,000 m^3/h during test operations in a one compressor for two ejectors configuration.

2.3.1.2.5 Optimisation of operations and reduction of energy consumption

Apart from ensuring fulfilment of nominations, while at the same time respecting limits set by reservoir engineering and equipment availability, there has been a growing demand on storage dispatching to fulfil client nominations as efficiently as possible. Conversely, there has been a strong demand from customers for flexible, even intra-day, re-nominations with a short lead time affecting decision making time. The main area for operating cost savings is linked to the consumption of energy for gas compression. Compressor efficiency varies substantially with different pressure and flow conditions. This requires finding the most efficient operating point at given conditions.

However, in the case of complex storage facilities (e.g. multiple reservoirs at different depths and pressures within the same field or UGS salt cavern pools operating at different pressures) or if several storages are managed from one dispatching, optimisation goes far beyond the setting of efficient operating points for compressor sets. Rather, it is focused on finding an optimal gas route via the storage facility. Such optimisations require sophisticated and either market or tailor-made tools based on data from several information systems dealing with the status of reservoirs, equipment availability, gas grid simulations and last but not least an information system for receiving, aggregating and confirming the client’s nominations.

Moreover, operating data are supplied by supervisory control and data acquisition (SCADA) control systems. From these data, the optimisation tool searches for the most efficient set-up of storage operations either by calculating all possible gas routes with their respective energy consumption or via mathematical algorithms. Optimisation tools are complemented with other features such as reporting (enabling the dispatcher’s decisions to be evaluated over time) or simulating the costs of planned maintenance or storage reservoir testing.

While implementation of an optimisation tool is likely to save only a small amount of fuel gas or electricity per day, the cumulative savings over a year can make a substantial difference to the economics of storage operations. Energy saving also helps to reduce the environmental impact of storage operations.

2.3.1.3 Drawing on UGS experience to store renewable energy

2.3.1.3.1 Setting the scene

During the last decade, concerns related to climate change and declining fossil fuels reserves have increasingly pushed energy transition policies to the forefront; and strategies have emerged, aimed at reducing carbon and environmental footprint together with dependency on fossil fuels. ‘’Green’’ renewable energy gained in some countries a sizeable share in the energy mix; and the EU set an ambitious 3 x 20 target for energy transition to be reached by 2020 (i.e.

nearly tomorrow) namely: - 20% CO2 emission; 20% share of renewables in the energy mix; +20% energy efficiency, with respect to the 1990 reference situation as defined in Kyoto protocol signed in 1997 and entered in force in 2005.

The intrusion of renewable energy and of the resulting intermittent electricity production into the energy markets materializes as a game changer, disturbs long established equilibria and generates a number of challenges. Until recently, traditional electricity suppliers achieved alignment of demand and production through a combination of nuclear, fossil fuels power plants and hydraulic energy covering both the needs for “base load” and seasonal swing, whereas peaks in the electricity demand were compensated by gas power plants, able to reach full regime in less than half an hour for big units (CCGs) and 15 minutes for smaller units (Gas Turbines < 150-200 MW). Additionally, on the demand side, interruptible contracts allowed to shave off extreme peaks.

The currently most developed renewable energy sources i.e. wind & solar are weather-dependent, intermittent (electricity is produced only when the wind blows or the sun shines), rather unpredictable, and they generate electricity due to be immediately released to the grid. This new setting does not facilitate reconciliation of production & demand. With current technology, there is namely no way to store large quantities of electricity so it has to be converted into another energy vector for storage; and neither the existing grid structure, nor the grid management (and the overall energy pricing policies) are tailored to accommodate the constraints linked to the specificity of these new energy sources.

A prerequisite to optimum contribution, use and efficiency of renewable energy requires being able to efficiently convert the intermittent electricity produced from wind, solar, etc… to a stable, reliable stream: this is typically a “storage” issue, familiar to the gas industry, which can claim in 2015 a century of experience in underground gas storage (UGS) in porous reservoirs, salt and rock caverns. These have ensured security of supply and have contributed to balancing swing and demand over a large range of timescales from yearly to hourly. UGS facilities store large volumes of natural gas at reasonable cost, with very strong safety and reliability records, high flexibility, a low environmental footprint and emissions, minimal land occupation and good public acceptance.

Figure 66 Surface equipment at the Epe salt cavern facility in Germany

It is hereby to be noted that whereas natural gas storage prior to a conversion process to electricity is a fully mature technology, storage of electricity must proceed through transformation into another energy vector, either used as such or re-converted to electricity, hence loss of efficiency.

Finding solutions is compulsory: in the future the share of fluctuating energy sources is expected to grow, and the corresponding increased swing in production will need to be bridged. The AIE forecasts that intermittent renewables might reach 1700 GW by 2035. In spite of the wide scatter of expert opinions as to quantification of the future electricity storage needs linked to the increase of the share of renewable energy in the energy mix, most studies fall in reasonable agreement in evaluating these needs in an order of magnitude of at least ten if not hundreds of TWh[14].

The challenge ahead is thus being able to adjust strongly fluctuating electricity production on the supply side to an independently fluctuating demand, at affordable cost and low environmental footprint while achieving societal and public acceptance. Reaching the target will obviously need a combination of solutions, among which innovative Underground storage techniques applicable to massive storage of electricity, for which the gas industry can contribute both its expertise and its experience.

2.3.1.4 Main UGS techniques and renewable energy storage solutions

A large choice of proven solutions relying on extensive operation feedback exist to safely and efficiently store underground large quantities of natural gas ranging from typically 10 mcm up to 10 bcm (n) (110 GWh up to 110 TWh) and more. The natural gas is stored deep below the ground surface, without contact with air and oxygen, thus excluding risk of formation of explosive mixture. It is injected into the subsurface and retrieved via production wells typically equipped with gas tight tubings and casings and downhole safety shut down devices closing automatically in case of emergency. The main UGS options available for storing pressurized natural gas include:

[14] *To put this into perspective, the global UGS working gas capacity in 2013 (Source IGU; CEDIGAZ) was in the order of 377 bcm (4150 TWh) i.e. nearly 11% of the global gas consumption, whereas the maximum daily deliverability from these facilities was some 6,8 bcm/day (3100 GW)*

- Reservoir storage, consisting in converted oil & gas fields or aquifers. The gas is stored within a geological trap, in the pore space of a permeable reservoir formation. This option typically provides a large storage capacity, well suited for strategic or seasonal storage. The storage gas is injected and produced typically over a few months period.
- Salt caverns, solution mined from salt deposits. Each cavern can host between 10 and more than 100 mcm (110 and 1100 GWh). This option allows for modular development of the storage volume. Furthermore, salt caverns provide high deliverability, flexibility and capability for rapid inventory cycling (the inventory of a cavern can typically be cycled in about one month). Salt caverns are primarily used as a flexibility tool. Turning from injection to production and vice versa can be achieved for recent facilities in less than 15 minutes.
- Rock caverns (unlined and lined). This option is less developed for natural gas than for storage of liquid and liquefied hydrocarbons. If applied to natural gas, it offers a performance envelope similar to that of salt caverns, but in a different geological environment, at however a significantly higher unit storage volume cost, especially in case of lined caverns.

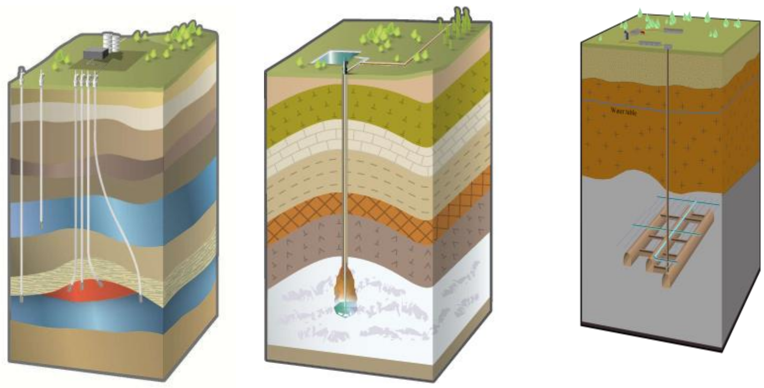


Figure 67 Schematics of the main Natural Gas Underground Storage (UGS) options (Courtesy Géostock)

The main weather dependent and fluctuating renewable energy sources are chiefly:

- Wind energy, recovered by onshore and offshore wind mills and wind farms
- Solar energy mostly converted to electricity via photovoltaic cells (or Concentrated Solar Power)
- Marine energy from waves & tides

Other more stable renewable energy sources include:

- Biomass, converted to heat or to biogas. Biogas can be injected into the gas grid, but gas quality issues may arise when injected into UGS facilities such as bacteriological development and contamination in the reservoir.
- Geothermal energy and heat storage in aquifers or in “dry rock” (ATES and UTES respectively: Aquifer and Underground Thermal Energy Storage).

The table below summarizes the main UGS solutions potentially applicable to storage of the surplus electricity produced in excess of demand from renewable sources, together with their status of development.

TYPE OF ENERGY VECTOR	STATE OF THE ART	UGS SOLUTION
MECHANICAL / KINETIC ENERGY		
Pumped Hydro Storage (PHS)	*Proven*	*Salt or Rock Caverns?*
CAES	*Proven. R&D effort to improve efficiency*	*Peak shaving mainly* *Salt caverns, (reservoirs??)*
THERMAL & THERMOCHEMICAL		
Heat (enhanced geothermal energy)	*Proven concept. Still some R&D effort needed for industrial implementation*	*Seasonal. Aquifer Thermal Energy Storage (ATES) or rocks Underground Energy Storage (UTES)* *Rock Caverns??*
CHEMICAL		
Hydrogen	*Proven. R&D to achieve in particular performance improvement of electrolysers and cost reduction.*	*Short & Long term storage* *Salt Caverns* *Rock caverns? Reservoirs?*
Methanation (from hydrogen)	*Proven concept.* *R&D effort to optimize process* *Buffer Storage needed for CO2, H2, CH4 (and possibly O2)*	*Short & Long term storage* *Salt Caverns* *Rock Caverns? Reservoirs??*
Process feedstock	*Production of valuable chemicals requiring massive electricity with electricity in excess… but stop & go process is a handicap*	*To be evaluated on a case by case basis*

Table 4 Main UGS solutions potentially applicable to storage of electricity

Other electricity storage options currently under development such as flywheels, batteries, condensators, supraconductors, etc… do not seem, at least as of today, to offer a large potential for UGS solutions.

The chart below displays the respective characteristics of the main options available in terms of energy storage content and timeframe over which this content can be released. It can be seen that UGS solutions (similar to natural gas UGS) are mostly applicable to massive storage (at least 10 MWh) released over a timeframe starting from a few hours and potentially extending from days to months.

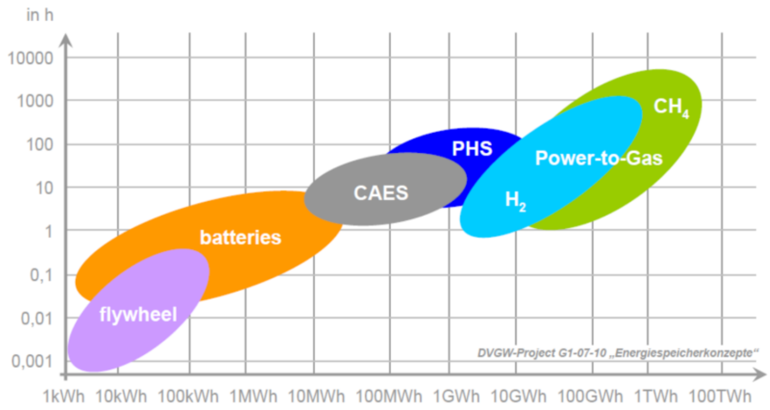


Figure 68 Respective characteristics of the main options available in terms of energy storage content

2.3.2 How can UGS contribute? Solutions and obstacles

The concept of UGS is usually associated with safe and massive energy storage…and with geographic and/or geological constraints (e.g. a salt deposit does not necessarily exist in the vicinity of a High Voltage grid or of a large wind farm; and if salt is readily present below a suitable grid location, no practical solution may be available to provide the large quantities of fresh water required to leach the caverns and to use or to dispose of the brine resulting from this process). Recent developments and innovative solutions like the lined rock caverns tend to widen the field of application of the UGS technology by both extending the range of geological conditions compatible with construction of UGS facilities and reducing their minimum capacity.
There are three main electricity storage solutions readily available or requiring limited R&D efforts with which UGS experience can help such as described hereafter.

2.3.2.1 Pumped Hydraulic Energy Storage (PHS)

PHS which was widely used in the 1970-90's and experienced a new wave in the 2000's in association to renewable energy deployment (People's Republic of China, EU) is currently the largest contributor to electricity storage (125 GW; 400 facilities). Surplus electricity is converted to potential energy by pumping water from a low-retention basin to a higher basin. The potential energy stored is retrieved and re-converted to electricity via hydraulic turbines during peak demand periods. Implementation requires a specific environment such as mountains (France, Germany, Luxemburg, Switzerland, Norway, Canada, People's Republic of China, etc…), or coastal cliffs (fjords in Norway, Japan).

Individual PHS facilities can be scaled from 10 MW to a few GW over a few hours/days. They offer a fast response (a few minutes), efficiency of 70-80%, a long service life (50 years+) and unlimited cycle stability.

Scale: 10 MW to a few GW (capacity in the order of a few to a few tens full load hours of the power plant); fast response (a few minutes). Efficiency 70% to 80%. Long lifetime (50 years+) and unlimited cycle stability.

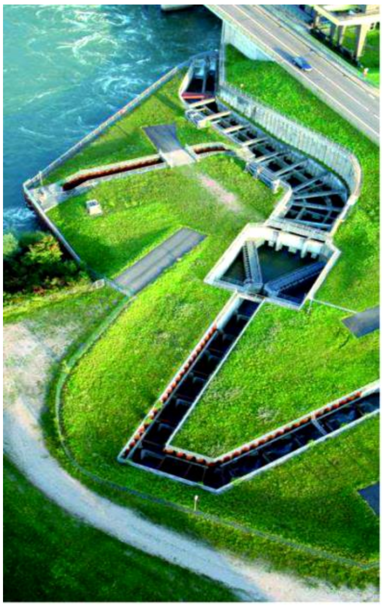


Figure 69 PHS facility in France (courtesy EDF)

As an alternative, UGS schemes have been suggested, including salt caverns with a surface brine pond, rock caverns (lined or unlined) or disused mines. However, the requirement for large flowrates, large diameter shafts, high performance pumps, together with economics and relatively limited capacity underground are not supporting hopes for a large deployment.

2.3.2.2 Compressed Air Energy Storage (CAES)

CAES is an attractive solution for peak shaving but is not suited for long-term (seasonal) electricity storage due to the low energy density it provides.

Surplus electricity is converted into potential energy by using electric compressors to compress air which is stored underground and released during peak consumption hours. The energy of the stored compressed air is recovered, for the current CAES by mixing it with natural gas, combusting the mixture and expanding it in a gas turbine. Operating cycles are short (a few hours typically) as well as the pressure swing applied in the storage space.

CAES offers a response time in the order of one minute, efficiency ranging from 40% for first generation facilities to 70% for the latest pilot projects, a minimum service life of 30 years and high cycling stability. Typical performance: 10 MW to 1 GW. For a unit cavern between 300 000 and 600 000m3 volume, the capacity is in the order of 1 to 2 GWh, corresponding to a 300 MW production during 4 to 6 hours (approx. 3 KWh/m3 cavern volume). Modular development by pooling several caverns is easily feasible.

There are currently two operational CAES facilities:

- Huntorf, Germany. Built in 1978, this has an efficiency of 42%, two caverns (150,000 m^3) with a capacity of 0.66 GWh each (330 MW for two hours) and a pressure range of 5 to 7 MPa.
- McIntosh, Alabama, USA. In this second generation CAES facility commissioned in 1991, the compression heat is partly recovered, resulting in an energy efficiency of some 54%. One 540,000 m^3 salt cavern is operated between 4.5 and 7.5 MPa with a capacity of 2.9 GWh (110 MW for 26 hours).

The main CAES technologies under development are adiabatic and isothermal.

In Adiabatic CAES (ACAES), the compression heat is stored on surface in a specific material and released during emission into the stored compressed air flow. This eliminates fossil fuel burning to heat the air after de-compression and improves energy efficiency up to 70%. The technological issues still partly unresolved include reaction of the salt caverns to quick cycling of massive air flows inducing quick pressure and temperature change, heat storage at a temperature of typically 600°C, development of efficient and reliable ACAES adapted turbines and mitigation of corrosion issues in the whole system. There are several pilot projects around the world such as ADELE in Germany involving RWE Power, GE, Züblin (80 MW during 5 hours) and the German Aeronautics and Space Research Centre (DLR). However, the large towers needed for heat storage may be a handicap in terms of public acceptance.

With Isothermal CAES (ICAES), temperature fluctuations are limited. There are several pilot projects in the USA. At SustainX's 1.5 MW facility in Seabrook, New Hampshire, the heat produced during compression is captured, trapped in water and the warmed air-water mixture is stored in pipes. When electricity is needed, the process reverses and the air expands, driving a generator. As with ACEAS, no fossil fuel is needed to reheat the air. General Compression, with ConocoPhillips as a partner, has a 2 MW (500 MWh) project in Gaines, Texas.

Figure 70 SustainX´s 1,5MW isothermal CAES in Seabrook, New Hampshire, USA

2.3.2.3 UGS experience

The gas industry's UGS experience can be drawn on for the sub-surface part of the facility.

- Salt caverns: the technology is there, but requires adaptations. One of the main advantages is modularity and the large experience gained from the natural gas UGS industry on salt behaviour (in particular under fast pressure and temperature cycling) and on salt caverns design, construction and operation.
- Mined caverns (or disused mines): the key issues for applicability of the unlined mined caverns (or disused mines) technology besides construction cost, are caverns stability and hydraulic containment of the stored air under rapid pressure cycling over a wide pressure interval. Adding a liner may provide a response, and would additionally allow the applicability of lined rock caverns CAES to most geological environments, but at the cost of a significant CAPEX increase.

- Aquifer storage is a priori not rated a viable option. The size of the geological traps available to ensure containment of the air exceeds generally the needs of CAES projects, and even in the case of extremely high reservoir permeability, ensuring the very large air emission flow rates required would entail an excessively high number of large diameter production wells. Other issues identified in addition to conflict of use of aquifers and hardly predictable development schedule include risks of bacteriological activity in the reservoir, of water coning and entrainment during production at high flowrate, of reservoir deconsolidation in the near wellbore, of clogging of the reservoir pore space due to interaction of oxygen with water and minerals, of corrosion in the wells and in the surface facility and the need to allow for an efficient conditioning of the air flow in order to meet the specifications of the turbine manufacturers (in particular large size, high performance dehydration units).
- Depleted reservoirs are excluded for obvious safety reasons (risk of explosive mixture with air).

As far as the surface facility is concerned

- Proven solutions exist, but achieve only a moderate energy efficiency.
- Innovative approaches are underway. Technological breakthroughs in particular in the field of heat storage and of design and construction of turbine machinery specifically adapted to new generation CAES could certainly boost the CAES deployment, but the market is rather a niche and might be considered too small to trigger large development efforts from the turbine manufacturers.

2.3.2.4 Obstacles

Obstacles to a wide implementation of CAES include cost and geographic/geological constraints. CAES facilities need to be located at “sweet spots” of the grid at reasonable distanced from both intermittent renewable energy production sources and the high voltage electric transportation system in order to avoid high connection costs, especially if buried power lines have to be considered.

For CAES in salt-leached caverns, rated the most favourable option, a minimum aggregated critical storage size is needed in case of a greenfield, stand-alone development to offset the cost of the leaching infrastructure. Moreover, developing new CAES sites could be further handicapped by lengthy and highly uncertain public consultation and permitting processes.

It can thus be inferred that conversion of existing salt caverns (either former storage caverns, or -stability allowing- caverns used for salt production) or creation of new caverns as an extension of existing cavern fields will be the primary target for future projects. This setting might additionally benefit from synergy with natural gas storage caverns if natural gas was to be used as a fuel for a non-adiabatic CAES.

In spite of a recently renewed interest in the technology, the fact that so far only few projects have been constructed, of which none in the last 30 years, translates probably a market sanction based on insufficient technical need and not attractive enough economics.

2.3.2.5 Power to Gas (P2G) - Hydrogen

2.3.2.5.1 Background information

The gravimetric energy content of hydrogen (some 33 kWh/kg) is close to three times that of pure methane, whereas its volumetric energy density is much lower (3 kWh/m3(n) for hydrogen versus 9.9 kWh/m3(n) for methane and some 11.5 kWh/m3(n) for typical high cal. natural gas).

No marked difference in the respective thermodynamic behaviours of hydrogen and methane is identified, excepted for the Z factor of hydrogen being greater than 1 and increasing with pressure in the pressure domain relevant for UGS applications.

Worldwide hydrogen production and consumption is in the range of 60 Mt/year (the corresponding energy content is some 2000 TWh). It is currently dominated by use in refineries and in the petrochemical industry and by production of ammoniac based fertilizers (90%), the remaining being used by the food industry and by mobility applications. Local, dedicated transportation grids exist in some parts of the world, to supply refineries and petrochemical sites (in Europe in the Antwerp-Rotterdam and in the Ruhr areas; in the USA in the Gulf of Mexico region).

Hydrogen production originates 95% from methane and hydrocarbons steam reforming and from coal gasification; less than 5% is produced from water electrolysis.

2.3.2.5.2 Use of Hydrogen as an energy vector

Besides its use as feedstock for the petrochemical and fertilizers industry, hydrogen is a very flexible and versatile energy vector acting as a common denominator to many concepts and giving surplus electricity after conversion to hydrogen (and oxygen) via water hydrolysis, potential access to a wide panel of uses and of transportation and storage options (the efficiency of the process in the order of 60% with about 1MWh electricity required to produce 200 sm^3 hydrogen). The main applications of hydrogen as an energy carrier include:

- Use as a "clean burning fuel" (hydrogen combustion does not generate CO_2) for:
  - Specific hydrogen powered Combined Cycle Gas Turbines (re-electrification process).
  - Fuel cells
  - Mobility applications (automotive fuel; hydrogen gas refuelling stations)
- Hydrogen can be injected in the gas grid and blended into the natural gas stream (ex. France, Dunkerque: GDF SUEZ Project GRHYD [15]). The European Gas Research Group (GERG) is currently preparing standards defining limits for the percentage of hydrogen acceptable without damaging gas networks, ancillary equipment and user's appliances. This can be considered a first step to opening the door of existing gas transportation and distribution infrastructures to hydrogen.
- The power to gas option consisting of producing "Synthetic Methane Gas" (SMG, or pure CH4) from combination of hydrogen generated through water electrolysis and CO2 captured from an industrial user or a power plant (Reaction: CO2 + 4 H2 = CH4 + 2 H2O (350°C). This "green methane" produced from electricity appears theoretically as a unique opportunity to link the electric network and the gas grid, as the SMG is compatible with injection, transportation and storage in the existing natural gas infrastructure. However, the energy efficiency of the process is low (typically around 10 to 15%).
- Conversion to Synthetic fuels (synfuels): kerosene, petrol, diesel, methanol.
- Converting surplus electric energy into hydrogen through water electrolysis (the high purity oxygen generated during the process might be monetized and could provide a fringe benefit) may thus be thought of as a convenient way to store electricity. In order to cope with the magnitude of the swing anticipated in the intermittent electricity production from renewables, this solution would however require prior development and commercialization at acceptable

[15] GRHYD is an initiative of GrDF, the French gas grid operator with a € 15 million budget over five years. The project was inaugurated on January 30, 2014 and will study the technical and economic aspects of Power-to-Gas. A hydrogen-natural gas blend, Hythane®, consisting of 80% natural gas and 20% hydrogen, will be introduced for use in an eco-neighborhood encompassing approximately 200 homes and in local transportation buses.

cost of more efficient and larger capacity hydrolysers, than the standard electrolysers presently on the market which consist of cells yielding typically a 10 to 40 m^3/h unit production.

2.3.2.5.3 State of the Art and perspective of hydrogen underground storage

The underground storage option for hydrogen generated from surplus electricity is only realistically applicable for large size storage (100 GWh i.e. approx. 3000 tons or 35 Mm^3 (n) hydrogen and above), whereas conventional pressure vessels or novel solid storage solutions (metallic hydride e.g.) could cover the needs for small size, distributed storage applications.

