Trends in Recent Underground Natural Gas Storage Projects
GK Mother companies

TOTAL

geostock

bp

ENTREPOSE CONTRACTING
Design - Construction - Operation

for

UNDERGROUND STORAGE FACILITIES

of

Hydrocarbons:
- liquid (Crude Oil and Products)
- liquefied (LPG and LNG)
- gaseous (Natural Gas)
Underground Storage Techniques

LEACHED SALT CAVERNS

MINED ROCK CAVERNS (UNLINED) DISUSED MINES

AQUIFERS DEPLETED FIELDS

CRYOGENIC ROCK CAVERNS (LINED)
Project development

Preliminary study and site selection

- Prefeasibility

Site investigation and feasibility

- Basic design

Planning permission

Detailed design - Selection of contractors and suppliers

Construction

Commissioning / Acceptance tests / Start-up

Training of operators

Preparation of operating documentation

Operation
Géostock’s experience in France

- Storage facilities in operation
- Projects underway
- Decommissioned facilities

- Liquid hydrocarbons
- Natural gas
- L.P.G

Geosub's experience in France includes facilities located in various regions across France. The map highlights the following locations:

- Gargenville
- Donges
- Sennecey
- Manosque
- Marseille
- Lavera
- Paris
- May/Orne

These locations are marked with icons indicating the status of the facilities. The map provides a visual representation of the distribution of storage facilities and projects related to hydrocarbons in France.
Main UGS references in Germany

- Kraak Salt caverns
- Porous media
- Salt caverns
- Jemgum
- Kalle
- Epe
- Xanten
- Bad Lauchstädt
- Kirchheilingen
- Reitbrook
- Harsefeld
- Ellenberg
- Peckensen
- Ketzin
- Buchholz
- Stäffurt
- Bernburg
- Teutschenthal
- Allmenhausen
Géostock’s experience outside France & Germany

Storage facilities in operation
Projects underway

- Liquid hydrocarbons
- Natural gas
- L.P.G
- Other

Diadema

6th Gas Centre Task Force on Supply, Infrastructure & Markets. UNECE. Paris, April 26th, 2012
Geostock US experience

6th Gas Centre Task Force on Supply, Infrastructure & Markets. UNECE. Paris, April 26th, 2012
As of 2010, more than 640 UGS sites.

- Working gas volume approx. 333 bcm (i.e. covering some 10.5% of the world approx. 3200 bcm Yearly Natural Gas Consumption).

- Maximum Withdrawal Rate approx 5.3 bcm/day i.e. Working Gas corresponds to some 60 days at maximum production rate.
Natural Gas UGS deployment worldwide

Working Gas capacity by Region: 1970 to 2009

Source: CEDIGAZ

6th Gas Centre Task Force on Supply, Infrastructure & Markets. UNECE. Paris, April 26th, 2012
Distribution of Natural Gas UGS by Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Depleted fields</th>
<th>Aquifers</th>
<th>Salt caverns</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>79.5%</td>
<td>11.1%</td>
<td>9.4%</td>
<td>-</td>
</tr>
<tr>
<td>Europe</td>
<td>55.0%</td>
<td>18.3%</td>
<td>24.4%</td>
<td>2.3%</td>
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<tr>
<td>C.I.S</td>
<td>72.5%</td>
<td>25.5%</td>
<td>2.0%</td>
<td>-</td>
</tr>
<tr>
<td>Asia/Oceania</td>
<td>91.6%</td>
<td>-</td>
<td>8.4%</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: CEDIGAZ
Traditional Gas Markets and Natural Gas Underground Storage

- UGS were originally promoted, owned and operated by the gas companies for their own benefit and were basically considered as off-sites of the gas grid. Key functions included security of supply and seasonal storage.

- Main UGS functions include:
  - Strategic storage
  - Seasonal storage
  - Swing storage

  A given UGS may cover several functions, depending on its performance attributes, but also on the way it is operated.

- Suitable Geology is always a prerequisite.
The increased requirement for security of supply favors the development of large capacity “strategic” reservoir storage both in mature gas markets and in emerging gas markets. Investment of cushion gas becomes a major issue.

In the mature gas markets large changes impacting the UGS industry are identified. These are triggered by the natural gas market environment which departed from its past stability to enter a fast moving ground.
Current evolution trends

- In the mature gas markets, market driven needs (modularity, flexibility) gain in importance and conventional UGS evolve to flexibility tools whereas UGS operators evolve to “service providers” as a result of Third Party Access in Europe and the USA

  - Operation becomes more aggressive (e.g. management of the cushion gas, inventive storage marketing) entailing the need for real time prediction of the storage performance

  - The requirement for increased flexibility favors the development of salt caverns and “huff & puff” operation
The UGS industry has to face a number of constraints and uncertainties including:

– Difficulty in finding new storage sites: best locations have already been used!

– Increased duration and uncertainty of permitting processes as a result of more and more complex regulation and of public perception

– Current funding shortage and difficulty in financing new large UGS infrastructure projects
The current technical challenges the UGS industry has to face include:

- Improving the performance of existing assets (de-bottlenecking; extending capacity, injectability/deliverability, lifetime)

- Finding and developing new storage sites adapted to the market needs:
  - Search for complex structures (deeper, “concealed” etc…)
  - Consideration of offshore UGS projects
  - Development of partnerships with oil & gas field or brine fields owners

- Minimizing the environmental footprint (cluster drilling, compact installations etc…)

- Maintenance of aging facilities: a large fraction of storage wells are above 30 years requiring sound Well Integrity Management procedures and consideration of "lifetime cycle analysis“.

- Decommissioning of facilities which do