As a matter of example, one single 500 000m^3 cavern with a typical 120 bar operating pressure range (e.g. from 180 to 60 bar) can accommodate the following working gas in the case of respectively hydrogen and natural gas (data for comparison purpose only, figures approximated):

- 45 Mm^3 (n) i.e. some 4000 tons Hydrogen or some 135 GWh
- 60 Mm^3 (n) Natural gas i.e. some 700 GWh

The above figures show that UGS in salt caverns is globally a less efficient process for hydrogen than for natural gas. For a same storage space at the same pressure, the working gas volume of natural gas will be greater than that of hydrogen, and the energy content stored in the natural gas storage will be in the order of five times that available in the hydrogen storage. Furthermore due to its low density, hydrogen compression during the injection phase will require some 8 times more energy than natural gas and the high value of hydrogen as compared to that of natural gas (ratio is in the order of 20), will impact the cost of the trapped, non-recoverable gas and of the immobilized cushion gas needed to ensure smooth emission of the working gas as per the facility design performance profile.

Currently, three underground hydrogen storage sites are in operation worldwide and a fourth is under construction, all in salt leached caverns, to store hydrogen used as feedstock for the local petrochemical industry:

- Teeside, the UK (SABIC Petrochemicals), operating since 1971 and encompassing 3 caverns at 370 m depth, with a unit volume of approximately 70 000 m3, in which the hydrogen is stored at 45 bar, with a working gas capacity of 850 tonnes (28 GWh);
- Clemens Dome, Texas, USA (ConocoPhillips), operating since 1983 with a working gas capacity of 2600 tonnes (86 GWh);
- Moss Bluff, Texas (Praxair), operating since 2007 with a working gas capacity of 3700 tonnes (122 GWh); and
- Spindletop’s project, Texas (Air Liquide).

For the latter three sites, the unit cavern volume is in the order of 580 000 m3.

These facilities can provide operational feedback on hydrogen storage in salt caverns; and the natural gas industry can call on a wide experience reaching back to the 60’s 70’s, of storing town gas (a mixture produced from coal of methane and up to 60% hydrogen) in both salt caverns and porous reservoirs. Salt is known not to interact with and not to be permeable to hydrogen (nor according to Gazprom researchers, to helium, which molecular size is close to that of hydrogen). The feasibility of hydrogen UGS may thus be considered proven, at least for caverns leached in pure (dome) salt. Some questioning may however be identified as to hydrogen tightness of bedded salt formations or of salt bodies displaying massive occurrence of insoluble minerals, which would deserve a site specific, case by case defined investigation.

Some of the physical properties of hydrogen are identified as unfavourable to UGS applications and require mitigating actions and/or dedicated R&D efforts. These include in particular:

- The high fugacity of hydrogen likely to generate containment issues, in particular in the cemented annulus of production wells (requiring development of adapted cement formulations, and of the related placement and evaluation procedures) or at the interface between the cement and respectively the production casing and the host formation.
- The small size of the hydrogen molecule calls on an adapted metallurgy due to its propensity to generate metal embrittlement through HIC (Hydrogen Induced Cracking), likely to impact the well tubulars, the surface lines and the surface equipment. Large experience derived from pressure vessels construction for high pressure hydrogen storage and from hydrogen pipelines exists in the industry, to tackle this issue.
- The chemical activity of hydrogen may adversely interact with synthetic seals present in some elements of the well completion (packers, seals, valves etc…).
- Dissolution of water in the stored hydrogen in case of reservoir storage and hard rock caverns or of brine trapped in the sump of salt caverns may require implementation of some dehydration process at surface. Conversely, dissolution of hydrogen in the formation water or in brine may lead to acidification problems with a potential adverse impact on corrosion of steel equipment and on deconsolidation of the reservoir rock or of inter-salt layers.
- Adapted compression technology is needed to minimize efficiency loss due to the high compression energy required to inject the hydrogen into the storage.
- Hydrogen is not detected by process gas chromatograph using helium as a carrier gas. Gas detectors would need to be recalibrated
- Hydrogen is highly flammable (LEL and UEL in air are respectively 4 to 75%) with a low activation energy and will require setting up approved rules for evaluation of safety distances in case of accidental release (these are however believed to be within those in force for natural gas).

A few additional issues and challenges are identified in relation with reservoir storage (aquifers and oil & gas fields) which might even materialize as showstoppers for pure hydrogen storage, or if injection of hydrogen at high concentration into the natural gas grid, entailing as a consequence potential injection of a hydrogen rich natural gas blend into the existing natural gas reservoir storage system, was to be implemented on a large scale:

- Contamination of the stored hydrogen with reservoir fluids (water, hydrocarbons) or mineral components is likely, whereas interaction with pyrite and sulphur bearing minerals and formation water might generate H2S and might lead to mineral deposit and clogging of the pore space in the reservoir.
- It may be feared that the fugacity of hydrogen might lead to migration phenomena across the geological sealing horizon ensuring the vertical containment of the stored gas and to long term alteration of the cap rock properties. Comprehensive studies undertaken as part of the design of nuclear waste repositories to address the migration of hydrogen originating from alteration of containers into various subsurface rock formations may contribute some answers to this concern.
- The low viscosity and high mobility of hydrogen may impact the sweep efficiency in the pore space, and generate extensive fingering, potentially leading to lateral gas escape across spill points out of the storage space.
- The risk of bacteriological activity and of biodegradation of hydrogen to methane has been mentioned to have occurred in town gas UGS facilities.

- Part of the injected hydrogen used as cushion gas will remain permanently trapped in the pore space and a fraction of the stored hydrogen will dissolve in the formation water or in the reservoir fluids leading to economic loss.

National or EU funded R&D Projects aimed at evaluating the feasibility of hydrogen UGS storage from a technical, but also economic and regulatory standpoint and at identifying technology gaps are ongoing, such as eg. InSpEE (Germany), HyUnder (International Consortium) and pilot projects Falkenhagen and Thüga Mainova (Germany).

Figure 71 The E.ON & Swissgas 2MW pover-to-gas unit in Falkenhagen (Germany)

As of today, hydrogen storage in salt caverns is the most mature and by far the preferred option. Salt caverns namely offer some discriminant advantages among which: experience feedback from 4 operating facilities, minimum R&D effort requirement, excellent performance envelope (high deliverability, modularity and flexibility if caverns are developed in stages). Additionally, synergy may be found from extending existing natural gas cavern fields or from converting former natural gas caverns to hydrogen, and, in the case of a “green methane” scheme to CO_2 and oxygen caverns. Storage in porous reservoirs may be feasible, but there are major uncertainties which need to be assessed and resolved by targeted R&D efforts. The HYCHICO pilot project (Patagonia, Argentina) considers injection in a depleted gas field of hydrogen produced from a wind farm (7 x 0,9 MW windmills) combined with two hydrolysers with a cumulated hourly production of 120 Nm^3 hydrogen and 60 Nm^3 oxygen (source HYCHICO website). The first pilot demonstration plant in Europe, with a (planned) real injection of mixture of natural gas and hydrogen into a depleted gas field and its subsequent withdrawal is going to be built in Austria under the Underground Sun storage project. The project run by a consortium led by RAG AG, is focused on assessing the impact of hydrogen on underground gas storage reservoirs based on (real) data from in-situ tests under actual in situ conditions.

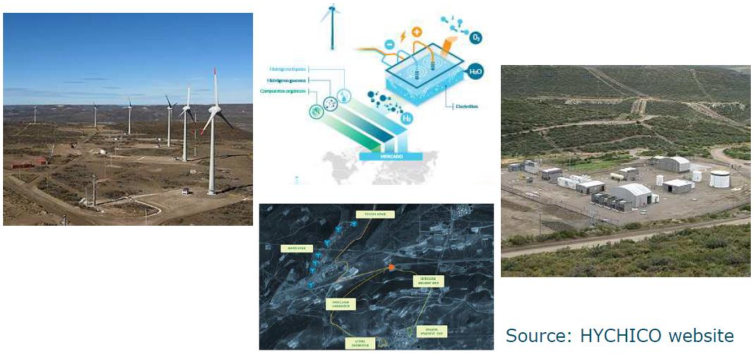


Figure 72 The HYCHICO pilot project in Patagonia (Argentina)

Unlined rock caverns are a priori not a viable option, whereas lined caverns, like the GDF Suez 40 000m3 natural gas Lined Rock Cavern (LRC) in Skallen (Sweden) would be very expensive to build and are not yet a demonstrated solution for hydrogen. An attractive alternative for small to medium hydrogen storage volumes (a few thousand m^3 capacity i.e. up to a few GWh energy content) could be provided by high pressure hydrogen storage in underground tubes, derived from surface and subsurface storage techniques already implemented for natural gas storage (e.g. in Switzerland).

Based on the above, it may reasonably be assumed that the technology is there –or nearly there- to extend at least some of the natural gas underground storage techniques to hydrogen storage in order to provide a versatile, flexible solution for massive storage of intermittent electricity. In terms of quantity, deliverability and response time, this would offer a unique opportunity to achieve the integration of the electricity and of natural gas grids in terms of production, transportation and storage, through conversion of surplus electricity either to hydrogen or to Synthetic Methane Gas.

However, there are obstacles and preconditions to the development of a stabilization process of electricity grids via massive hydrogen UGS storage, the main of which include:

- An economically efficient deployment of UGS storage techniques calls on large hydrogen volumes and flowrates and hence requires implementation of large capacity hydrolysers. A single typical salt cavern can namely host some 50 mcm hydrogen working gas, while as of today, demonstration hydrolyser facilities such as Falkenhagen (2 MW capacity) only achieve a hydrogen production rate in the order of 360 m^3(n)/h (i.e. it would take some 15 years to re-fill the single cavern!). Furthermore, the electrolysers represent the main cost item of the conversion chain. A significant R&D effort leading to technological breakthroughs is needed both to increase the performance of hydrolysers and to significantly reduce their cost.
- The Hydrogen produced from electricity may most efficiently be used as pure hydrogen rather than as “green methane” or for re-electrification. This option, besides entailing minimized loss of the energy content is compatible both with disseminated and concentrated hydrogen production and demand. Transportation via road carriers would certainly provide a short term but limited scale solution, whereas developing the use of hydrogen would require the creation of a hydrogen pipeline network entailing significant investment, permitting and public acceptance issues.
- Injection of some hydrogen percentage [16] into the existing natural gas grid, although looking very attractive at a first sight, faces several obstacles which will likely not be

[16] *Natural gas metrology limits the H2 content to 0,5 % as defined by EN ISO 6974*

resolved in the short term. Based on current belief and evaluations injecting up to 5% vol. hydrogen [17] (and possibly/likely more, up to 10% [18]) into gas flows in the natural gas grid is deemed feasible [19], whereby storage caverns could contribute to enhance stability of the mix.

A major R&D investigation effort is indeed required to define the actual percentage of hydrogen acceptable without damage in the existing gas grid, thus converting it to a “hybrid gas grid”. This includes in particular, but not limited to, evaluating the impact on the whole transportation system (pipes, compressor stations, storage facilities in particular pore storage facilities) and assessing full compatibility over the entire users chain (Compressed Natural Gas tanks in vehicles, domestic and industrial natural gas based equipment, etc…). Setting up a harmonized regulation at European level is another critical and long term prerequisite to be addressed if the solution of hydrogen blending into the natural gas grid was to be widely implemented as a cross border option requiring interoperability. Conversely, hydrogen blending might only be considered at local grid scale, in which case, large UGS storage facilities would probably not be needed.

Conversion of hydrogen to “green methane’ would largely relieve the above constraints and allow to take maximum advantage of the existing gas infrastructure, but the energy efficiency of the conversion process from electricity to “green methane” is quite low, homogeneity of the methane/hydrogen mix remains an issue and economics, even if excess electricity would be “available for free”, are apparently not supporting the option at least under current market conditions.

The main obstacle to the power to gas route is indeed economics; and as of today, the Power to Gas option cannot make it on its own. Recent studies (in particular the HyUnder Project and publications by the Fraunhofer Institute and other organizations) show that electricity storage via hydrogen production or SMG does not offer a real business case (even under the hypothesis of a nil value of the distress electricity to be stored). The only potentially profitable application identified under current market conditions is use of hydrogen for mobility as an automotive fuel. As a matter of illustration, in Germany the “mobility initiative” plans to build and operate 100 hydrogen filling stations by 2017 and 400 by 2022. Whether this option will call on massive hydrogen UGS storage remains an open question… To make any flexibility measure to balance intermittent energy generation profitable, there has to be a market mechanism that values and rewards the flexibility/capacity that energy storage offers. In the current market there is no incentive to invest in these measures, even though the growing share of renewable energy does necessitate the development of these measures.

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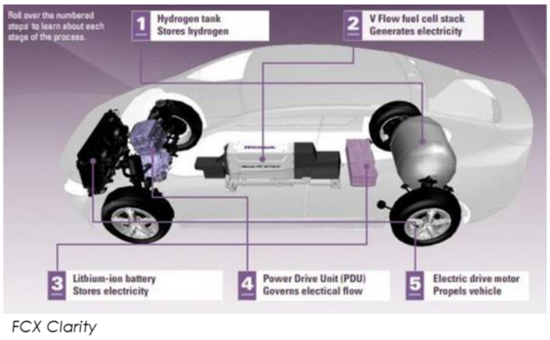
17 Calorific value calculation limits the H2 content to 5% as defined by EN ISO 6976

18 ISO/TC 193 « natural gas » has launched works to increase H2 content up to 10% in the EN ISO norms 6974 & 6976

19 EASEE-gas - Gas Quality Specification [2] used in Europe does not fix a limit for H2 content. But outcomes from GERG H2 hydrogen project [3] shows that there are still some important areas where issues remain:

- *underground porous rock storage, a limit value for the maximum acceptable hydrogen concentration in natural gas cannot be defined at the moment;*
- *steel tanks in natural gas vehicles: specification UN ECE R 110 stipulates a limit value for hydrogen of 2 vol%;*
- *gas turbines: most of the currently installed gas turbines were specified for a H2 fraction in natural gas of 1 vol% or even lower. 5 % may be attainable with minor modification or tuning measures. Some new or upgraded types will be able to cope with concentrations up to 15 vol%;*
- *gas engines: it is recommended to restrict the hydrogen concentration to 2 vol%. Higher concentrations up to 10 vol% may be possible for dedicated gas engines with sophisticated control systems if the methane number of the natural gas/hydrogen mixture is well above the specified minimum value;*
- *many process gas chromatographs will not be capable of analyzing hydrogen.*

Investigations have been conducted to evaluate the impact of hydrogen as related to the above topics. At present it is not possible to specify a limiting hydrogen value which would generally be valid for all parts of the gas infrastructures and, as a consequence, a case by case analysis is strongly recommended



HONDA

Figure 73 Principle of and Hydrogen powered car (courtesy Honda and hydrogen filing station (courtesy Air Liquide)

2.3.2.6 Intermittent electricity storage: deploying the UGS experience

The natural gas UGS industry can claim a 100 year experience and proven safety records in the field of engineering, design, construction, operation and monitoring of underground natural gas storage facilities, mostly onshore. In the course of this long history, our Industry has built a reputation of sound safety and reliability culture and has gained recognition for low environmental footprint and open communication with regulatory bodies and neighbouring communities.

In an energy transition process, natural gas is identified as a bridging fuel allowing to adjust electricity production and demand and to provide fast response to peak demand via the existing infrastructure, including the existing natural gas storage facilities.

Large scale integration of intermittent renewable energy will call on storage solutions for electricity at all time, capacity and deliverability scales. The gas industry can readily answer this demand and evolve to a provider of technical solutions to store underground surplus intermittent electricity production, provided quantities to be stored are large enough. These storage solutions, calling on in particular salt caverns and possibly in the future lined rock caverns include:

- CAES applications well suited to shave peaks of demand owing their limited capacity and fast response time.
- Hydrogen storage: providing flexibility from hours to weeks and large capacity typically from a few MWh up to a few TWh in case of a large salt caverns field. Advantage may be taken from this perspective, to extend natural gas storage sites (as an alternative to “grass root” storage projects) and to leach new salt caverns for hydrogen, CO2, oxygen, i.e. covering the full range of the components potentially generated by large scale water hydrolysis and/or SMG production. To that effect, re-conversion of former natural gas caverns should be considered a priority target.

Whereas technical solutions for massive electricity storage exist, and can be provided by the UGS industry, it is questioned what the market needs will be and in particular to what extent the characteristics of the UGS solutions will match future demand, if one excludes a few large storage facilities to be constructed at “sweet spots” in the electric grid such as dead ends, poorly connected “energy islands” or “peninsula”, hubs, or in the immediate vicinity of large wind farms.

One key unresolved issue in particular, for the level of deployment of UGS solutions for electricity storage is the extent to which the intermittent electricity generation from renewable sources will be centralized or dispersed and the resulting volatility. In the case of a widely dispersed renewable intermittent electricity production, it can be expected that small size dispersed storage capacity calling on surface pressure vessels or innovative solids such as hydrogen hydrides rather than large scale UGS will be implemented. Demand side management (e.g. smart heat pumps and domestic appliances switched on and off depending on electricity price and availability on the grid, etc…) and energy savings in particular in the domestic sector could also reduce volatility; and so will the integration of networks and emerging ''smart grid'' management technologies.

On top of the above technical issues, future pricing of energy, "new rules of the game" and regulations yet to be invented, could lead to new business models which, together with long term energy policies will dictate future UGS needs triggered by intermittent electricity production. In short, it is anticipated that energy systems may change dramatically over the next 30 years. How many new (or novel) massive energy underground storage facilities will be needed by the market is unclear as of today and this will dictate the extent to which the UGS industry will have the opportunity to contribute its storage facilities and its storage expertise. It is hereby to be mentioned that the UGS industry could take advantage of its current know-how to extend its field of services to other energy storage techniques such as geothermal heat storage in aquifers or dry rocks, to subsurface monitoring, and in the wider perspective of a de-carbonated energy society, to CO2 storage. Namely, all these technologies call on disciplines widely in use in the UGS industry such as subsurface engineering, well & completion engineering, reservoir engineering, geochemistry, environmental impact monitoring, surface and process engineering, and facility operation. The extensive experience of the UGS industry with permitting processes might be considered a further feather in its cap.

However the future evolves our industry is ready to face the change and to respond to the challenges ahead with a combination of experience feedback and technology driven innovation.

2012-2015 Triennium Work Report
June 2015

REPORT OF STUDY GROUP 2.3

HUMAN RESOURCES: ATTRACTING STUDENTS TO STORAGE ACTIVITIES

3 Report of Study Group SG2.3

3.1 Introduction

The Study Group leader: Nikita Barsuk (Russia)

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Acknowledgements:
We thank the members of SG2.3 and their companies (GazProm, Storengy-GDF-Suez, NAFTA, AGH Crakow University of Sciences &Technology) and all the companies that have answered to our questionnaire.

3.1.1 Continuity

Study Group 2.3 will continue its activities successfully launched in the previous triennium. We plan to continue promoting underground gas storage as one of the most important sectors of the gas industry, and to enhance outreach among students of engineering disciplines. Taking into account the limited number of universities providing training in the sphere of UGS, developing methods and techniques to attract students of technical disciplines to this sector may be one of the most significant tasks of WOC 2. One of the topics to focus on may be finding the ways to develop young professionals' special skills required in various areas of underground storage including hydrodynamic computation, well drilling and engineering as well as engineering simulation.

3.2 Aims

Define the key factors affecting talent attraction to the underground storage sector and develop strategic approaches to HR development to assure the availability of skilled/trained workforce required at a particular location in particular moment of time. Assure sustainable and comprehensive development of the underground gas storage sector as an integral element of the gas industry.

3.2.1 Objectives

- Develop a list of specialists and managers most needed for projects implementation and business activity in the UGS sector. Engage other IGU members to analyse the demographic profiles of available personnel, identify the commonalities and differences depending on countries and regions, and define qualitative and quantitative characteristics of skills and resources required for the successful current and future development of the UGS market.
- Identify the main gaps and drivers of HR management affecting the short-term and long-term performance of the UGS sector, including those related to recruitment and training.
- Define the degree to which various factors affect talent recruitment, training and retention.
- Develop the most efficient training techniques and programmes with the account of specific features of different countries and business sectors, including the opportunities arising from inter-sector synergies and programmes for training mono-specialised employees.
- Define the role of government, industrial associations, universities and private companies in personnel training.

- Define the role of female workforce in the current HR management under the conditions of strong HR deficit in the gas industry and in particular – in the UGS sector.

3.3 Results

3.3.1 Special survey to explore UGS sector gender, demographic and skill characteristics

In recent years, the natural gas industry has seen change in its image by communities, policy-makers and the public. Part of the industry's success is its ability to promote the benefits of natural gas to these groups.

The past three years have had a major impact on the gas industry. Tremendous changes put human resources and capability back in the spotlight. The human resource and talent building issues cannot be solved on short notice and will have an effect on the long-term sustainability of the gas industry. Key issues of this specific questionnaire are to evaluate the process of attraction and retention of talent in the gas industry (particularly UGS business), the key drivers to develop a strategic approach to human capacity building and present best practices and initiatives being developed across different countries, companies and regions. Given the number of workers in or approaching the retirement age, this will create a shortage in skills within the industry. Also the industry will be pressed to find skilled workers to meet demand and make the industry more reliant on professionals who have crossed retirement age. Despite the fact that women are a majority among the holders of a diploma, the percentage of women employees in the gas industry represents a minority in almost all companies throughout the globe, with some regions lower than others. We wish to both consolidate the current representation of the female workforce in the industry as well as encourage the industry to become more female friendly in order to attract more females that are talented.

The goals of the Survey is gathering statistic information across IGU's members to understand the demographic of the industry and gender characteristics, which skills and resources and in which quantity is necessary to deliver the UGS business of today and develop the UGS sector of the future. The Survey results will be complemented with interviews of industry experts, reviews of best practice, case studies and dialogue with a range of organizations inside and outside the gas industry.

Questionnaire structure and description - There were 45 questions in total related to:

- General Information part
- Questionnaire part A "Skill requirements"
- Questionnaire part B "Demographic characteristic"
- Questionnaire part C "Female Workforce"
- Questionnaire part D "Career Development and retention".

According to SG2.3 members' decision survey is an independent one from TF1 IGU questionnaire sent to all type of companies of the gas industry. UGS companies (10 members of WOC2) have answered directly to SG2.3. This gives the possibility to interpret the answers in framework of WOC2 and write an appropriate chapter in the final report to describe a specific portion of HR problematic of the UGS business. Comparisons with TF1 survey results are presented.

Eleven answers have been received from different countries. Not to disclose the individual answers of companies, all the charts are presented by countries. Most of the countries are represented by one company and some of them are not the biggest of the country. It is the reason why results, even consistent and valuable, must be taken carefully.

3.3.2 Program of competition in honour of 100th anniversary of UGS

The objective of the **SG2.3** in the triennium is to provide status and deliver some sorts of solutions for increasing attractiveness of gas industry but especially storages. The "Programme of competition in honour of 100th anniversary of UGS" is dedicated for students and young specialists working with or willing to work in UGS industry. The limiting age of the candidates is thirty. Authors of the three best theses will be awarded participation to the world gas conference in Paris 2015 free of charge. Topics of theses correspond to "gold" and "green" strategic pillars of WGC Paris 2015.

Topics for the call for thesis:

- **Combination with renewables & electricity**
  - New roles of storages (support of renewable energies, energy storage, electric grid balancing, etc.) and their impact on storage design and operation;
  - CAES (Compressed air energy storage) with heat recovery (capturing heat generated during a phase of air compression and its usage for pre-heating of expanded gas)
  - Concept "Gas to power" and usage of underground gas storage for storing (mixture of natural gas with hydrogen, synthetic gas, hydrogen storage, bio methane)

- **Natural gas for sustainable development**
  - Reduced emissions and increased efficiency in compression technology;
  - UGS facilities as a core and cost-effective tools to match supply and demand on peak and seasonal basis;
  - technical improvements in design or operation to use the capacities of the UGS facilities at their maximum;
  - end-user and gas market needs in terms of operation flexibility and reliability of UGS, plus gas withdrawal and injection rates;
  - partial replacement of cushion gas with non-hydrocarbon gases (projects on CO2 sequestration or nitrogen injection);
  - new technologies for new projects (salt caverns with two wells, multi-cycling mode, drilling in strongly depleted field, etc.);
  - efficient operation, technical and economical optimization, balancing energy consumption in real-time vs prices forecast.

3.3.3 Contemporary challenges of building human capital in gas industry, particularly – in underground gas storage companies

Today the younger generation selects the future profession taking into account numerous positive and negative aspects of their potential professional career.

3.3.3.1 Strengths of the gas industry image

- innovative nature of the gas industry and the UGS sector in particular;
- international (transcontinental) nature of the gas business;
- specialists are in demand both in producing and importing countries;

- environmental focus (in the future there is assumed the link between UGS and renewables has been getting stronger); Not really in Europe now
- new functions of UGS as an integral element of the energy supply system (storing energy, regulating the market);
- high level of investment security.

3.3.3.2 Drawbacks of the gas industry image

- uses non-renewable natural resources;
- as a rule, is associated with the oil industry, so all the negative features of the latter are automatically carried over (mainly, environmental impacts);
- the strengths of the gas industry and its significance for the energy mix of most countries are not actively communicated;
- in importing countries this industry is not attractive enough for the younger generation;
- younger generation does not perceive the gas industry as a high-tech one;
- young specialists receive the most interesting offers from the banking sector;
- geopolitical aspects often interfere with the standard market functions.

3.3.3.3 According to the decisions of Task Force-1, the following common approaches should be used for building the human capital

- multicultural approach (young specialists representing different ethnic and social groups are treated equally);
- technical and engineering universities should be the main source for recruiting human resources;
- possibility for research and access to the respective equipment and technology should be guaranteed to young specialists;
- focus on female workforce and its share in the overall human capital;
- improve the gas industry image in general – not of just certain companies;
- strategic partnership is a true remedy for human capital deficit;
- create innovative and environmentally friendly image of the gas industry.

3.3.4 Generational change in the gas industry, particularly – in underground gas storage companies, and the related issues

In 2015 the underground gas storage sector will celebrate its 100th anniversary. For companies operating for half a century (and more) aging of skilled workforce is one of the most acute challenges. The accumulated knowledge, skills and practices need to be transferred to the young generation of operators and engineers.

Fast-growing companies have their specific needs too: competitive expansion demands on-going revamping and introducing state-of-the art technology. Complex equipment sets higher professional qualification requirements; advanced knowledge and skills are in demand. Everyone has to be subject to permanent training and retraining. Naturally, older people have more difficulties with such changes, that is why HR managers need to gradually substitute older specialists with the promising younger ones with a great level of delicacy and professionalism

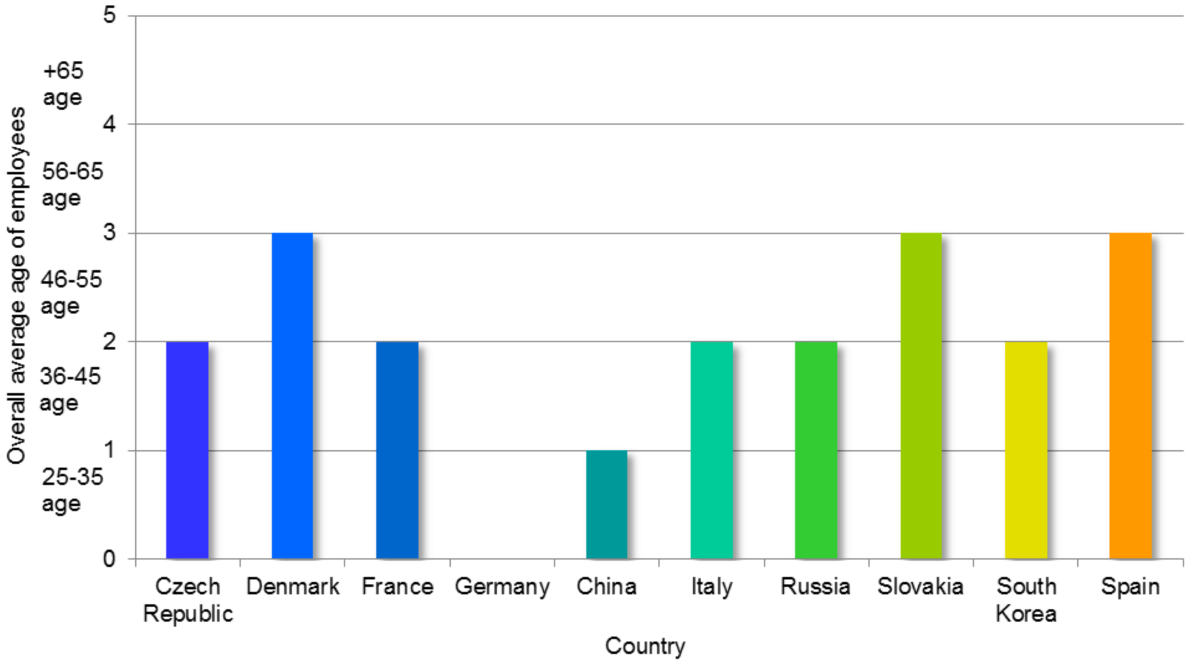

Figure 74 Overall average age of employees in UGS companies

As shown in Figure 74 UGS company in People's Republic of China has the youngest workforce, its employees being under 35 years old. It is obviously because People's Republic of China just at the beginning of creation of his UGS system. Some companies in West Europe (France, Italy and Czech Republic), Russia and Korea show a slightly more aged personal 35-45 year. The companies with the oldest workforce in the UGS industry are located in the Spain, Denmark and Slovakia.

Companies need to fine-tune the mechanisms of mass "outside" the recruitment and set up a "conveyor" for transferring the accumulated experience and best practices based on knowledge management systems and other similar tools. It is important that techniques for such a "flow-production of professionals" are easy to implement and user-friendly (electronic testing, packaged training, etc.).

Young specialists represent the future of any company. If a company is planning to grow and develop its business, it cannot do without young specialists.

Many companies start their search for a talent in the leading universities among students and graduates. They are especially interested in full-time students with excellent performance in special disciplines and with a certain project background, the ones who have some hands-on experience in the future professional area. At this stage, companies make presentations for students, workshops or conferences, when a company representative may describe available jobs and invite for internships. Various employment fairs and career expos are organised. Companies are interested in working with young specialists: they organise competitions for positions and internships with future employment options

Depending on the company's area of business and its niche in the market, the share of young specialists in the total headcount may vary, but in any case, it is a certain percentage of new-hires selected through a competition, not exceeding the number of middle-aged specialists with stronger professional background.

Answering the question why is difficult to get proper experts into UGS activities. Survey participating companies mentioned the following:

- The benefits are to small comparing to the effort.
- The business is on decline in Europe.
- Skilled personal concentrated in former monopolist companies.
- Difficulties in recruiting international professionals.
- Similar skills are required in oil and gas exploration and production industry where salary is higher and broader career development is possible.

Concerning initiatives being developed in UGS companies regarding attracting professionals who have crossed retirement age some Survey participating companies mentioned that they have a retirement package to keep professional in the job as long as possible. Keep them on as consultants and provide them a shorter work week – 15-30 hours.

3.3.5 Pre-university and university motivation, talent search for further employment in gas industry and particularly in UGS

Today to be competitive, any company must have enough highly skilled workforce capable of quick adjustment to the requirements set by the modern production environment. Workforce capable of resolving a set of complicated tasks assures competitiveness.

The specific features of such a social demographic group as young people define their low competitiveness in the labour market and are not attractive for employers. Most of the companies are not willing to spend time and money on “nurturing” a young employee until he/she becomes a mature specialist. They prefer hiring higher level experienced specialists with relevant background. Thus, when screening candidates, an employer will prefer the one with some professional experience, at least minimal.

Despite these obvious issues, younger people represent the most capable part of economically active population. They are ready to undertake risky experiments; they have the highest level of physical health and significant energy reserves. Their lives are emotionally intense because of their struggle for economic independence, prosperity, social recognition and self-fulfilment. That is why in case of relevant attention on behalf of the management and friendly mentoring on behalf of senior peers their lack of experience may very quickly turn to professional maturity and their competiveness will grow.

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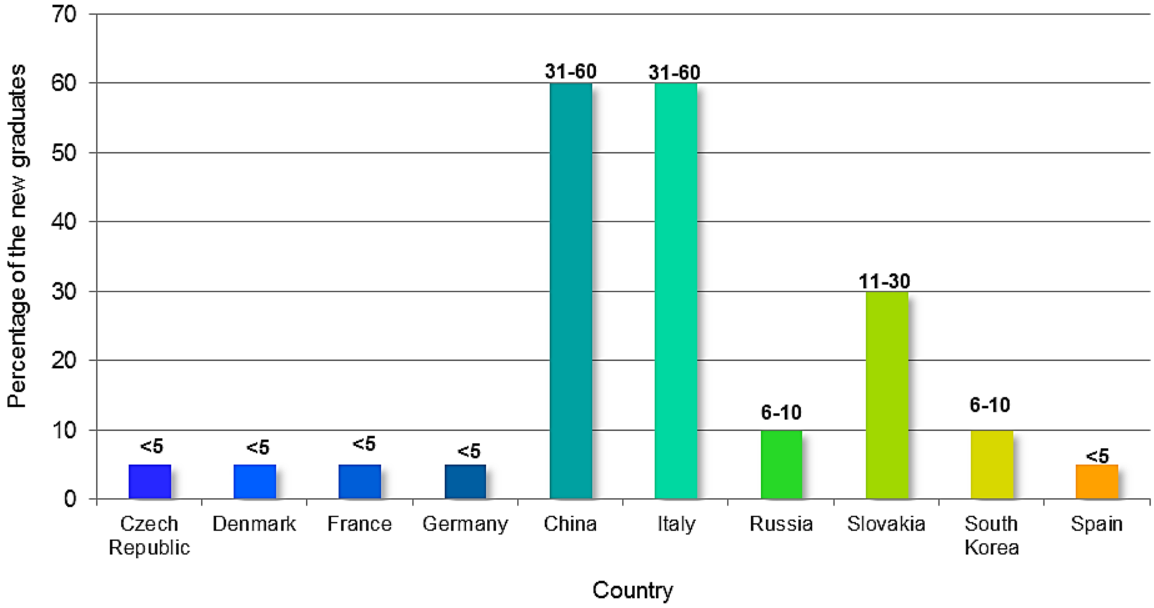

Figure 75 Percentage of New Graduates in Total New Hires over the past 2 yrs

According to Figure 75 most parts of UGS companies prefer to hire experienced professionals while new graduates represent a relatively small percentage in the number of total hires. In almost 70% Survey participating UGS companies, new graduates hired represent 5-10% of total hires. Results regarding People's Republic of China close corresponds with aged of UGS personal (Figure 74) but not the same for Italy.

The following conclusion seems appropriate: the current situation with supporting **young talent** requires significant change very fast. In addition to competitions for employment and internships, methodological tools of working with younger generation need to be enhanced, as well as educational networks integrating schools and extended education. Besides, a necessity arises for setting up the support system to provide for not just early identification and development of school pupils' and students' capabilities, but also for assuring the succession between the pre-school, school, vocational and academic education.

The following problems are defined as having the most effect on young people employment:

- Lack of professional knowledge and skills resulting in preferences for higher skilled and more experienced workers. The university graduates are not competitive enough due to theoretical and not practical focus of their schooling.
- Connections among potential employers and educational institutions are in embryo. Unfortunately, not many companies today are ready to train and employ specialists.
- Misbalance between labour market needs and specialists training arising due to the lack of elementary forecasting of employers' needs in specialists.
- Regulatory framework for graduates' employment is missing; so many graduates cannot find a job due to the lack of professional background.

3.3.5.1 Pre-university career guidance

In the environment where the prospects for certain industries are unclear, lack of the career guidance system in school induces uncertain motivation of young people when they select their future profession. They are enrolled with universities and select their specialisation without taking into account their individual specifics, dispositions and capabilities. Thus, profession selection for them becomes a spontaneous process, which may consequently result in unemployment.

This turns universities into an instrument for fulfilling social, but not professional ambitions of young people. It leads to a low level of learning and cognitive activity, to a very pragmatic attitude to education. Some students go to universities due to family traditions and under parents´ pressure and some want to prolong their worries-free way of living.

The correct choice of future profession has a direct impact on the level of interest in education. For many students who were no conscious enough when selecting their specialisations, the disciplines taught in such universities are of no interest; and students have very little motivation to obtain new knowledge and skills.

Today the key priorities of students and graduates' social values are financial prosperity, social pragmatism and self-dependence. High salary and remuneration based on the quality of labour are the key means to achieve financial prosperity. These are the main incentives for graduates when they select their jobs.

To avoid such negative effects the correct career guidance need to start in elementary schools. Between the years of 10 and 15, children and adolescents may be engaged in after-classes activities based on their interests. In particular, career guidance in the gas industry may include geology and other natural science groups for children, tourism activities, etc. The obtained knowledge may be reinforced via children's intellectual contests and/or Olympics at the local or national level. Respective certificates may be awarded to winners of such Olympics or contests, and such certificates may give to their holders the right to be enrolled in universities without competition or the right for receiving educational grants.

Search for talented young people with disposition to certain professions needs to start before they enter universities. It means that universities will admit young people with certain career guidance background – close to first-year or second-year students.
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3.3.5.2 Cooperation between industrial companies and universities

The interaction between companies and universities is focused on creating and improving the conditions for assuring a high quality of professional training specialists in the key areas of the gas business. The most optimal way of cooperation is assisting universities in the curricula development and coordination, provision of laboratory equipment and simulators/trainers, organising internships of students, engaging the companies' executives, and leading experts in delivering lectures. The future prospects of the gas industry development and the demand for different professions including new specialisations relevant for the new industry needs should be monitored.

Irrespective of how wide is the circle of specialists engaged in the gas industry, the critically important specialisations are as follows: Technical skills (e.g. engineering), Geologists and Geophysics, Drilling/completion specialists, Core skills (numeracy, IT&C), Business skills (economical, financial), Enabling skills (HR, team builders), Projects, Commercial/Marketing. That is why it may be feasible to select just several of critical (base) universities from the long list of training institutions. They should be the ones providing training in most of the disciplines required by gas companies. Establishing partnerships with such base universities may optimise achieving the following objectives:

- improving the efficiency of targeted training specialists for the key areas of the company's business, enhancing the curricula in accordance with the business needs, optimising the costs of young specialists adaptation in the company and in their positions;
- timely organisation of pro-active personnel retraining to implement strategic projects and innovative technology;
- improvement of career guidance efficiency to attract the best among universities graduates to work at the company's facilities;
- assure high effectiveness of joint projects in the sphere of educational technology; improve the level of equipment in universities

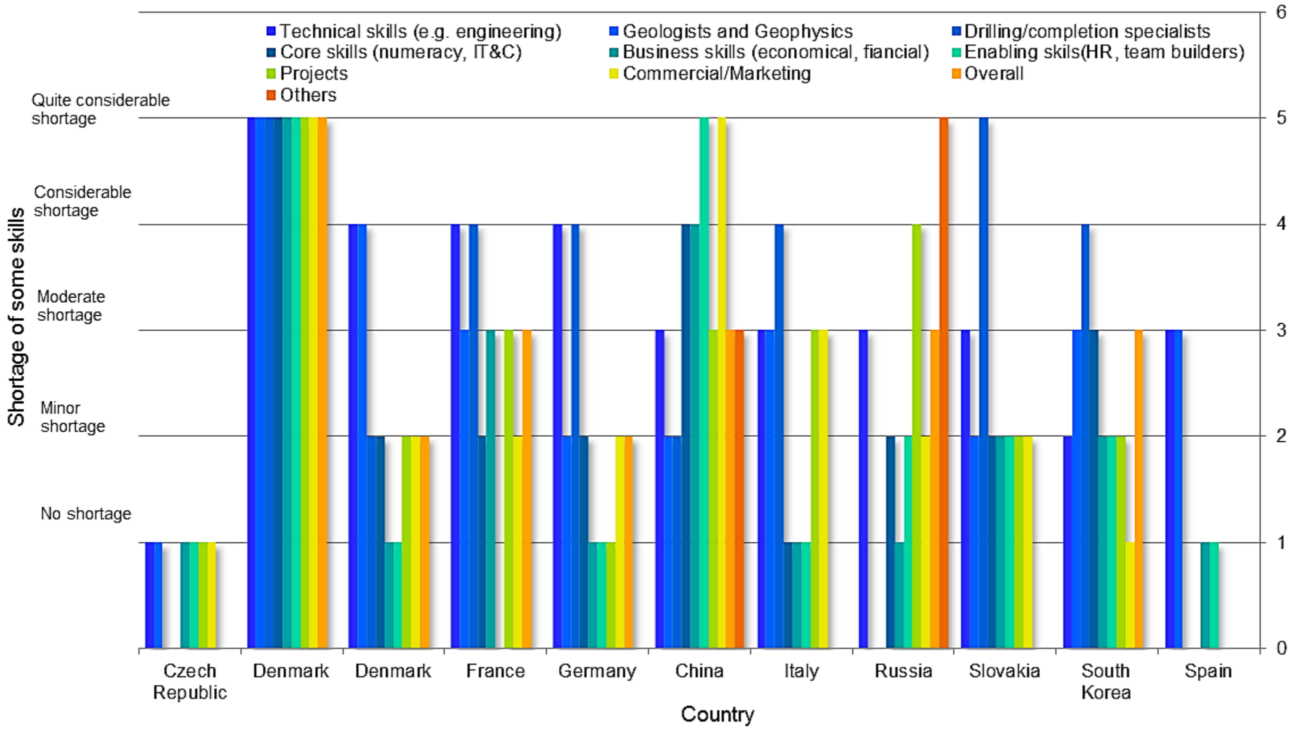


Figure 76 Shortage of the following skills in UGS companies

Technical and Drilling/completion skills are the hardest to find for UGS gas companies. Companies in Europe (Czech Republic, Italy, Slovakia, Germany and Spain) benefit from somewhat less of a shortage compared to other regions. Figure 76 depicts that the biggest overall skill shortage is felt by companies from People's Republic of China, Russia, Denmark-1 and France. It is clear that young UGS industry in People's Republic of China is under development and shortage of specified skills is obvious. Intensification of UGS industry development in Russia (programme for creation of new UGS in new regions) also resulting in shortage of skilled personal.

Today it has become quite common for graduates and young specialists having just their degrees, but no professional background, to dictate their terms and conditions when they are recruited: a comfortable workstation, a good salary, a clear job description, labour law compliance, etc. – all this is too big a luxury for people with zero working experience.

Employers often accuse universities in forming such overestimated self-esteem in students, because universities claim to be providing brilliant education and training specialists of high demand. In reality, a set of specialisations and professions taught in the universities often does not correspond with the labour market requirements. Based on the above the following problems may be identified:

1) Young people are not aware about specifics of different professions or about labour market forecasts.
2) University graduates are not skilled in searching for jobs.
3) The majority of graduates do not have a clear vision of their future career or professional development, as a result – it is difficult for them to adjust at the labour market.
4) Overall, the misbalance of supply and demand still exists in the labour market, which complicates employment for graduates.

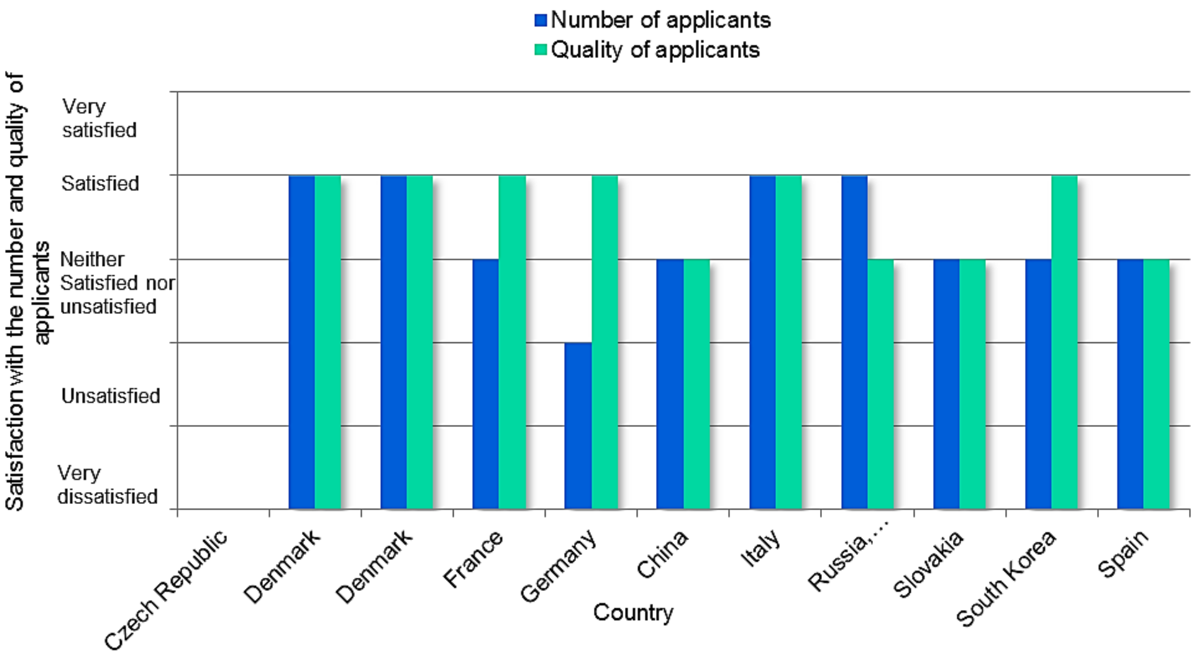


Figure 77 How satisfied are UGS Companies with the No and quality of applicants with a STEM qualification (Science Technology Engineering Mathematics)

Figure 77 indicates that there is a fair number of students with a STEM (Science, Technology, engineering and Mathematics) background that are applying for jobs in the UGS industry. In Spain, People's Republic of China and Slovakia the quality and preparation of these students is little lower than the rest Western Europe. Companies in Europe appear to be receiving more applications from better prepared STEM students.

It means that representatives of Universities and UGS Companies need to start a dialogue about the joint development of the training process, so that companies have a possibility to select among candidates with relevant specialisations being in demand today and – more important – tomorrow.

In today's environment most important for a candidate is not just to have a relevant set of skills, but being able to master them in future. A university or another educational institution may be competitive only in case it is developing and changing. Consequently, positive shifts in education will be largely dependent on the universities mastering modern management techniques allowing for their adjustment to new requirements, to organise training processes in a different way, to create all the preconditions for effective development of this educational institution. A higher level of professionalism in management becomes an important pre-requisite of innovations in the sphere of education.

The main requirements of employers to job seekers:

1) All companies prefer to hire highly skilled professionals with a certain background in the respective sphere, and the level of their preparedness for the job is very important for business. Students need to remember about this all the time they are studying.
2) Future employees also need to develop certain personal competencies: responsibility is the first priority, being ready for an on-going professional development is the second, and the third priority is a spacious mind and ability to acquire new knowledge. These are the key reference points for becoming a true professional, a valuable employee and a specialist of high demand.
3) The main social competency is teamwork, ability to cooperate. Organising skills, ability to reach understanding and to share best practices are also important, though yet to a lesser extent, (these competencies become more relevant while a specialist becomes more mature).
4) Many employers believe that graduates lack professional knowledge first. Another important skill is planning (maybe time management needs to be included into curricula, or students need to undergo such trainings independently).

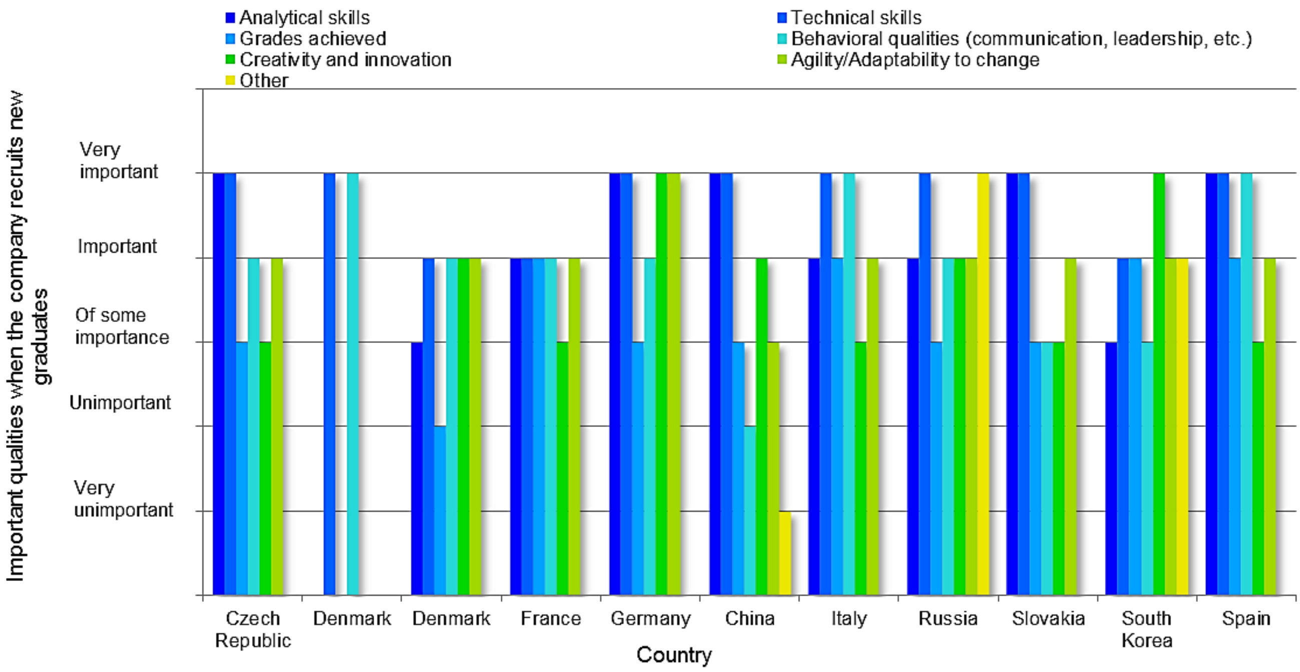


Figure 78 Important qualities when the UGS Company recruits new graduates

Somewhat surprising from Figure 78 the Grades achieved appear to be the least significant element when UGS companies are recruiting graduates. It appears that the importance of grades fall way below other desired qualities such as technical and analytical skills developed through education. Also quite important for UGS companies qualities that they look for when hiring graduates are behavioural qualities and agility/adaptability to change. At the same time creativity in innovation is less interesting.

The common requirements of employers (in addition to professional qualifications):

- computer skills, a good command of foreign language;
- general intelligence and fundamental knowledge;

- systemic thinking, ability to process large quantities of data;
- ability to put knowledge to use, teamwork skills, ability and willingness for on-going learning;
- commitment to career, determination to have things done, adequate self-assessment.

3.3.6 Attraction, retention and professional development of talented students and young specialists in the gas industry and

3.3.6.1 HR management policies in gas UGS companies

General Provisions

The human capital management policy means a system of principles and conceptual approaches to personnel management to guarantee successful development of the company and balance of interests among its employees, shareholders, customers and government.

The goal and key principles of human capital management policy

The main goal of the Policy is to assure the maximum return on investment into personnel based on:

- assuring a stable “preferred employer” status;
- integrated system of incentives motivating every employee to achieve the company’s goals;
- setting up and developing objective and efficient system of personal performance assessment.

Key elements of human capital management policy

Key interrelated elements of the human capital management policy are the following: selection, assessment and use of personnel; training and development; motivation and remuneration; social policy; corporate communications.

<u>Selection, assessment and use of personnel</u>

The key elements of the corporate training system:

- strict adherence to the general corporate strategy;
- prioritisation of the identified capabilities of employees and practical needs for training different groups;
- planning and coordination, quality and effectiveness audits;
- use of modern efficient training formats based on economic and methodological feasibility;
- development of new forms of training;
- development of a training centres network and expansion of relations with foreign professional training organisations;
- individual approach to training and development of young specialists;
- enhancement of mentoring and engaging highly skilled professionals; making a mentors’ status not just an honourable duty and measure of recognition of their merits, but also the basis for financial awards;

- pro-active top executives succession policy, targeted training of the selected high-potential employees.

<u>Motivation and remuneration</u>

Labour remuneration system should be performance-based and targeted to attraction, motivation and retention of highly skilled and high-performing talent assuring successful achievement of business targets with the maximum efficiency and at the minimum cost.

An efficient remuneration system shall provide for:

- standard approach to remuneration across the entire company and concurrence between demonstrated performance and fair remuneration;
- both financial and non-financial awards;
- maintenance of a decent salary level;
- optimal ratio between a base salary (tariff-based) and additional pay-outs (bonuses);
- base salary change depending on the inflation rate and financial position of the company;
- additional incentives for excellent performance and higher productivity;
- development of awards system, including awards for creation and introduction of new equipment, for completed research, for solutions to financial, economic, social, labour and other issues.

<u>Social policy</u>

The social policy is an inalienable element of human capital management targeted at improving the image of the company as a prestigious employer and assuring the following:

- comfortable and safe working environment;
- medical services;
- various types of insurance;
- safety guarantees against on-the-job incidents and occupational diseases;
- support and promotion of healthy living and sports;
- support of creative work of employees;
- assistance in resolving issues with housing using mortgage mechanism;
- support of young specialists, their faster adaptation and their strive for self-fulfilment;
- voluntary corporate pension support through no-government pension funds;
- support of former company employees – now pensioners, their engagement in corporate events.

The company shall define its social policy in coordination with its employees and their trade-union representative.

<u>Corporate communications</u>

Corporate communications are targeted at clear, open, timely and feedback-based awareness of employees on various aspects of the company's business.

Top executives of the company need to recognise the value and pay special attention to the corporate communications development and efficient information exchange (both vertical and horizontal) assuring active and open interaction between different levels:

- Vertical information exchange allows for awareness of personnel on the company's goals and objectives. At the same time, it provides opportunities for the employees to

communicate their proposals on improving the company's operations and their opinions about working environment.
- Horizontal information exchange is targeted at the coordination of interaction between employees of different subdivisions with the purpose to achieve common business targets.

Corporate communications allow for preventing and resolving potential conflict situations.

3.3.6.2 Personnel recruitment, assessment and deployment

Recruitment sources

As per human capital management policy, the employees are viewed as one of the key strategic resources of the company, assuring its competiveness and success in achieving the business targets.

Promoting the positive image of the company, its top executives need to obtain and maintain a stable status of a "preferred employer" – both in the eyes of those already employed, and in the eyes of desirable workforce.

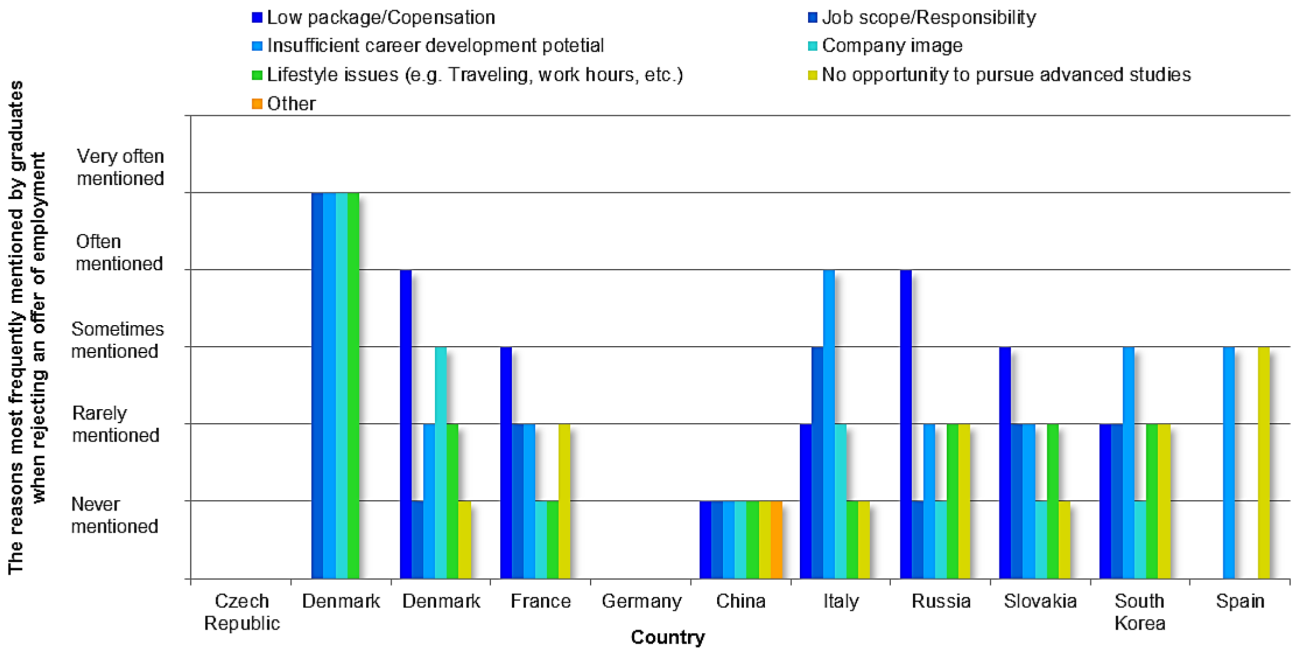


Figure 79 The reason most frequently mentioned by graduates when rejecting an offer of employment in UGS company

Graduates refuse to join the UGS industry mainly because of the low packages and compensation available and insufficient career development potential. The results of Survey illustrated in Figure 79 above are in line with the findings of TF1's 2012 report 'Building Strategic Human Capital'. Interestingly, company image is the least mentioned reason for refusal, suggesting that energy companies tend to have an overall good reputation.

The respective functions need to assure regular internal communications about the company's goals, objectives, values, and priorities, as well as about opportunities for professional development and career promotion for employees.

The company uses the following recruitment tools:
- internal succession pool;

- vacancies portal;
- external information and human resources;
- specialised recruitment agencies

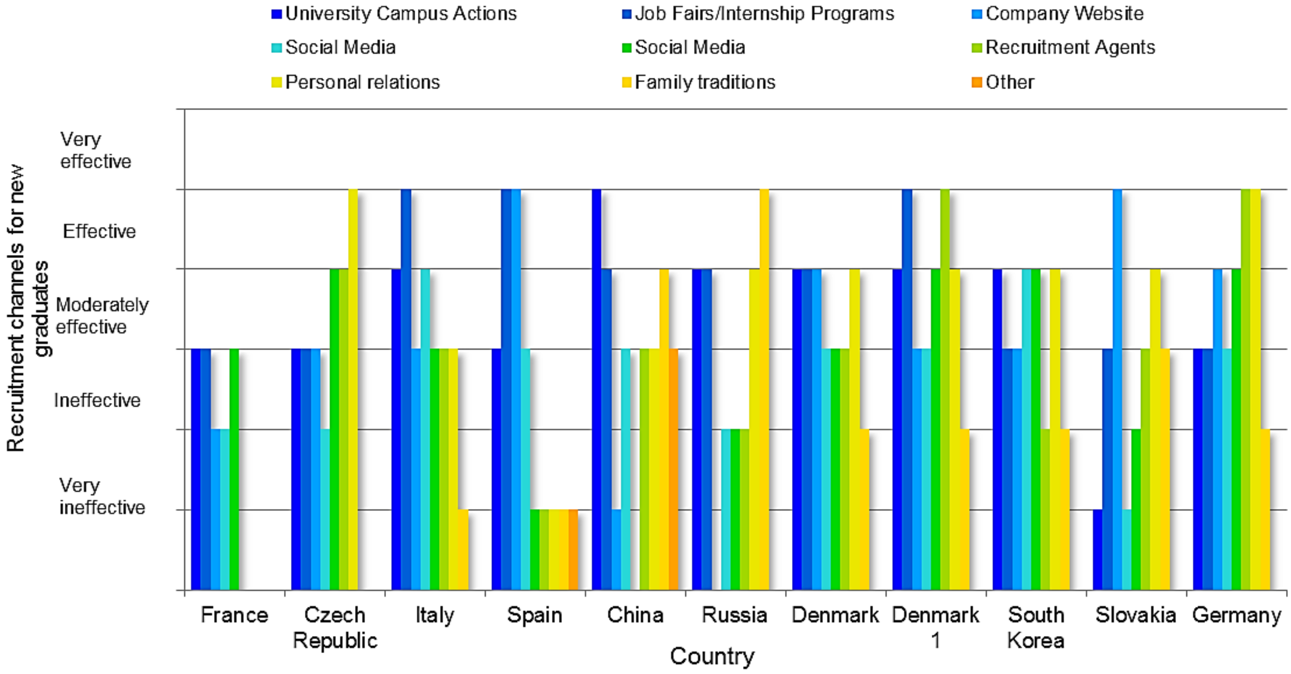


Figure 80 UGS companies recruitment channels for new graduates

UGS companies like other gas companies tend to rely on themselves for recruiting new graduates and prefer to approach directly potential employees. Figure 80 shows that seldom do gas companies turn to outside recruitment agents for resolving their hiring needs.

The recruitment channels considered most efficient by gas companies are: Job Fairs, Internship Programs; Personal relations; and various Actions on the University Campus. It is interesting and different from results of TF-1 Survey that more than 70% of UGS companies participated WOC-2 Survey considers Personal relations as a effective and very effective recruitment channel. This opportunity is attractive by low expenditures and high compatibility of applicants with a company, but at the same time it is necessary to keep in mind that company's staff is a "non-professional recruitment source" and also could be partial. Other recruitment channels considered effective by gas companies are public recruitment and word of mouth. More and more companies are also making use of Websites for recruitment purposes.

The family tradition channel is quite different according the countries. It is the strongest in People's Republic of China and Russia.

In recruiting a talent, the company also pays serious attention to the enhancement of partnerships with leading national universities and professional colleges, carrying out systemic work and organising various events to identify, select and recruit the best performers among graduates.

UGS companies responding to the Survey regarding best practices and initiatives being developed in their companies concerning **Attracting Talents** say that the most important subjects are: intensive cooperation with Universities; international Job Fares (Energy Day); M.SC Scholarship; Competitions for postgraduate grants.

More than 80% of gas UGS companies globally maintain active cooperation programs with Academia. But at the same time sponsoring students does not appear to be a popular practice amongst gas companies. Globally, only 27% of companies sponsor STEM undergraduates.

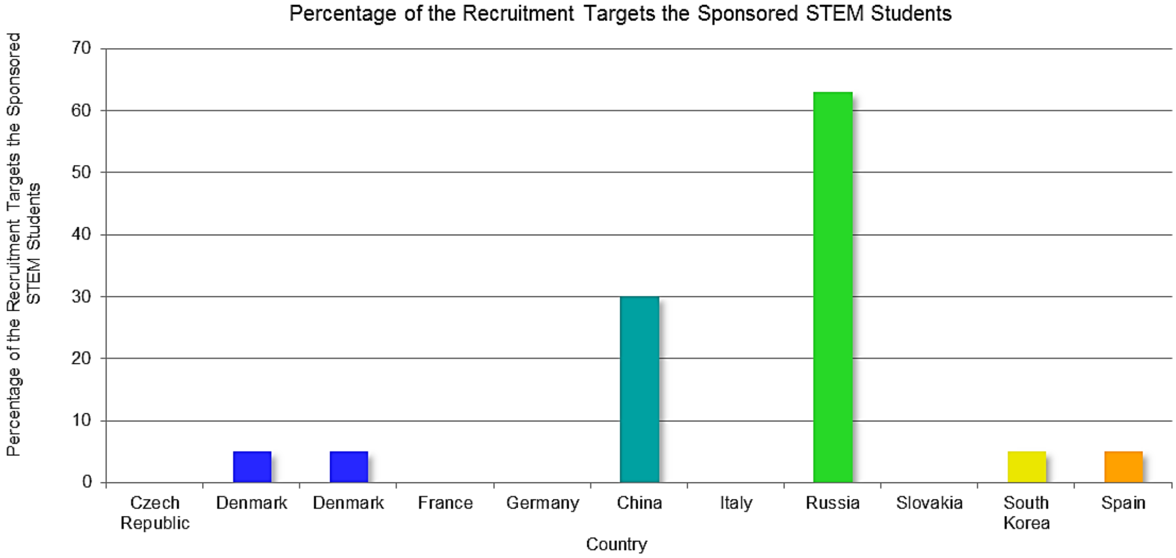


Figure 81 Percentage of the Recruitment Targets the Sponsored STEM Students

About 3 quarters of the surveyed UGS companies aim to cover less than 5% of their recruitment targets by sponsoring students. On the other hand, People's Republic of China and Russia aim however to cover near 11-30% and >61% of their recruitment targets by sponsoring students respectively.

Considering the data from Figure 81 it can be reasoned that while some gas companies 'grow' their future generation, the most companies are content with what the market has to offer.

In all cases, the key recruitment and appointment criteria are feasibility and commitment to achieving the established targets.

Recruitment and use of human capital

- **Selecting and recruiting personnel**

High performance of employees, managers especially, is the key success factor for any business (company, organisation). That is why selecting proper candidates to fill the vacancies is a very demanding and responsible task, and a creative one at the same time.

Resolving this task should start with developing a set of requirements to candidates including definition of their professional, personal, health and other parameters depending on the job description and working environment (workstations passports developed for every position in the company).

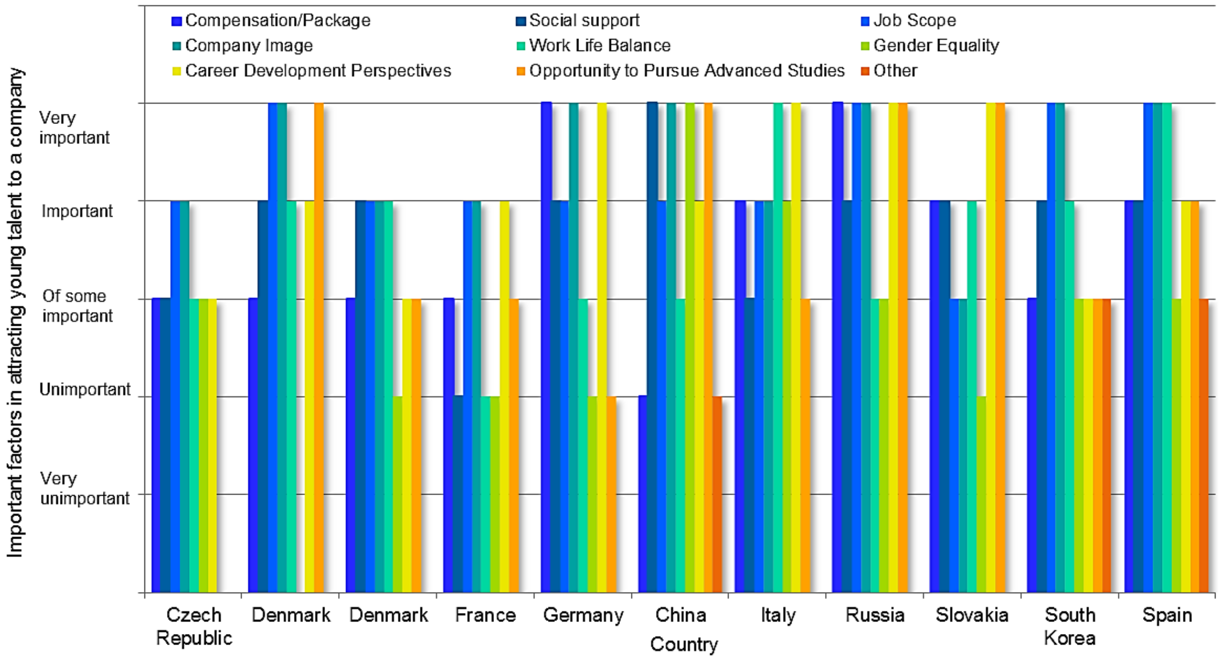


Figure 82 Important factors in attracting young talent to UGS company

Gas UGS companies consider Career Development Perspectives and Job Scope as the most important factors in attracting young talent. Figure 82 suggests that companies believe youth are looking for jobs that matters and that provide opportunities to develop themselves in the future. The Company Image that employees will be identifying themselves with is also considered very important by gas UGS companies for attracting youth. This factor definitely makes a discrepancy with data on Figure 78 where “Company image” is the least mentioned by graduates reason when rejecting an offer of employment in UGS company.

As illustrated earlier one can see that while the findings of Figure 79 place Low Package/ Compensation as the main refusal reason mentioned by graduates, findings from Figure 82 above show that gas UGS companies on average consider Compensation/Package as the 4th or 5th factor of importance in attracting young talent. The same results could be found in TF1 Survey.

In reality, there are often cases, when a person formally having all the required parameters turns out to be inefficient. Alternatively, this person may be successfully coping with the established duties, but be dissatisfied with the content of the job or working environment, and eventually leave the company. In both cases, it is the result of incorrect personnel sourcing, selection and recruitment.

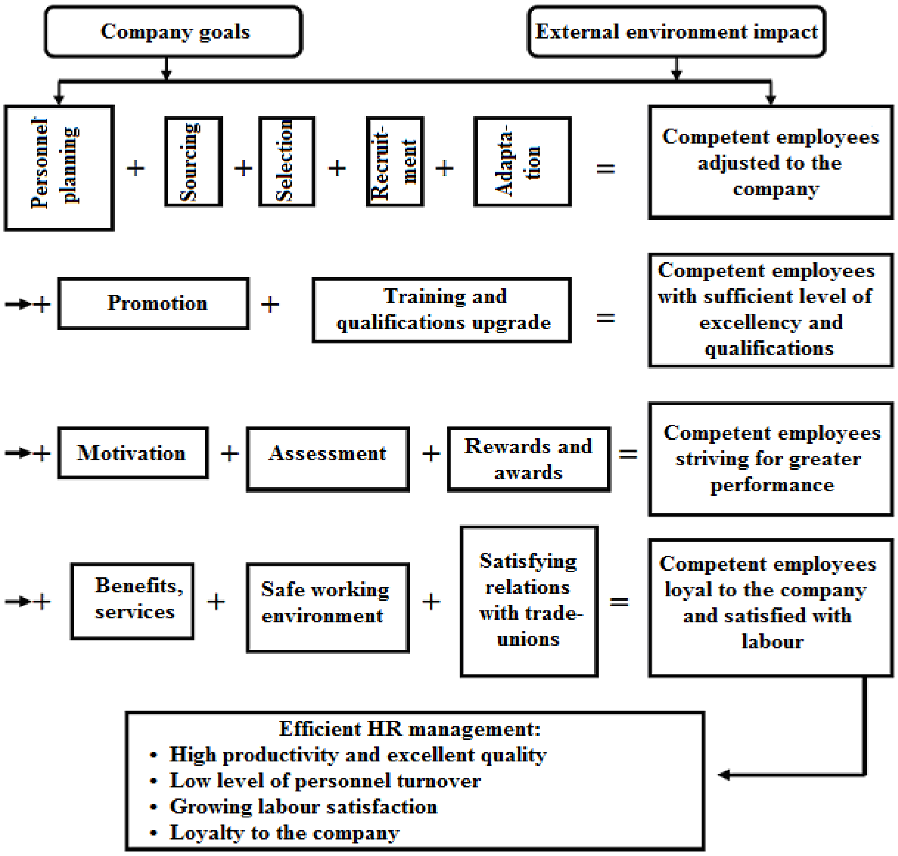


Figure 83 Approximate HR management flow chart, sourcing, selection recruitment and adaptation of personnel

The system of personnel sourcing, selection, recruitment and adaptation should stipulate for a comprehensive approach to the issue with the maximal use of all forms and techniques available in the global best practices.

The system of personnel sourcing, selection, recruitment and adaptation should include the following relatively autonomous blocks (Figure 83):

- personnel sourcing;
- selection of candidates;
- recruitment;
- adaptation of new hires.

Each block uses a certain flow chart of the key process, its tools, methods and techniques.

The above listed charts stipulates for several stages. Implementation of each stage provides for a new quality of the entire HR management system and requires performing certain actions in strict order.
Personnel may be sourced both from outside and within the company. Outside means sourcing from candidates without any prior labour relations with the company. Sourcing internally means finding candidates for a vacancy among people already employed by the company.

Sources	Strengths	Weaknesses
Internal	1. Employees are inspired by success stories of their peers 2. Better opportunities for assessing the relevant characteristics of employees 3. Deeper understanding of strengths and weaknesses of employees 4. Recruitment costs minimization	1. Risk of personal relations difficulties build-up; 2. "old boy" network leading to low competition, lack of new ideas and inventions 3. Unfriendly attitudes may develop with former peers
External	1. Bigger number of candidates to select from 2. New comers may bring new ideas and work methods 3. Lower risk of intriguing inside the company	1. Longer period of adaptation 2. Morals of those working long for the company may be deteriorated 3. You never know for sure the style and techniques of working of the outside hires

Table 5 Comparison of external and internal recruitment

The company image is one of the key factors defining successful talent sourcing. Creating such positive image is a lengthy, complicated and rather expensive process. However, these costs are eventually offset. The Table 5 gives a general idea about building the company's image in the modern environment, and the main stages of this process.

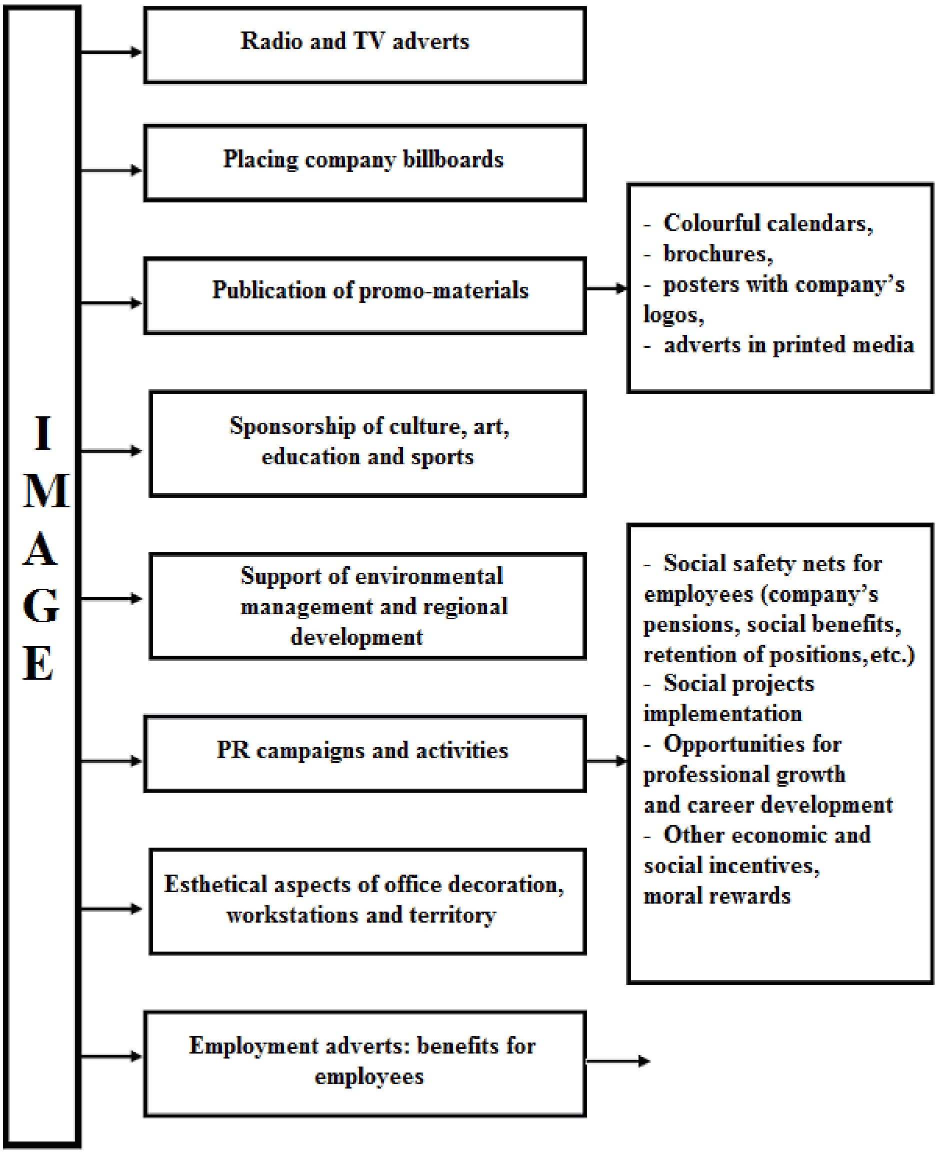


Figure 84 Key areas of building the company image

- **Adaptation of new hires**

Adaptation comes from Latin adaptare (adjust). In a broad sense, it means adjusting to the environment. Adaptation of new hires in the company is to a great extent measure of success/failure of HR activities in sourcing, selecting and recruiting personnel.

Any employee undergoes several stages of adaptation:

- overall acquaintance with the company and its environment;
- adjustment to working environment and behavioural patterns;
- inclusion into social environment and business process, assimilation (complete adjustment);
- identification (matching personal and collective aims);
- active work.

Adaptation needs to provide for every employee achieving the following:

- sense of ownership with regards to the company's business;
- correct understanding of functions and targets;
- developing the necessary skills;
- high level of motivation;
- personal involvement in improving/developing the company's business;
- understanding of his/her position in the organisation.

- **Personnel motivation**

Listing personnel motivation factors priority should be given to working environment:

○ **Sanitary and hygienic conditions** – Labour hygiene – Moderate physical load ○ **Labour organisation** – Convenient workstation – Engineering and administrative support – Working hours ○ **Social and psychological aspects** – Company prestige – Importance of work performed – Career outlook, promotion opportunities – Opportunities for qualifications up-grade – Moderate neuro-psychic load – Group dynamics, relations with peers	○ **Legal terms** – Privileges and benefits ○ **Financial terms** – Level of salary – Bonuses programme ○ **Housekeeping** – Amenities at work ○ **Content** – Scope of work – Diversity – Level of autonomy – Level of responsibility

3.3.6.3 Personnel training and development

The company objective is not only correct selection of new hires, but assuring their development. Maintaining and improving business qualities is required due to growing operations and quality requirements, technologies and innovations, need to capture new markets. Personnel rotation and promotion issues arise in business operations of any company. This is why employees need to be professionally prepared for such situations.

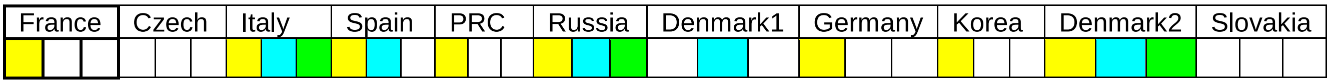


Table 6 What UGS companies arrange some courses for graduated newcomers

- Training internships - Postgraduate courses - PhD scholarship

Only few UGS companies (Italy, Russia, Denmark) make comprehensive training and development for graduate newcomers (Table 6).

Efficient Gas Company needs to set up a system of not just comprehensive but continuous corporate professional training.

The company's demand for quality employees is mainly satisfied by recruiting more a less stable personnel (little turnover), their training, developing the necessary skills and competencies, and retraining for deployment in new areas of business. Training is delivered through existing and actively developing continuous corporate training system. This system needs to be based on two underlying fundamental principles:

- continuity – targeted process of on-going qualifications upgrade or retraining matching the interests of employees, company, society and government ("life-long learning");
- professionalism – acquisition of knowledge and skills required for successful performance of employees with account of their positions and priority of tasks.

This system is established to implement training-related provisions of human capital management policy and stipulates for periodical (every 1-3 years) qualifications upgrade of all specialists and managers.

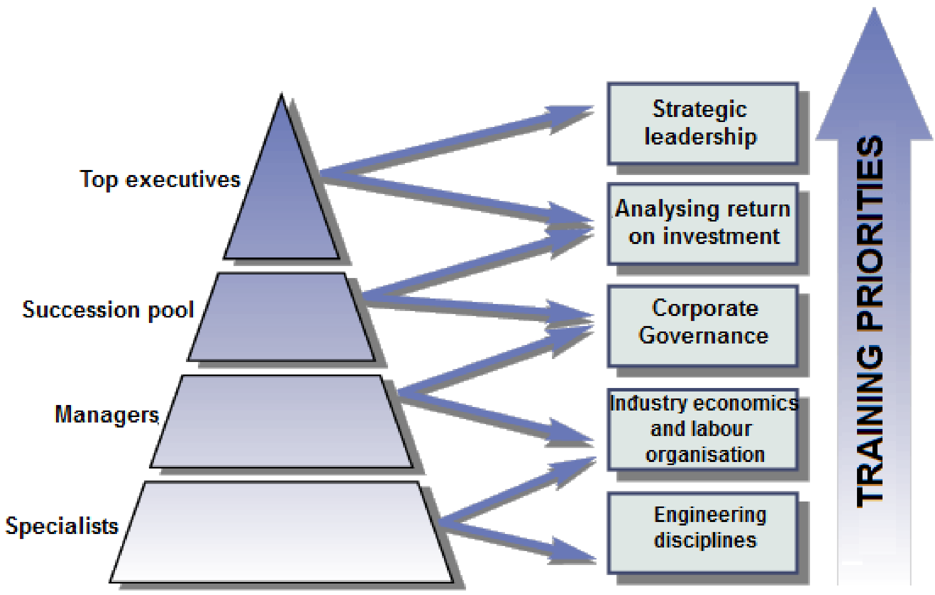


Figure 85 System of continuous professional training personnel inside the company

Continuous corporate training system is designed to provide the following:

- primary training for new hires;
- first year training for specialists to adapt and to learn the details of organisation, equipment and processes;
- qualifications upgrade with the established periodicity across the entire period of employment to maintain the required level of professionalism;

- training for management succession pool;
- retraining personnel to ring into concurrence the base professional education with the requirements of the new position.

Systemic task-oriented approach to personnel training is one of the ways to form the necessary human capital of the company and to develop its potential. It allows for guaranteeing every employee opportunities for qualifications upgrade and retraining, for mastering new skills. Training content depends on the established objectives. On the one hand, it needs to provide for obtaining new knowledge (engineering, economic, environmental, etc.), and on the other hand – for the enhancement of managerial and other practical skills, psychological personal features, analytical and problem-solving abilities.

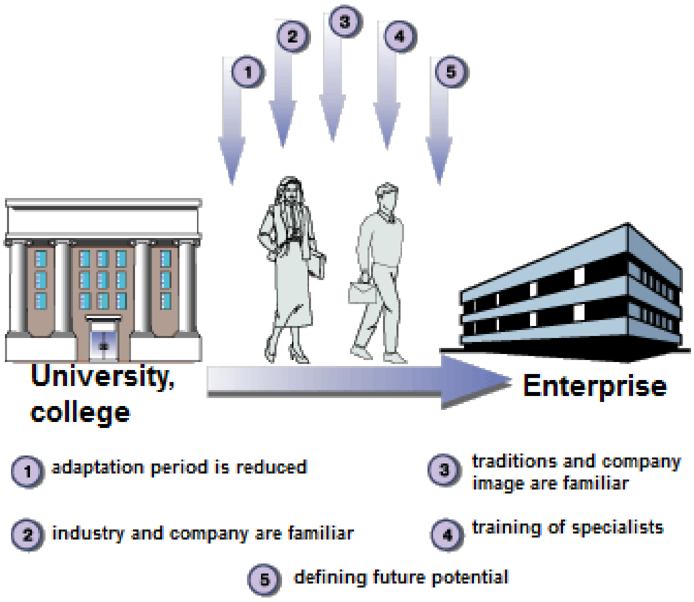


Figure 86 Training and development of young specialists

For more effective selection and faster adaptation of young specialists in gas industry, multi-staged corporate post-university training programme is recommended ("School for Young Specialists").

Such training is targeted at the minimisation of adaptation period for young specialists, their familiarisation with corporate traditions, qualifications upgrade in accordance with the main areas of their professional activities. Another objective of this Programme is to identify young specialists with the highest potential for further training with "Promising Manager" programme, specialised foreign languages training and internships abroad.

Thus, continuous training process includes:
- **Students training (specialists, bachelors)**
- **Post-graduate training**
- **Masters training**
- **Supplementary professional training**
- **Retraining courses**
- **Qualifications upgrade courses**
- **Short-term training courses**

France			Czech			Italy			Spain			PRC			Russia			Denmark			Germany			RK			Denmark			Slovakia		
		PhD					M.SC.	PhD	B.SC.	M.SC.		B.SC.	M.SC.	PhD	B.SC.	M.SC.	PhD			PhD										B.SC.	M.SC.	PhD

Table 7 What UGS companies support talented students and young specialists by means of a scholarship

(yellow) - B.SC. (cyan) - M.SC. (green) - PhD scholarship

Among UGS companies there is a tendency to support M.SC. and PhD scholarship of skilled specialists and not support B.SC. scholarship of young specialists (Table 7.). It definitely could create a gap between generations of professionals.

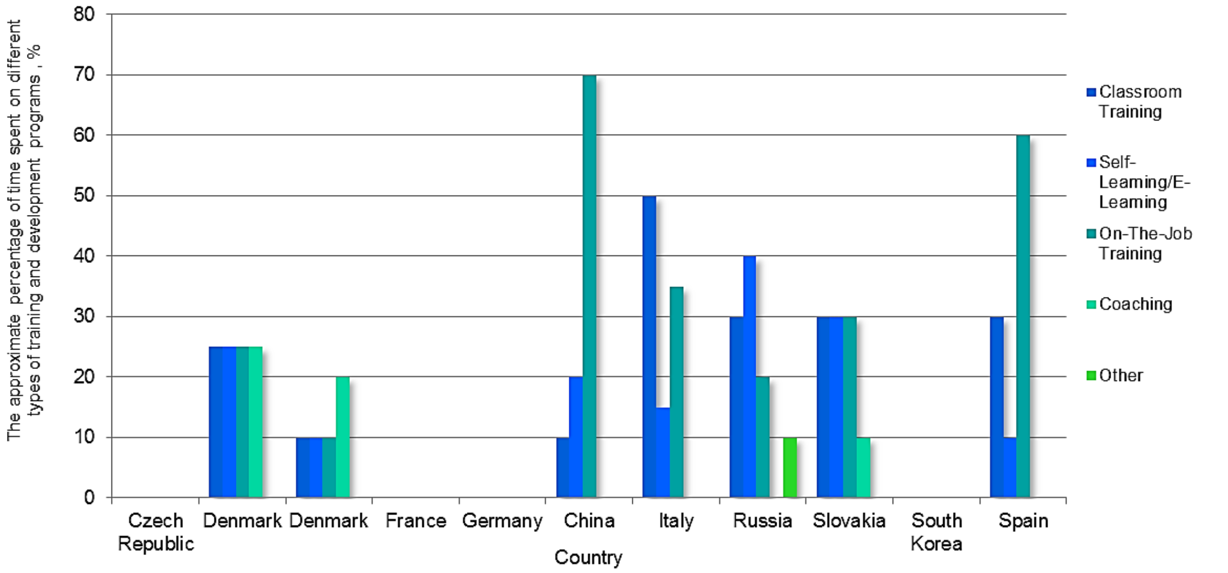


Figure 87 The approximate percentage of time spent on different types of training and development programs for junior (<= 3 yrs seniority) technical staff

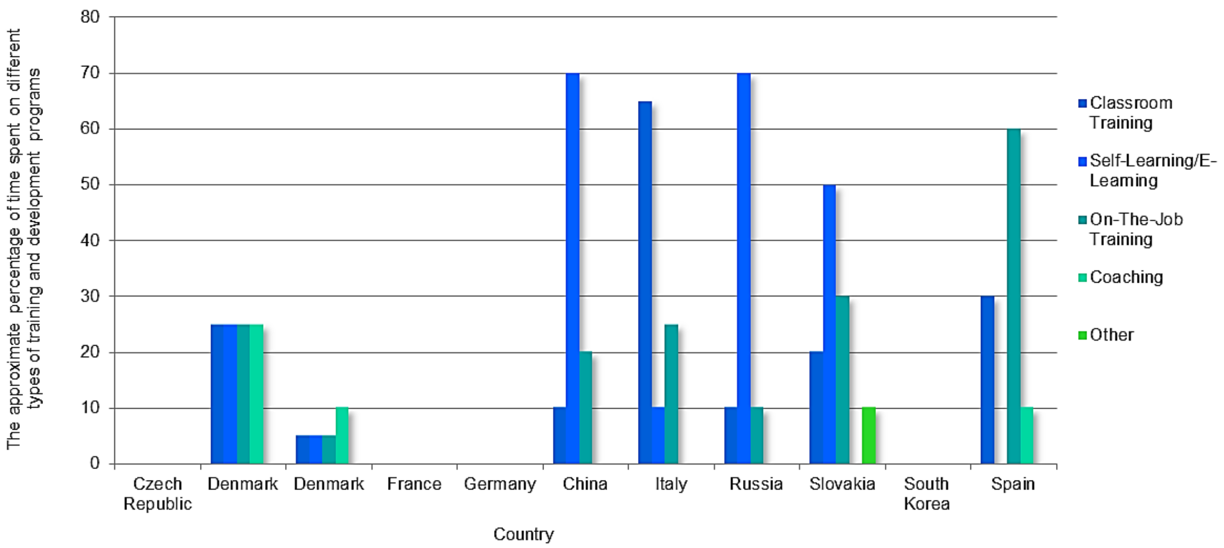


Figure 88 The approximate percentage of time spent on different types of training and development programs for experienced (>3 yrs seniority) technical staff

As illustrated in Figure 87 and Figure 88 above, Classroom training is the prefer method of training employed by gas UGS company in Italy. Both junior as well as experienced technical staff invest more time in Classroom training than any other training and development program.

On the job training is the prefer method of training employed by gas UGS companies in Spain and People's Republic of China for junior staff. And Self-learning and E-learning is the prefer method of training employed for experienced staff by gas UGS company in People's Republic of China, Russia and Slovakia.

3.3.6.4 Career Development and retention

France		Czech		Italy		Spain		PRC		Russia		Denmark		Germany		RK		Denmark		Slovakia	
		NO	NO	NO	NO											NO	NO				

Table 8 What UGS companies have an established career ladder

- For technical professionals

- For commercial professionals

Table 8. above shows that career ladders are used by most gas UGS companies, for the development of both for technical as well as for commercial professionals. However, Czech Republic, Italy and Korea don't have it.

France		Czech		Italy		Spain		PRC		Russia		Denmark		Germany		RK		Denmark		Slovakia	
NO	NO	NO	NO					NO	NO												

Table 9 What UGS companies have individual development programmes

- For new graduates

- For experienced professionals

Most UGS companies make use of individual development programs exactly like career ladders (Table 9). Only three companies don't have it (France, Czech Republic and People's Republic of China). And Czech Republic doesn't have both options nor career ladder, nor individual development program.

The lack of individual development programs is felt by graduates, who mention insufficient of career development potential as on the most important reason for not joining the UGS industry (Figure 79).

UGS companies develop succession plans with less activity nether individual development programs and career ladders. Only two companies (Denmark and Slovakia which represents 18%) have it.

New employees in companies from Europe (Denmark, Russia, Spain, and Slovakia) tend to become autonomous faster than their peers in companies from Asia (People's Republic of China and Korea). Almost 90% of new employees working for companies in the Europe become independent in less than 2 years as opposed to new employees in the Asia, who becomes independent usually after 3-5 years (Figure 89).

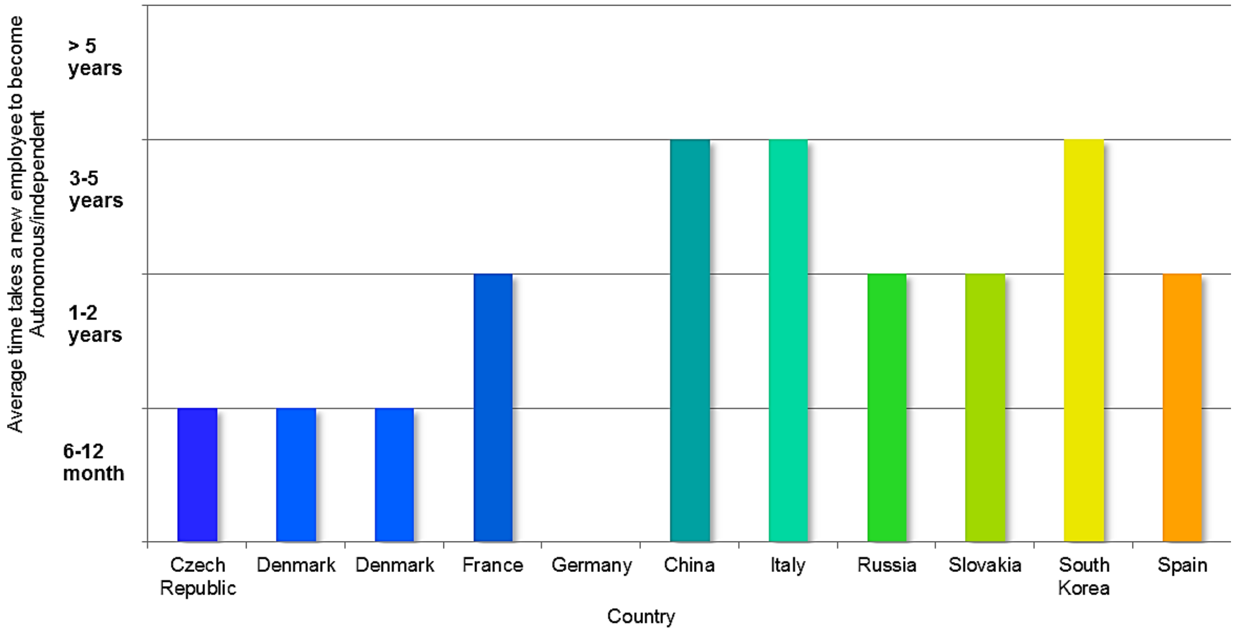


Figure 89 Average time takes a new employee to become Autonomous/Independent

It could have a link with the age of people joining companies. The Figure 75 demonstrates that Italy, People's Republic of China (and Slovakia) hire mainly new graduates. In this case, it is normal that the time to become autonomous is longer. Experienced people could be autonomous in a shorter time.

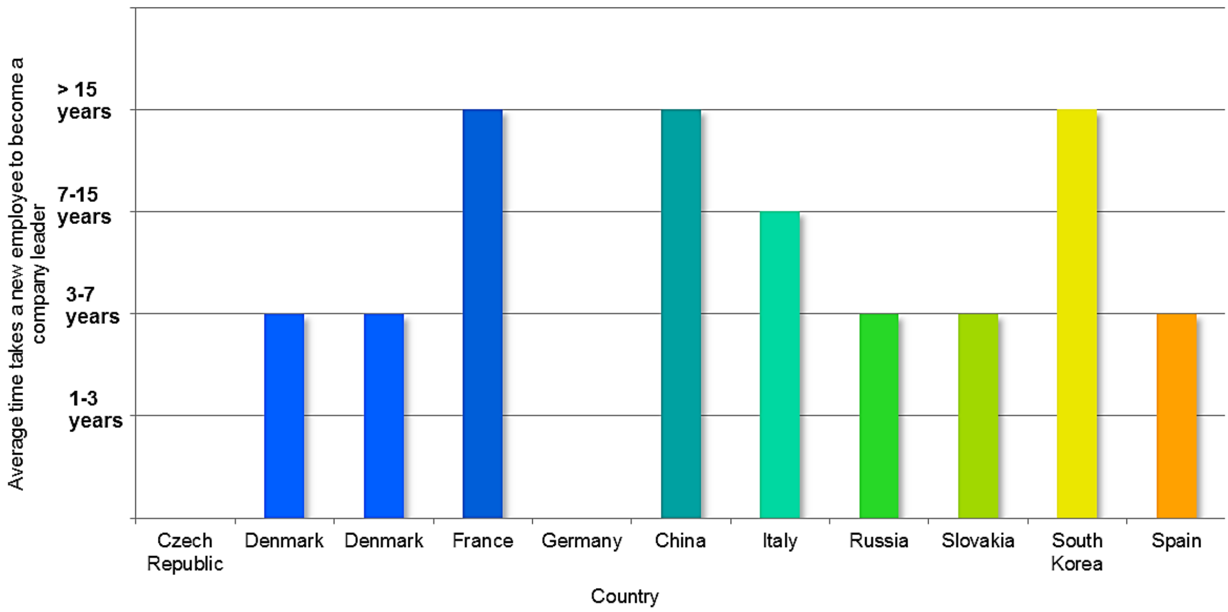


Figure 90 Average time takes a new employee to become a company leader

A possible reason of that could be in specific chief-junior relations in Asia. In TF1 Survey stipulated different explanation - use of considerably more training and development programs such as career ladders, individual development programs and succession plans could slow down career development. But logically it should be vice-versa.

Figure 90 illustrates that European companies are the fastest in molding their employees into leaders. It takes on average 3 to 7 years for a new employee in most European companies to become a leader, whereas companies in Asia (People's Republic of China and Korea) require over 15 years preparing their employees for becoming leaders.

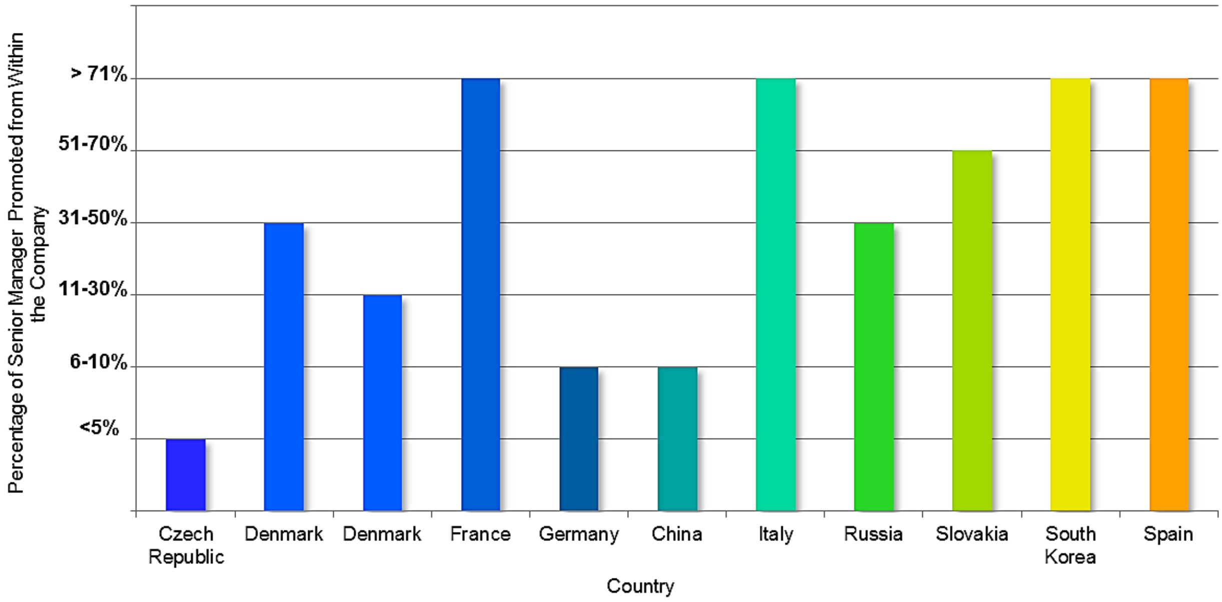


Figure 91 Percentage of Senior Manager Promoted from Within the company

Figure 91 shows that most senior managers in the gas UGS industry are promoted from within their own company. Around 50% of companies promoted over 50% of their senior managers internally.

Most part of the companies in Europe; say they promote 50-70% of senior managers internally. As shown Table 8 and Table 9 European companies also tend to use career ladders, individual development programs and succession plans.

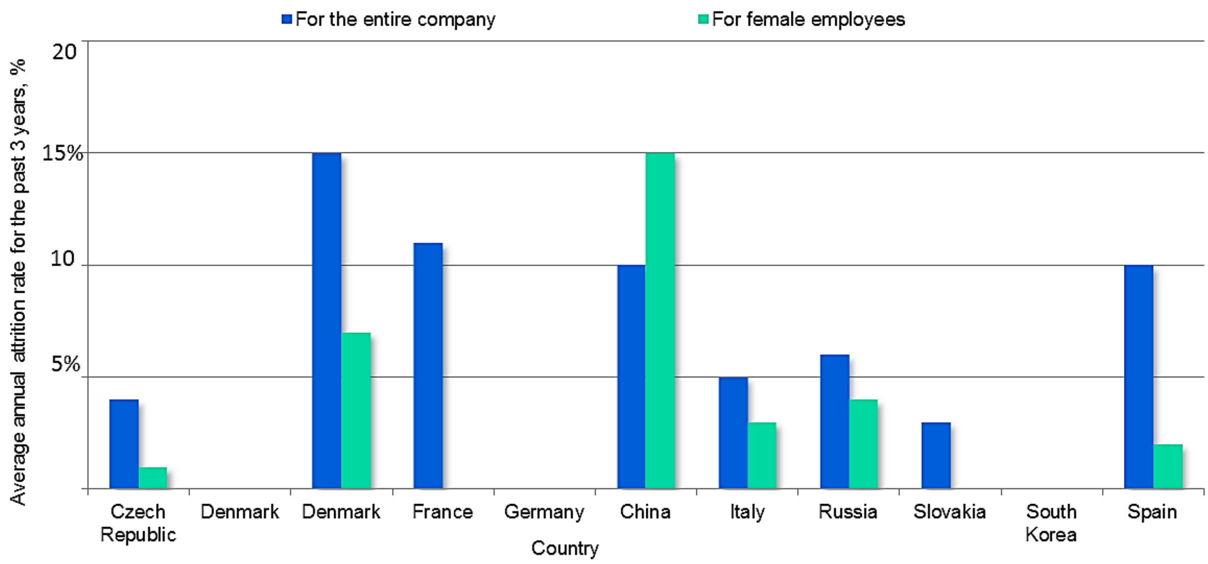


Figure 92 Average annual attrition rate for the past 3 yrs

Figure 92 shows that the attrition rate for female employees is on average lower than that for male employees (one exception - People's Republic of China). One might conclude that female employees tend to stay in UGS companies longer.

The highest attrition rates for both female and male employees are found in People's Republic of China and Denmark-2, near 15%, significantly higher than the average 5-10%.

The lowest attrition rates are found in Czech Republic and Slovakia, around 1% for women and around 4% overall.

Only 18% of UGS companies don't offer long term incentive plans to they employees (People's Republic of China, Slovakia). Companies which tend to use long term incentives more often also tend have the lowest attrition rates.

As shown in Figure 93. Retirement is the number 1 most mentioned reason by employees of UGS companies when they are leaving a company. This is especially true for European companies, Russia and Korea. Lack of Career Progression Opportunities is the second reason mentioned most often. Furthermore, while compensation package is the most often reason mentioned by youth refusing to join a UGS gas company as illustrated in Figure 79 it is only the third most often mentioned reason by people that are leave a UGS company. Company reputation is the least mentioned reason by people leaving the company, which suggests that natural gas companies not only have a good image in amongst young people as suggested by Figure 79 but maintain also a good reputation with experienced employees that are now leaving the company. Results of Chinese answers looks like misprint.

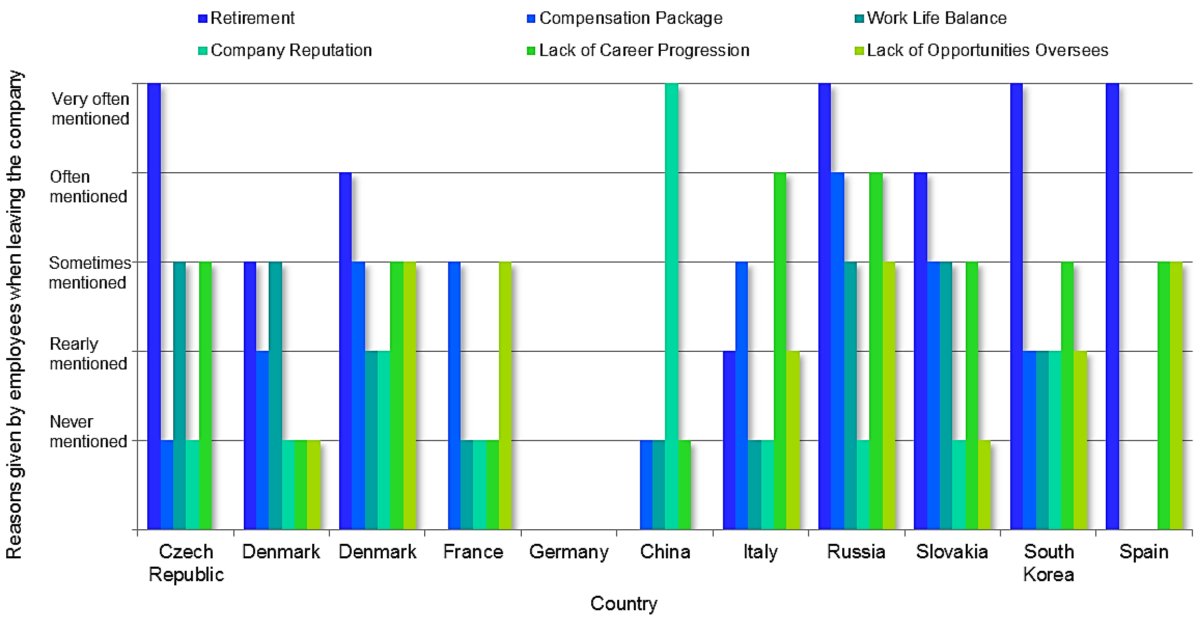


Figure 93 Most often mentioned reasons by employees when leaving the UGS company

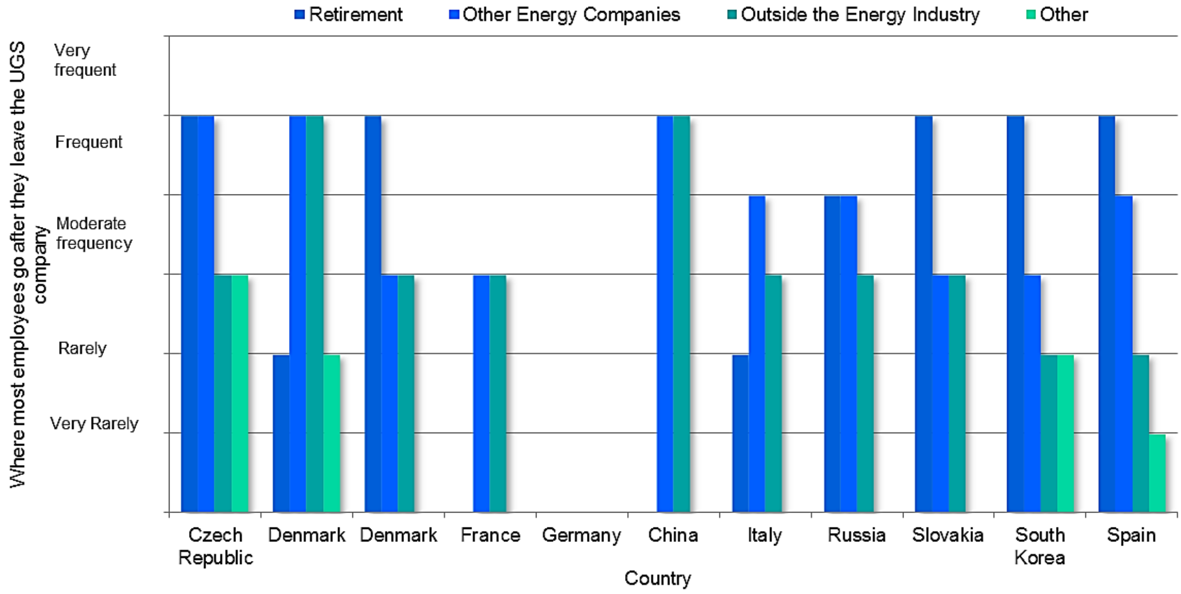


Figure 94 Where most employees go when leaving the UGS company

According to the result in Figure 94. above, most employees when leaving UGS company, head towards retirement. From amongst the employees that leave a gas company but do not retire, most of them tend to stay within the energy industry and join other energy companies. Figure 93and Figure 94 not consistent with Storengy answers on retirement.

3.3.7 Female Workforce (based on responses to Questionnaire part C “Female Workforce”)

In the economic crisis environment, we can witness escalation of employment/unemployment problems. The situation with employment of disadvantaged social groups, including women, is especially aggravating.

The young specialists/graduates employment problems are also female-related, because females constitute three quarters of schools/lyceums/colleges/universities graduates, and they have additional difficulties finding jobs. Female employment situation is especially problematic in the young workforce market: traditionally women constitute a significant share of graduates, while as employers prefer males.

The main barriers for female workforce today are not only maternity issues but also some objective and subjective questions generated by employers. Among main problems we have to mention: historical and social factors of gender inequality; “double load” on women; statistical discrimination; occupation of less paid positions; “glass ceiling”; “sticky floor” and etc.

The more this factor is taken into account, the better social and economic conditions are created for successful combination of professional employment of female workforce and reproduction of population. Differences in using male and female workforce may be mitigated if the equipment and labour/leisure organisation are more in conformity with female specifics.

3.3.7.1 Female employment growth

During the last century, women radically came beyond private family lives and quite naturally integrated into the labour and social life. Thanks to the process of the equalisation of male and female rights, the level of female workforce employment was growing and the level of professional training of these two groups got closer. As a result, already in 1980s male and female workforce had practically an equal share of specialists with higher education and vocational training. In the age group of under 40 female workforce was characterised by even higher share of universities and colleges graduates. Therefore, in 1990s a total level of education in female workforce grew versus male workforce, taking into account the number of graduates from secondary schools, colleges and universities. During the period of 1960-1980s, a share of employed women grew across all main professions requiring university or college degree (engineers, economists, teachers, medical personnel, agronomists, and lawyers). In some professional groups a share of female workforce achieved 60-80%. At the same time, this share in groups of skilled workers and in the group of top-level managers and executives is much smaller than a share of male workforce. This is the main difference in the quality of male and female workforce at the current stage. As a rule, women are more often given jobs with very low probability of promotion and career development, low salaries and unstable employment. It may be noted that the differentiation of professions into "male" and "female" varies by periods of times and by cultures. In some cultures, professions traditionally attributed to women may be considered the "male" ones. A profession, which at a certain point of time was viewed as a "male" occupation, may become perceived as a "female" profession under the influence of several factors – and vice versa.

3.3.7.2 Female share of total workforce

One of the remarkable current trends is a growing share of female workforce, which allows for women in many regions of the world to implement their professional potential and become self-sustainable from financial point of view (ILO, Time for Equality at Work, 2003)1. In 1960s the share of female workforce in Europe was about 30%, and by mid-1990s it grew to 42.5%. For example, in the Netherlands in early 1980s only one-fourth of employed women continued their professional careers after having the first baby. A decade later, approximately half of female workforce was doing this.

The growth of the female share in a total workforce number turned out to be one of the most remarkable trends in labour markets over the recent years. Global female workforce (employed and unemployed women) reached 1.2 bln in 2003 versus 1 bln in 1993. In this context, the level of male workforce economic activity dropped in many regions of the world. It resulted in bridging the gender gap in the area of employment. However, it did not put a complete end to the gender inequality in any region.

Thus, in transitional economies there are 91 economically active females per every 100 active males in the labour market. In East Asian countries, the ratio is 83 females per every 100 males. In the Middle East and Northern Africa, as well as in South Africa there are only 40 economically active females per every 100 active males in the registered economy. It clearly demonstrates that traditional gender patterns for men and women are still popular there.

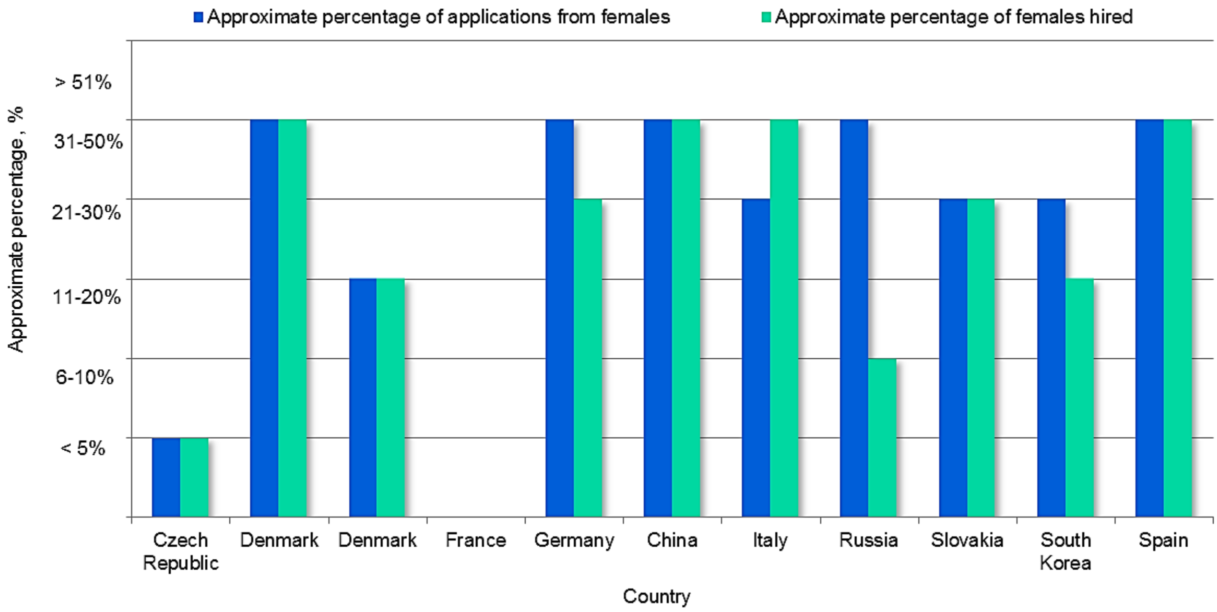


Figure 95 Approximate percentage of applications from females, as a proportion of the total number of applications received, and approximate percentage of females hired, as a proportion of the total number new hires made by UGS company over the past 12 months

Figure 95 above suggests that women's interest in the gas industry is significantly lower than the interest shown by men. Near half of companies receive less than 30% of their applications from women. Most part of UGS companies participated Survey have stipulated that percentage of applications from females over the past 12 months was in the limits 20-30% of the total number of received applications. Only Czech Republic shows much less figures – 5%.

Figure 95 also illustrates that in UGS companies women represent less than a third in their number of total of new hires made over the past 12 months. But it is necessary to note that there is no grate differences in quantity of females hired comparing with applications, the same 30%. It means that HR departments of the most part of UGS companies implement an adequate and measured gender policy. Only Slovakia shows quite big difference in quantity of applications (10-20%) and females hired (6-10%).

3.3.7.3 Labour legislation and employed women

In the majority of developed economies, the labour legislation prohibits using female workforce under arduous and harmful labour conditions, as well as for underground work. There are limitations for employing females in night time, engaging them in overtime work, working over weekends and holidays. It is also restricted to send pregnant women and women with children under 14 on business trips. Maternity leave aspects are also regulated.

The international labour law trend is to refuse from paternalistic and prohibitive measures pertaining to female labour, because such measures:

- introduce the double standard for male and female workforce, when only men are free to make their choice;
- view women as incapable persons not being able to independently decide on selecting a job, so they need the government to protect them by introducing the list of prohibited types of work;
- are discriminative against men (arduous and harmful labour conditions are bad for their health, too);

- represent disincentives for employers to improve the working environment.

This trend does not relate only to maternity protection measures, which according to Article 4 of UN Convention on Elimination of All Forms of Discrimination against Women (1979) are not qualified as discrimination (in this case, unequal treatment of women is considered justified).

3.3.7.4 Skilled female workforce potential

Industry data analysis shows that female activities are often not related with high status or growth prospects. In most emerging economies in industrial production, male workforce dominates over female. In emerging economies, the industrial development takes place based on the priority of export-oriented production characterised by dominating female labour (in particular, in Export Processing Zones). Such zones have become the gates for many women to enter the registered economy, where wages are higher than in the agricultural sector or wages of the house-keeping.

The problems of women who are forced to stay at homes as housewives, who are unemployed or employed in the grey economy (semi-criminal) sector turn into a political problem: limited governmental funds go to resolving social and labour issues; there is not enough skilled workforce.

Demographic trends become meaningful limitations in shaping the employment and its structure, barriers to balance the rapidly growing economic demand for workforce and shrinking supply in the labour market. The number of employable population decreases, and the workforce is turning into a scarce and expensive factor.

The innovative character of the modern economy determines the growing need for the skilled workforce capable of intellectual labour.

Women are more adaptive to a changing environment, and it is easier for them to change professional activities. However, their choice is often influenced by a lack of information about the employment opportunities. They are not aware which professions have the highest potential for employment and promotion, and this often results in selecting professions with which the market is saturated already (accountants, secretaries).

At the same time, females are often better than males professionally. In the process of socialisation, women develop such features as meticulousness and accuracy, attentiveness, precision, sensibility. Female workforce is usually recruited where the content of the job and working environment require the above listed qualities.

Part-time employment is becoming more and more popular, and it supports women in the labour market. Part-time employment may be actively used in services provision sector. Possibility to work only half a day or half a week allows the employment of women with a big housework load. In the past, they were reluctant to seek jobs or could count only on occupation for unskilled workforce. Nowadays, with new non-standard employment types developing, they have much broader opportunities to apply their professional skills. Employment is becoming more flexible and broadens the sphere for the female workforce use.

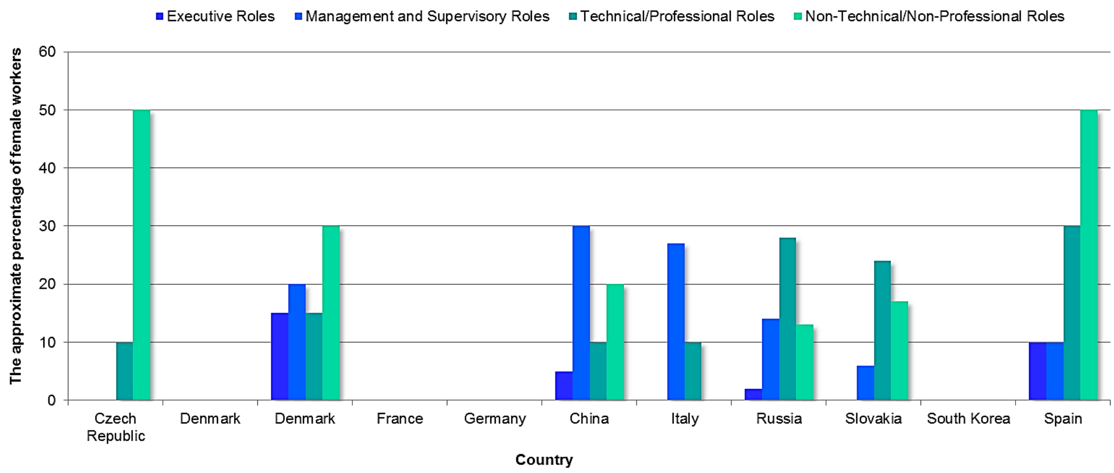


Figure 96 Approximate percentage of female workers, as a proportion of the total workforce occupying

Storengy give the answer that 21-30% of management and supervision role are hold bu women. Even if the answer is not complete, please include it in Figure 96.

Gas industry continues to be a male dominated industry. As illustrated Figure 96 the majority of women in the UGS companies currently activate in non-technical/non-professional roles. Non-technical and non-professional specialities could be occupied by female employees up to 50% of the total workforce occupying (Czech Republic and Spain).

Technical/Professional specialties could be occupied by female employees up to 20-30% (Spain, Russia, Slovakia). Quite big amount (20-30%) of female employees working at Executive and Managing positions in People's Republic of China and Italy.

Trade unions in the companies employing female workforce have a broad field for their activities. Collective agreements reviews showed that the social female protection list is still uncompleted and does not resolve major issues. Based on the current situation, trade unions may be expected to insist on including the creation of the favourable environment for qualifications upgrade and professional development of female workforce into collective agreements. This is especially important for improving competitiveness of female workforce in the labour market.

3.3.7.5 Global trends in assuring gender equality

International Labour Office (ILO) strives to increase the female participation and share in all areas through its numerous programmes and projects. ILO promotes strategies targeted at supporting the female entrepreneurship, demonstrating gender equality principles in businesses and the benefits of having women on top management positions in trade unions.

The UN Millennium Declaration adopted in 2000 calls for different countries to promote the equality of men and women and to broaden the rights of and opportunities for women. This is considered an efficient tool in fighting poverty, hunger and diseases, an incentive for the truly sustainable development. It talks about the Third Millennium Goal in the development sphere: "to promote the equality of men and women, and to broaden opportunities for women".

ILO admits the importance of promoting the gender equality in the labour sector and strives for improving the potential of trilateral partnerships (governments, associations of employers, associations of employees) in developing national gender policies.

There are two approaches to the gender inequality elimination: In Russia, the government first tried to utilise the state's monopoly in the economy and to provide equal opportunities by the way of communalisation of family and household duties, then – by the way of providing certain privileges to working mothers. The western approach is mainly focused on redistribution of housework between spouses (including parental duties), increasing responsibilities of fathers, strict discrimination restraints.

In the EU, the social policy's focus has shifted from the equality of male and female rights to the equal treatment of men and women in the labour market by the way of guaranteeing equal opportunities across the entire society. This move raised awareness of new issues and formed new questions:

- How to harmonise professional activities and family/household duties?
- How to overcome vertical and horizontal segregation in the labour market?
- How to guarantee women's participation in decision-making?

The situation in the USA is somewhat different. There women's action for the equal distribution of family/household duties does not require any governmental incentives. The lawmakers there did not just develop the legal framework to establish the gender equality (1963 Equal Pay Act, 1964 Civil Rights Act). The government adopted federal anti-discrimination programmes based on "positive discrimination" measures. For example, recruitment and promotion in private firms having executed federal contracts with government agencies (goods or services providers) are monitored by especially established Federal Contracts Coordination Department. The requirement process is that companies themselves have to analyse the extent of the female workforce utilisation and develop relevant actions to eliminate situations of insufficient use. Usually contracts are terminated with the companies, which do not fulfil these requirements.

Table 10 shows that while about 15% of the UGS companies have in place no special program for women, almost 70% of the companies responded that they use 1 special program to recognize and encourage their women employees. 15% of the surveyed companies use 2 or more special programs.

Country, company	Active professional network for female employees	Active inclusion program in place for female employees	Flexible working hours for nursing female employees	Special mentoring and coaching for female employees	Other
France,	YES	NO	NO	NO	NO
Czechia,	NO	NO	YES	NO	NO
Italy,	NO	NO	YES	NO	NO
Spain,	YES	NO	YES	YES	NO
People's Republic of China	NO	YES	NO	NO	NO
Russia,	NO	NO	YES	NO	Company's kindergarten for employee's

					children
Denmark,	NO	NO	NO	NO	NO
Germany	NO	NO	NO	NO	NO
Southern Korea,	NO	NO	YES	NO	NO
Denmark,	NO	NO	YES	NO	NO
Slovakia,	NO	NO	YES	NO	NO

Table 10 Recognizing and encouraging of female employees in UGS companies

Storengy has a "company's kindergarten for employee's children. This is not included in our questionnaire answer because we think it is for the benefit of both male and female employees. If it is possible to take it into account.

Amongst the companies implementing special programs to encourage female employees, the most commonly used programs are focusing on women returning from maternity leave. Other special programs used are professional networks dedicated to female employees, inclusion programs, and mentoring and coaching. In Russia UGS company provides (gratuitously) kindergarten to employee's family to make women available for professional work.

More than 70% of companies responding to the Survey say they have no target set in terms of gender equality. One company explained that its aim is to hire the best person for the job, irrespective of gender. Another one mentioned that it is promoting new female employees for "Traditional male positions". Achieving a minimum percentage of female employees in the total workforce (20%) represents a long term objective for only one respondent.

Country, company	Minimum percentage of female employees in the workforce	Minimum percentage of female employees at different levels of seniority	Other
France,	YES – 20%	NO	NO
Czechia,	NO	NO	NO
Italy,	NO	NO	NO
Spain,	NO	NO	Promotion of new female employees for "Traditional male positions"
People's Republic of China	NO	NO	NO
Russia,	NO	NO	NO
Denmark,	NO	NO	NO
Germany,	NO	NO	Equal employment without discrimination, differing dependent on job profile
Southern Korea,	NO	NO	NO
Denmark,	NO	NO	NO
Slovakia,	NO	NO	NO

Table 11 Long term objectives for gender equality in UGS companies

3.3.7.6 Recommendations

Social policy in the employment sector stipulates for certain social actions to improve the female workforce competitiveness in the labour market. They are as follows:

- The key principle is to provide female workforce with an equal and better access to employment opportunities, to income and to micro financing based on the human rights fundamentals. It means certain legal regulations forcing employers to develop their human capital management policies with account of the gender structure of workforce in this industry as well as to adjust the recruitment policy respectively.

- In parallel with applying sanctions to employers implementing the discriminative recruitment and payroll policy, subsidies need to be provided to support companies achieving progress in integrating female workforce into traditional "male type" of jobs and in raising female salaries versus the male remuneration.
- The combination of working for remuneration and doing housework without remuneration is the key factor in the female employment development and extending women's economic opportunities.
- It is necessary to implement policies and programmes securing an equal access to education and professional training for women, specifically – using modern IT and communications technology. Overcoming gender stereotypes is a very important aspect of selecting the future profession; it has far-reaching effects and influences females' access to a decent employment and income.

One of the main problems for women on maternity leave – losing professional qualifications, because of staying away from work for a long time. Another category of moms includes women planning either to upgrade their qualifications or to undergo retraining in order to change the employer. In most cases, women planning to attend training courses in near future want office specialisations: accountant, HR manager, and clerk. There are very few women on maternity leave willing to get workers' or engineering professions. Moreover, mothers need to be able to choose the most convenient format of training – full-time, part-time or distant learning.

- Campaigns against the female workforce discrimination should not stop, in particular – by way of ratifying and putting into practice international labour norms and standards. Governments, associations of employees and employers need to continue working on increasing female representation at all levels including leadership.
- Fundraising, favourable environment for charity, and for community mutual aid funds are important factors.
- Subsidised employment is of significant help for certain social groups, especially for women.
- Availability of affordable childcare institutions will be positively effecting women's decision to enter labour markets and on their choice of employment.

3.3.8 Program of competition in honour of 100th anniversary of UGS

To organize Competition Program in proper way some preparative efforts were made according to developed time table:

- To deliver Invitations to appropriate participants the listserv of such potential participants were developed (responsible organization - Gubkin Oil and Gas University). Listserv includes near 40 UGS companies and 70 Universities;
- Timely distribution of invitations were fulfilled and then periodical telephone conversations to confirm receiving and preparation of participants were maintained;
- After fulfillment by participants papers submission accumulation of abstracts and sorting according to Pillars were fulfilled;
- To evaluate quality of submitted papers international Valuation Committee was created. Members of valuation committee: Ladislav Goryl, Polakova Maria, Nikita Barsuk, Helene Giouse, Maria Haidyna, Jerzy Stopa, Sergey Khan, Irina Popova;
- Special Criteria for scoring was developed. That criteria based upon: Relevance and degree of benefit to the gas industry; Originality; Actuality; Personal contribution; Content and execution quality (max 10-20 scores for each position);

Unfortunately no paper from students was delivered to Valuation Committee. On the contrary Young specialists were active and delivered 10 papers.

#	First Name	Last Name	Organisation	Country	Paper Title
1.	Vladimir	Dorokhin	OOO «Gazprom VNIIGAZ»	Russia	Features of replacement of cushion gas by carbon dioxide of different aggregate states. Advantages of liquid and supercritical states
2.	Ylia	Dudnikova	OOO «Gazprom VNIIGAZ»	Russia	Active Methods to Control process of Forming the Gas bubble in aquifer UGS
3.	Damien	Lavergne	Storengy	France	Innovative technology for monitoring an Underground Gas Storage
4.	Cécile	Mousset	Storengy	France	Evaluating and improving the accuracy of salt cavern thermodynamics models using in situ downhole data
5.	Andrey	Sergeyev	"Gazprom UGS" LLC	Russia	The regulation of methanol consumption at UGS
6.	Nikita	Tarkhov	Gubkin University	Russia	New technologies for drilling UGS wells in strongly depleted fields
7.	Victoria	Voronova	Gubkin University	Russia	Technological solutions for evaluation of the applicability of naturally fractured carbonate aquifers for the underground gas storage
8.	Roman	Závada	NAFTA	Slovakia	Utilizing waste heat in a gas reservoir environment
9.	Zaho	KAI	RIPED-Lanfang	People's Republic of China	Inventory verification of the gaz-cap oil reservoir gas storage
10.	Rafał	Mrzygłód		Poland	Optimization Model Filling the Cavern Gas Storage Mogilno

Table 12 List of participants of Competition Programme

After evaluation of all papers the list of winners were approved. As a result of Competition Program in honour of 100th anniversary of UGS Four young specialist winner´s papers were declared:

- **Damien Lavergne**, Storengy, France, Topic: Innovative technology for monitoring an Underground Gas Storage
- **Yila Dudnikova**, Gazprom VNIIGAZ, Russia, Topic: Active Methods to Control process of Forming the Gas bubble in aquifer UGS
- **Rafał Mrzygłód**, Operator Systemu Magazynowania Sp. z o.o., Poland, Topic: Optimization Model Filling the Cavern Gas Storage Mogilno
- **Roman Zavada**, NAFTA, Slovakia, Topic: Utilizing waste heat in a gas reservoir environment

According to IGU Coordination Committee decision each participant will get a letter of valuation Committee with confirmation of achievements with some words of professional evaluation of the paper. Each participating company will get a letter of thankfulness.

The winning authors of the Program will be presented at the WGC 2015 as a part of WOC2.3 session.

The external VIP speaker will be a part of this session: Professor Sergey Khan, Russia and Professor Pierre Berest, France.

3.4 SG2.3 Conclusion

For UGS companies operating for half a century (and more) aging of skilled workforce is one of the most acute challenges. Average age in Europe and Russia is near 40-50 years. Therefore accumulated knowledge, skills and practices need to be transferred to the young generation of operators and engineers.

Young specialists represent the future of any company. If a company is planning to grow and develop its business, it cannot do without young specialists.

However most part of UGS companies participated Survey prefers to hire experienced professionals while new graduates represent a relatively small percentage in the number of total hires. In almost 70% Survey participating UGS companies, new graduates hired represent 5-10% of total hires. The following conclusion seems appropriate: the current situation with supporting young talent requires significant change very fast.

The correct choice of future profession has a direct impact on the level of interest in education. For many students who were no conscious enough when selecting their specialisations, the disciplines taught in such universities are of no interest; and students have very little motivation to obtain new knowledge and skills. It allows for the following conclusion: higher education today is to a certain extent neither professional, nor specialized. It has a rather general character and is just a condition for future professional self-fulfilment.

As a confirmation of above stipulation could be a result of "**Program of competition in honour of 100th anniversary of Underground Gas Storage**" organised by WOC2 where **no** student from 70 invited Universities was interested enough or informed enough to submit a paper.

Therefore in addition to competitions for employment and internships, methodological tools of working with younger generation need to be enhanced, as well as educational networks integrating schools and extended education. Besides, a necessity arises for setting up the support system to provide for not just early identification and development of school pupils' and students' capabilities, but also for assuring the succession between the pre-school, school, vocational and academic education.

The correct career guidance means that specialised events need to start in elementary schools. Between the years of 10 and 15, children and adolescents may be engaged in after-classes activities based on their interests. In particular, career guidance in the gas industry may include geology and other natural science groups for children, tourism activities, etc. The obtained knowledge may be reinforced via children's intellectual contests and/or Olympics at the local or national level. Respective certificates may be awarded to winners of such Olympics or contests, and such certificates may give to their holders the right to be enrolled in universities without competition or the right for receiving educational grants.

Search for talented young people with disposition to certain professions needs to start before they enter universities. It means that universities will admit young people with certain career guidance background – close to first-year or second-year students.

The interaction between companies and universities is focused on creating and improving the conditions for assuring a high quality of professional training specialists in the key areas of the gas business. The most optimal way of cooperation is assisting universities in the curricula development and coordination, provision of laboratory equipment and simulators/trainers, organising internships of students, engaging the companies' executives, and leading experts in delivering lectures. The future prospects of the gas industry development and the demand for different professions including new specialisations relevant for the new industry needs should be monitored.

Technical and Drilling/completion skills are the hardest to find for UGS gas companies. Companies in Europe (Czech Republic, Italy, and Spain) benefit from somewhat less of a shortage compared to other regions. The biggest overall skill shortage is felt by companies from People's Republic of China, Russia, Denmark, Korea).

Somewhat surprising from WOC2 Survey, the Grades achieved appear to be the least significant element when UGS companies are recruiting graduates. It appears that the importance of grades fall way below other desired qualities such as technical and analytical skills developed through education. Also quite important for UGS companies' qualities that they look for when hiring graduates are behavioural qualities and agility/adaptability to change. At the same time creativity in innovation is less interesting.

At the same time graduates refuse to join the UGS industry mainly in case of the low packages and compensation available and insufficient career development potential. Interestingly, Company image is the least mentioned reason for refusal, suggesting that energy companies tend to have an overall good reputation.

UGS companies like other gas companies tend to rely on themselves for recruiting new graduates and prefer to approach directly potential employees. Seldom do gas companies turn to outside recruitment agents for resolving their hiring needs.

The recruitment channels considered most efficient by gas companies are: Job Fairs, Internship Programs; Personal relations; and various Actions on the University Campus. Other recruitment channels considered effective by gas companies are public recruitment and word of mouth. More and more companies are also making use of Websites for recruitment purposes.

UGS companies responding to the Survey regarding best practices and initiatives being developed in their companies concerning **Attracting Talents** say that the most important subjects are: intensive cooperation with Universities; international Job Fares (Energy Day); M.SC Scholarship; Competitions for postgraduate grants. More than 80% of gas UGS companies maintain active cooperation programs with Academia. But at the same time sponsoring students does not appear to be a popular practice amongst gas companies. Only a few companies sponsor STEM undergraduates. Thus just few gas companies really "grow" their future generation, the most companies are content with what the market has to offer.

The specifics of different generations need to be taken into account when planning the professional development. "Fathers and sons" contradictions definitely create certain misunderstanding on a labour market. For example Gas UGS companies consider Career Development Perspectives and

Job Scope as the most important factors in attracting young talent. Companies' HR staff believe youth are looking for jobs that matters and that provide opportunities to develop themselves in the future. The Company Image that employees will be identifying themselves with is also considered very important by gas UGS companies for attracting youth. This factor definitely makes a discrepancy with young specialists preferences, "Company image" is the least mentioned by graduates reason when rejecting an offer of employment in UGS company. Low Package/ Compensation is the main refusal reason mentioned by graduates, gas UGS companies on average consider Compensation/Package as the 4^{th} or 5^{th} factor of importance in attracting young talent.

The company objective is not only correct selection of new hires, but assuring their development. Maintaining and improving business qualities is required due to growing operations and quality requirements, technologies and innovations, need to capture new markets. Personnel rotation and promotion issues arise in business operations of any company. This is why employees need to be professionally prepared for such situations. But in reality only few UGS companies (Italy, Russia, Denmark) make (ready to pay for) comprehensive training and development for graduate newcomers (Training internships, Postgraduate courses, PhD scholarship).

Efficient gas company needs to set up a system of not just comprehensive but **continuous** corporate professional training.

The company's demand for quality employees is mainly satisfied by recruiting more a less stable personnel (little turnover), their training, developing the necessary skills and competencies, and retraining for deployment in new areas of business. Training is delivered through existing and actively developing continuous corporate training system. This system needs to be based on two underlying fundamental principles:

- continuity – targeted process of on-going qualifications upgrade or retraining matching the interests of employees, company, society and government ("life-long learning");
- professionalism – acquisition of knowledge and skills required for successful performance of employees with account of their positions and priority of tasks.

Thus, continuous training process includes:

- Students training (specialists, bachelors)
- Post-graduate training
- Masters training
- Supplementary professional training
- Retraining courses
- Qualifications upgrade courses
- Short-term training courses

According to results of WOC2 Survey among UGS companies there is a tendency to support M.SC. and PhD scholarship of skilled specialists and not support B.SC. scholarship of yang specialists. It definitely could create a gap between generations of professionals.

Career ladders are used by most gas UGS companies, for the development of both for technical as well as for commercial professionals. Also most gas UGS companies make use of individual development programs. At the same time UGS companies develop succession plans with less activity nether individual development programs and career ladders.

Personnel may be sourced both from outside and within the company (Table 5). Outside means sourcing from candidates without any prior labour relations with the company. Sourcing internally means finding candidates for a vacancy among people already employed by the company.

In any case process of adaptation of newcomers normally takes years. As a results of WOC2 Survey new employees in companies from Europe (Denmark, Russia, Spain, Slovakia) tend to become autonomous faster than their peers in companies from Asia (People's Republic of China and Korea). Almost 90% of new employees working for companies in the Europe become independent in less than 2 years as opposed to new employees in the Asia, who becomes independent usually after 3-5 years. A possible reason of that could be in specific chief-junior relations in Asia. Also European companies are the fastest in “molding” their employees into leaders. It takes on average 3 to 7 years for a new employee in most European companies to become a leader, whereas companies in Asia (People's Republic of China and Korea) require over 15 years preparing their employees for becoming leaders.
Most senior managers in the gas UGS industry are promoted from within their own company. Around 50% of companies promoted over 50% of their senior managers internally.

Most part of the companies in Europe say they promote 50-70% of senior managers internally. It in a logical consistency when European companies also tend to use career ladders, individual development programs and succession plans.

WOC2 Survey results indicates that only two UGS companies don't offer long term incentive plans to they employees (People's Republic of China, Slovakia). Companies which tend to use long term incentives more often also tend have the lowest attrition rates.

The highest attrition rates for employees are found in People's Republic of China and Denmark is near 15%, this is significantly higher than the average 5-10%.

Retirement is the number 1 most mentioned reason by employees of UGS companies when they are leaving a company. This is especially true for European companies, Russia and Korea. Lack of Career Progression Opportunities is the second reason mentioned most often. Furthermore, while compensation package is the most often reason mentioned by youth refusing to join a UGS gas company and it is only the third most often mentioned reason by people that are leave a UGS company. Company reputation is the least mentioned reason by people leaving the company, which suggests that natural gas companies not only have a good image in amongst young people, but maintain also a good reputation with experienced employees that are now leaving the company. Therefore most employees when leaving UGS company, head towards retirement. From amongst the employees that leave a gas company but do not retire, most of them tend to stay within the energy industry and join other energy companies.

The innovative character of the modern economy determines the growing need for the skilled workforce capable of intellectual labour.

Women are more adaptive to a changing environment, and it is easier for them to change professional activities. However, their choice is often influenced by a lack of information about the employment opportunities. They are not aware which professions have the highest potential for employment and promotion, and this often results in selecting professions with which the market is saturated already (accountants, secretaries).

At the same time, females are often better than males professionally. In the process of socialisation, women develop such features as meticulousness and accuracy, attentiveness, precision, sensibility. Female workforce is usually recruited where the content of the job and working environment require the above listed qualities.

Results of WOC2 Survey suggests that women's interest in the gas industry is significantly lower than the interest shown by men. Near half of companies receive less than 30% of their applications from women. Most part of UGS companies participated Survey have stipulated that percentage of applications from females over the past 12 months was in the limits 20-30% of the total number of received applications. Only Czech Republic shows much less figures – 5%.

Consequently in UGS companies women represent less than a third in their number of total of new hires made over the past 12 months. But it is necessary to note that there is no grate differences in quantity of females hired comparing with applications, the same 30%. It means that HR departments of the most part of UGS companies implement an adequate and measured gender policy. Only Slovakia shows quite big difference in quantity of applications (10-20%) and females hired (6-10%).

Gas industry continues to be a male dominated industry. The majority of women in the UGS companies currently activate in non-technical/non-professional roles. Non-technical and non-professional specialities could be occupied by female employees up to 50% of the total workforce occupying (Czech Republic and Spain).

Technical/Professional specialties could be occupied by female employees up to 20-30% (Spain, Russia, Slovakia). Quite big amount (20-30%) of female employees working at Executive and Managing positions in People’s Republic of China and Italy.

There are two approaches to the gender inequality elimination: In Russia, the government first tried to utilise the state’s monopoly in the economy and to provide equal opportunities by the way of communalisation of family and household duties, then – by the way of providing certain privileges to working mothers. The western approach is mainly focused on redistribution of housework between spouses (including parental duties), increasing responsibilities of fathers, strict discrimination restraints.

In the EU, the social policy’s focus has shifted from the equality of male and female rights to the equal treatment of men and women in the labour market by the way of guaranteeing equal opportunities across the entire society.

In Gas industry there is definitely some space for recognizing and encouraging of female employees. While about 15% of the UGS companies participating WOC2 Survey have in place no special program for women, almost 70% of the companies responded that they use 1 special program to recognize and encourage their women employees. 15% of the surveyed companies use 2 or more special programs.

Amongst the companies implementing special programs to encourage female employees, the most commonly used programs are focusing on women returning from maternity leave. Other special programs used are professional networks dedicated to female employees, inclusion programs, and mentoring and coaching. In Russia UGS company provides (gratuitously) kindergarten to employee’s family to make women available for professional work.

More than 70% of companies responding to the Survey say they have no target set in terms of gender equality. One company explained that its aim is to hire the best person for the job, irrespective of gender. Another one mentioned that it is promoting new female employees for “Traditional male positions”. Achieving a minimum percentage of female employees in the total workforce (20%) represents a long term objective for only one respondent.

Conclusion

In North America, CIS and Europe, the most gas developed regions, storage plays and will play an important role in the future. Despite the fact that there are differences concerning indigenous productions (Europe is importing ca 50% of its gas demand, CIS is exporting gas and the US is to become a potential exporter), **the need for flexibility will still be there. One common reason is that gas is still substantially used for heating in residential and commercial** sectors and, apart from Europe, increasingly used for power generation. In Europe, the situation with power generation might change also in the future. So, even though there is not so much greenfield development plans for the future, much of the existing storage capacity will stay in use.

In developing gas markets such as Asia or Middle East, there is a strong demand for flexibility which may come from storages and LNG. Even though both regions have their own challenges, e.g. China has very deep and low permeable reservoir for conversion while Iran is still producing gas from potential storages, there are lots of activities. These are the regions where a massive UGS development is expected.

The new driver, especially in the US and Europe, are renewables and their raising share in energy mix. **Storages may provide solution for storing surplus of electricity from renewables** in a form of hydrogen or synthetic gas if new technologies are applied and developed. Work of SG 2.2 demonstrates that companies have already started to work on this topic and UGS is “storing energy” even today. Storage operators have also skilled staff and a new generation of engineers who are capable of tackling challenges and come up with efficient solutions. This is demonstrated by SG 2.3 activity aimed at “Programme of competition in honour of 100th anniversary of UGS” where young engineers will get the floor to present their way for solving UGS challenges.

Moreover, storage for security of supply is increasingly needed even though it depends on regional specifics and may vary accordingly.

Storage provides general benefits to the entire gas infrastructure but not only for balancing of gas grids. Right from the beginning, storages were developed in order to efficiently modulate variations in gas consumptions. Instead of developing oversized pipelines or LNG regasification terminal, storages help the final customers to get their gas in efficient, reliable and secured way. And this is crucial and the most important fact for any energy fuel not only in case of the natural gas.

References

[1] ”Upcoming U.S. Natural Gas Storage Facilities” EIA 2015, http://www.eia.gov/naturalgas/data.cfm

[2] Yahoo Finance; Kinder Morgan and Cheniere Announce Long-Term Transportation and Storage Agreements; 10 December, 2014; http://finance.yahoo.com/news/kinder-morgan-cheniere-announce-long-210500478.html?.tsrc=applewf)

[3] “http://interfaxenergy.com/gasdaily/article/12472/iran-to-access-to-azerbaijans-underground-gas-storage; Iran to access to Azerbaijan’s underground gas storage”

[4] http://en.trend.az/business/energy/2367164.html

[5] presentation of NGSC during WOC2 meeting in Tehran, October, 2013

[6] 2009-2012 Triennium WOC 2 report for WGC 2012 in Kuala Lumpur

[7] EASEE-gas - Gas Quality Specification - E10064-TB10.25 - EASEE-gas Common Business Practice (CBP) 2003-001/01.

[8] GERG H2 hydrogen project outcomes - Klaus Altfeld and Dave Pinchbeck.

[9] Source: ILO, Key Indicators of the Labour Market, 2003.

[10] Source: http://transparency.gie.eu/

[11] ENTSOG Winter supply outlook 2014/15

[12] presentation of CNPC during WOC2 meeting in Xi’an, March 2015

[13] www.gazprom.ru

[14] Short-Term Energy Outlook, February, modified by IGU 2015

[15] GRHYD is an initiative of GrDF

[16] EN ISO 6974, EN ISO 6976, ISO/TC 193

Appendices

Appendix 1 List of Figures

Appendix 2 List of Tables

Appendix 3 List of Appendices

Appendix 4 List of Abbreviations and Acronyms

AGA	American Gas Association
CAES	Compressed Air Energy Storage
CEGH	Central European gas hub at Baumgarten
CGV	Cushion Gas Volume
CIS	Commonwealth of Independent States
CO_2	Carbone Dioxide
E & P	Exploration & Production
EDF	Electricité de France
EIA	U.S. Energy Information Administration
EU	European Union
GSE	Gas Storage Europe
GIS	Geographic Information System
H_2	Hydrogen
HR	Human ressources
IGU	International Gas Union
ILO	International Labour Office
LNG	Liquefied natural gas
LPCD	Large combustion plant directive
NA	North America
NOx	Nitrogen Oxide
p	Pressure
PHP	a server-side scripting language designed for web development but also used as a general-purpose programming language
PWR	Peak withdrawal rate
R&D	Research & Development

SG	Study Group
STEM	Science, Technology, Engineering and Mathematics
SW	Software
UGS	Underground Gas Storage
UK	United Kingdom
UN	United Nations
USA	United States of America
WGC	World Gas Conference
WGV	Working Gas Volume
WIM	Well Integrity Management
WOC	Working Committee

Appendix 5 List of Units

UNITS	
bcm	Billion Cubic Meters
bcm/d	Billion Cubic Meters per day
mcm	Million Cubic Meters
mcm/d	Million Cubic Meters per day
mcm/d/bcm	Unit PWR in mcm/d of PWR per one bcm of WGV
kWh	Kilowatt Hour
GWh	Gigawatt Hour
TWh	Terrawatt Hour
MW	Megawatt
m	Meter
m^3	cubic metre
Mm^3	thousand cubic metre
Nm^3	Gas volumes are related to temperatures and pressures at normal conditions: 273,15 K (0°C) and 1,01325 bar
bar/10 m	pressure gradient in bars (10^5 Pa) per 10m depths of top of reservoir

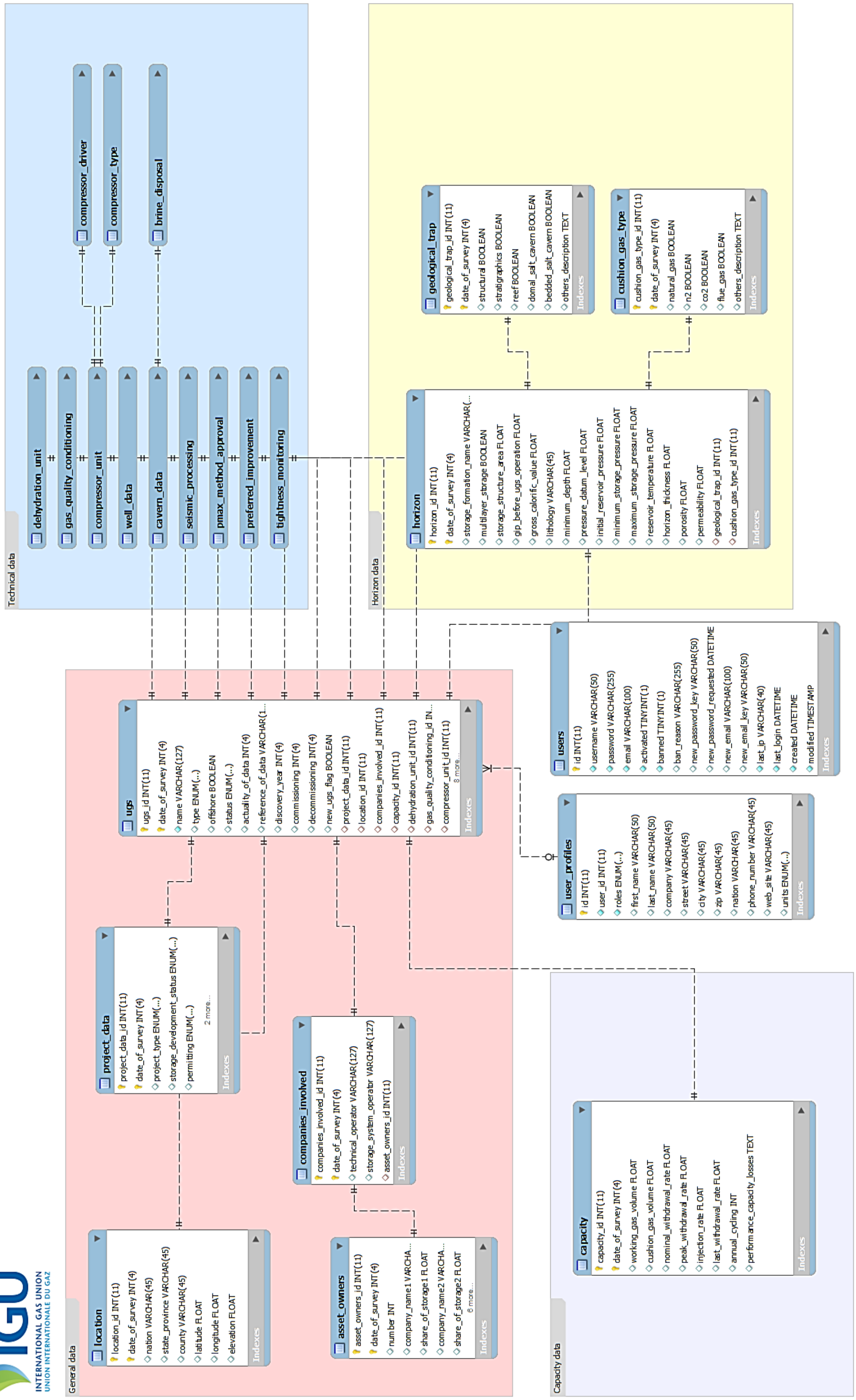
Note: decimal marker is a comma

Appendix 6 List of WOC2 Members

Surname	Name	SG	Organisation/ Company	Country
Annunziata	Gaetano	2.2	Edison Stoccaggio	Italy
Asipchyk	Natallia	2.1	JSC Gazprom Transgaz Belarus	Belarus
Bach	Lars	2.2	DONG Energy	Denmark
Barsuk	Nikita	SG 2.3 leader, WOC2 vice-chair	JSC GAZPROM	Russia
Beňo	Ján	2.2	NAFTA a.s.	Slovakia
Böhmer	Andreas	2.2	E.ON Gas Storage GmbH	Germany
Börner	Reina	2.2	RAG	Austria
Denbow	Kimberly	2.1	AGA	USA
Ding	Guosheng	2.2	RIPED - Langfang Petrochina	People's Republic of China
Dzafarov	Kerim	2.3	Gazprom VNIIGAZ ltd.	Russia
Favret	Fabien	SG 2.2 leader	EDF	France
Garcia Dominguez	Ana Maria	2.2	Enagas	Spain
Giouse	Helene	2.3	Storengy	France
Goryl	Ladislav	WOC2 chair	NAFTA a.s.	Slovakia
Grappe	Jacques	2.2	GEOSTOCK	France
Grigoriev	Alexander	2.2	Gazprom VNIIGAZ ltd.	Russia
Hansen	Leif	2.2	Energinet.dk	Denmark
Haq	Amer Abdel	2.2	Geotechnologie-Systeme GmbH	Germany
Holschumacher	Frank	2.2	E.ON Gas Storage GmbH	Germany
Chiodaroli	Marie-Claire	2.2	Storengy	France
Kaczmarczyk	Monika	2.2	PGNiG SA	Poland
Khan	Serguei	2.2	JSC GAZPROM	Russia
Khaydina	Maria	2.3	Gubkin Russian State University of Oil and Gas	Russia
Khvostova	Viera	2.1	Gazprom VNIIGAZ ltd.	Russia
Kreuz	Michael	2.1	OMV Gas GmbH	Austria
Lee	Kangwon	2.2	KOGAS	Korea
Lenk	Gunar	2.2	Geotechnologie-Systeme GmbH	Germany
Loghmani	Mahmoud	2.1	Natural Gas Storage Company (NGSC)	Iran
Lorenc	Vladimir	SG 2.1 leader	NAFTA a.s.	Slovakia
Luner	Karel	2.2	MND Gas Storage	Czech Republic
Małyszko	Aleksandra	2.2	Polish Oil and Gas Company (PGNiG SA)	Poland
Metzger	Frederick	2.2	Kinder Morgan	USA
Meynard	Philippe	2.1	Storengy	France
Nemati	Mahmood	2.2	Natural Gas Storage Company (NGSC)	Iran
Nikitin	Roman	2.2	Gasprom PHG	Russia
Pandurski	Ivaylo	2.2	Bulgartransgaz EAD	Bulgaria

Surname	Name	SG	Organisation/ Company	Country
Pavlova	Mariana	2.2	Bulgartransgaz EAD	Bulgaria
Poláková	Mária	WOC2 Secretary	NAFTA a.s.	Slovakia
Popova	Irina	2.3	LLC Gazprom PHG Moscow	Russia
Rajabi	Gholamali	2.2	Natural Gas Storage Company (NGSC)	Iran
Rodriguez	Juan José	2.1	Repsol YPF	Argentina
Salatti	Lucia	2.2	Edison Stoccaggio	Italy
Samivand	Masoud	2.1	Natural Gas Storage Company (NGSC)	Iran
Seo	Heungh Seok	2.2	KOGAS	Korea
Shterev	Dimitar	2.2	Bulgartransgaz EAD	Bulgaria
Stopa	Jerzy	2.3	AGH University of Science and Technology	Poland
Tang	Ligen	2.1	RIPED - Langfang Petrochina	People's Republic of China
Teymouri	Ali	2.1	Natural Gas Storage Company (NGSC)	Iran
Thomas	Lionel	2.2	TIGF	France
Tkachou	Viktar	2.2	JSC Gazprom Transgaz Belarus	Belarus
Wagter	Marije	2.1	GasTerra	Netherland
Walbrecht	Joachim	2.1	GaSCON - Gas Storage Consultant	Germany
Wang	Quing	2.2	RIPED - Langfang Petrochina	People's Republic of China
Wei	Guoqi	2.2	RIPED - Langfang Petrochina	People's Republic of China
Wicquart	Emmanuelle	2.1	WGC 2015	France
Wolf	Jiri	2.2	SPP Storage, s.r.o.	Czech Republic
Zheng	Dewen	2.2	RIPED - Langfang Petrochina	China

Appendix 7 Database scheme



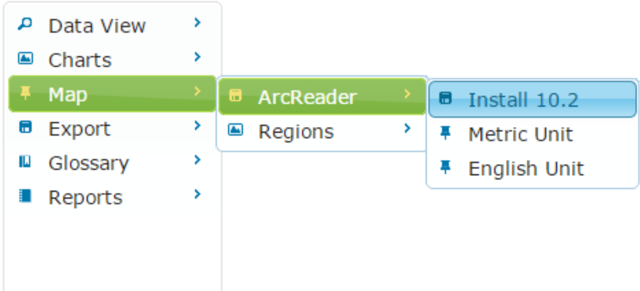
Appendix 8 ArcReader 10.2 Setup Guide

Before you can use dynamic map visualisation, you'll need to download and install ArcReader 10.2. This setup guide will introduce you how to download, install and open dynamic map.

Step 1: Download ArcReader 10.2

You can download **ArcReader 10.2** from two places:

from UGS Web Application by click on the **Install 10.2** menu item



or directly from the link :

http://ugs.igu.org/map/ArcReader102Windows.zip

and from Esri official download page http://www.esri.com/software/arcgis/arcreader/download

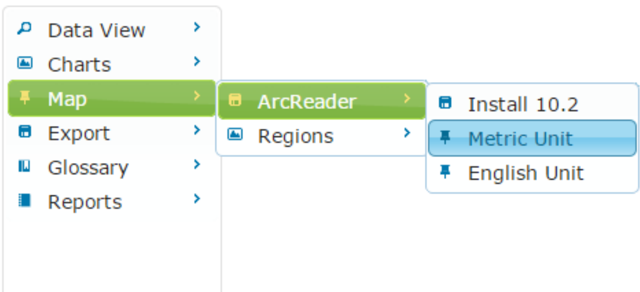
Step 2: Install ArcReader 10.2

a) Existing users must first **uninstall** the **older version** of **ArcReader**.
b) **Unzip** ArcReader102Windows.zip file and **launch** ArcReader_for_Windows_102_136051.exe.
c) The first panel of the extraction wizard will allow you to indicate the location on your computer to which you would like the installation files extracted. When satisfied, click **OK.**
d) You will be notified when the file extraction is complete. To automatically install the software, leave the Launch the setup program check box on the final panel of the extraction wizard checked. To install the software at a later time, uncheck the check box. You can install the software at any time by browsing to the product's extracted location and running the setup.exe. The Setup program will guide you through the installation process.
e) Note:

Administrative privileges will be required for installing the **ArcReader** software product. If you do not have the necessary privileges, an administrator on your system can install the software by running the setup.exe at the product's extracted location.

Step 3: Download Map

You can download **Map** from UGS Web Application by click on the **Metric Unit** or **English Unit** menu item:



or directly from the links :

http://ugs.igu.org/map/UGS_Map_2015_metric_unit.zip

http://ugs.igu.org/map/UGS_Map_2015_english_unit.zip

Step 4: Open Map

Unzip UGS_Map_2015_metric_unit.zip or UGS_Map_2015_english_unit.zip file and **open PMF** file, which is located in the following directory structure:
UGS_Map_2015_metric_unit/ pmf / IGU_2015_UGS_metric_unit.pmf

UGS_Map_2015_english_unit/ pmf / IGU_2015_UGS_english_unit.pmf

Appendix 9 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 o Storage in aquifers o Storage in former gas fields o Storage in former oil fields – Caverns o Storage in salt caverns o Storage in rock caverns (including lined rock caverns) o 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
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

Term	Definition
	(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 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 approved by authorities
Pressure Datum Depth	Vertical reference depth in a pore storage, normally

Term	Definition
	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 10 Projects by regions and storage types

Region	Storage Type	Project type	Storage Development Status	Number of UGS	WGV (bcm)
Asia	**Gas Field**	Extension of existing UGS	Under construction	9,0	9,1
		Extension of existing UGS Total		9,0	9,1
		Green Field UGS Project	Under construction	3,0	2,1
			Unknown	1,0	0,0
		Green Field UGS Project Total		4,0	2,1
	Gas Field Total			**13,0**	**11,3**
Asia Total				**13,0**	**11,3**
Asia Pacific	**Gas Field**	Green Field UGS Project	Planned	1,0	0,0
			Postponed	1,0	0,0
			Unknown	1,0	0,0
		Green Field UGS Project Total		3,0	0,0
	Gas Field Total			**3,0**	**0,0**
Asia Pacific Total				**3,0**	**0,0**
CIS	**Aquifer**	Green Field UGS Project	Planned	2,0	1,7
			Under construction	1,0	7,2
		Green Field UGS Project Total		3,0	8,9
	Aquifer Total			**3,0**	**8,9**

Region	Storage Type	Project type	Storage Development Status	Number of UGS	WGV (bcm)
	Gas Field	Green Field UGS Project	Under construction	1,0	1,0
			Unknown	1,0	0,0
		Green Field UGS Project Total		2,0	1,0
	Gas Field Total			**2,0**	**1,0**
	Salt Cavern	Extension of existing UGS	Under construction	1,0	0,2
		Extension of existing UGS Total		1,0	0,2
		Green Field UGS Project	Planned	3,0	1,2
			Under construction	1,0	0,3
		Green Field UGS Project Total		4,0	1,5
	Salt Cavern Total			**5,0**	**1,7**
CIS Total				**10,0**	**11,6**
Europe	**Aquifer**	Extension of existing UGS	Planned	1,0	0,5
		Extension of existing UGS Total		1,0	0,5
		Green Field UGS Project	Cancelled	2,0	0,0
			Planned	2,0	0,5
			Unknown	2,0	0,0
		Green Field UGS Project Total		6,0	0,5
	Aquifer Total			**7,0**	**1,0**
	Gas Field	Extension of existing UGS	Cancelled	1,0	0,0
			Extension completed	1,0	0,0
			Planned	8,0	3,8
			Under construction	1,0	0,2
		Extension of existing UGS Total		11,0	4,0
		Green Field UGS Project	Cancelled	6,0	0,7
			Planned	14,0	2,8
			Postponed	5,0	2,5
			Under construction	3,0	1,2
			Unknown	11,0	3,5
		Green Field UGS Project Total		39,0	10,7
	Gas Field Total			**50,0**	**14,7**
	Oil Field	Green Field UGS Project	Cancelled	1,0	0,0
			Planned	1,0	2,1
			Under construction	1,0	0,6
			Unknown	1,0	0,0
		Green Field UGS Project Total		4,0	2,7
	Oil Field Total			**4,0**	**2,7**
	Rock Cavern	Green Field UGS Project	Planned	1,0	0,2
		Green Field UGS Project Total		1,0	0,2
	Rock Cavern Total			**1,0**	**0,2**
	Salt Cavern	Extension of existing UGS	Extension completed	1,0	0,0
			Planned	12,0	3,8
			Postponed	1,0	0,4

Region	Storage Type	Project type	Storage Development Status	Number of UGS	WGV (bcm)
			Under construction	1,0	0,3
		Extension of existing UGS Total		15,0	4,4
		Green Field UGS Project	Planned	13,0	9,9
			Postponed	5,0	0,4
			Under construction	2,0	1,2
			Unknown	4,0	0,0
		Green Field UGS Project Total		24,0	11,5
	Salt Cavern Total			**39,0**	**15,9**
Europe Total				**101,0**	**34,5**
L. America & Caribbean	**Aquifer**	Green Field UGS Project	Planned	1.0	0.0
		Green Field UGS Project Total		1.0	0.0
	Aquifer Total			**1,0**	**0,0**
	Gas Field	Green Field UGS Project	Unknown	1,0	0,0
		Green Field UGS Project Total		1,0	0,0
	Gas Field Total			**1,0**	**0,0**
	Salt Cavern	Green Field UGS Project	Unknown	1,0	0,0
		Green Field UGS Project Total		1,0	0,0
	Salt Cavern Total			**1,0**	**0,0**
L, America & Caribbean Total				**3,0**	**0,0**
Middle-East	**Aquifer**	Green Field UGS Project	Planned	1,0	0,6
		Green Field UGS Project Total		1,0	0,6
	Aquifer Total			**1,0**	**0,6**
	Gas Field	Green Field UGS Project	Planned	1,0	0,0
			Unknown	1,0	0,0
		Green Field UGS Project Total		2,0	0,0
	Gas Field Total			**2,0**	**0,0**
Middle-East Total				**3,0**	**0,6**
North America	**Aquifer**	Extension of existing UGS	Extension completed	1,0	0,0
		Extension of existing UGS Total		1,0	0,0
		Green Field UGS Project	Planned	1,0	0,0
		Green Field UGS Project Total		1,0	0,0
	Aquifer Total			**2,0**	**0,0**
	Gas Field	Extension of existing UGS	Extension completed	2,0	0,2
			Planned	2,0	0,0
			Unknown	2,0	0,0
		Extension of existing UGS Total		6,0	0,2
		Green Field UGS Project	Planned	16,0	0,4
			Under construction	1,0	0,0
			Unknown	1,0	0,0

Region	Storage Type	Project type	Storage Development Status	Number of UGS	WGV (bcm)
		Green Field UGS Project Total		18,0	0,4
	Gas Field Total			**24,0**	**0,6**
	Not defined	Green Field UGS Project	Planned	33,0	0,0
			Under construction	2,0	0,0
		Green Field UGS Project Total		35,0	0,0
	Not defined Total			**35,0**	**0,0**
	Oil Field	Green Field UGS Project	Planned	1,0	0,0
		Green Field UGS Project Total		1,0	0,0
	Oil Field Total			**1,0**	**0,0**
	Salt Cavern	Extension of existing UGS	Extension completed	5,0	0,2
			Planned	3,0	1,2
			Under construction	1,0	0,5
		Extension of existing UGS Total		9,0	2,0
		Green Field UGS Project	Planned	23,0	0,2
			Under construction	5,0	0,0
			Unknown	2,0	0,0
		Green Field UGS Project Total		30,0	0,2
	Salt Cavern Total			**39,0**	**2,2**
North America Total				**101,0**	**2,8**
Grand Total				**234,0**	**60,7**

Appendix 11 UGS in operation by regions and storage types

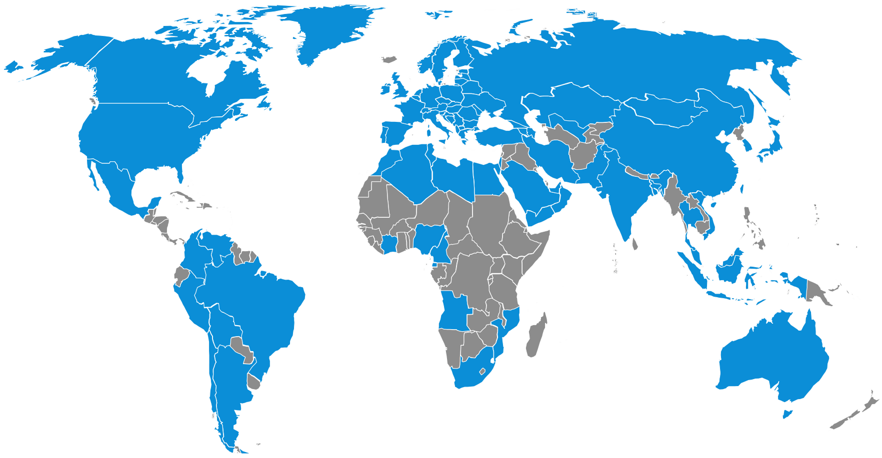
Row Labels	Count of Name of UGS Facility	Sum of WGV (bcm)	Sum of PWR (mcm/day)
Asia	**21**	**4,8**	**134,5**
Gas Field	18	4,2	115,0
Oil Field	1	0,2	6,0
Salt Cavern	2	0,4	13,5
Asia Pacific	**12**	**4,3**	**23,2**
Gas Field	12	4,3	23,2
CIS	**50**	**118,9**	**1 151,3**
Aquifer	12	18,2	236,0
Gas Field	32	96,0	858,0
Oil Field	3	4,3	23,5
Salt Cavern	3	0,5	33,8
Europe	**149**	**110,4**	**2 194,6**
Abandoned Mine	1	0,0	1,0
Aquifer	24	17,3	301,0
Gas Field	75	75,5	1 114,8
Oil Field	3	0,9	16,8
Rock Cavern	2	0,1	7,0
Salt Cavern	44	16,6	754,0
L. America & Caribbean	**1**	**0,2**	**1,9**

Gas Field	1	0,2	1,9
Middle-East	**2**	**6,0**	**28,7**
Gas Field	2	6,0	28,7
North America	**480**	**148,7**	**3 121,6**
Aquifer	51	11,2	258,0
Gas Field	341	107,2	1 749,9
Oil Field	36	19,7	357,9
Salt Cavern	52	10,5	755,8
Grand Total	**715**	**393,3**	**6 655,9**

Appendix 12 Gender, demographic and skills survey participants SG2.3

Gender, demographic and skill survey participants:

1. Storengy -	France
2. SSP Storage –	Czech Republic
3. Edison Stoccaggio S.p.A. -	Italy
4. Enagas -	Spain
5. China National Petroleum Corporation	People’s Republic of China
6. Gazprom UGS -	Russia
7. Energinet.dk -	Denmark
8. Storengy Deutschland –	Germany
9. Kogas -	Korea
10. Nafta	Slovakia



The International Gas Union (IGU) was founded in 1931 and is a worldwide non-profit organisation promoting the political, technical and economic progress of the gas industry with the mission to advocate for gas as an integral part of a sustainable global energy system. The IGU has more than 142 members worldwide and represents more than 97% of the world's gas market. The members are national associations and corporations of the gas industry. The working organisation of IGU covers the complete value chain of the gas industry from upstream to downstream. For more information please visit **www.igu.org**

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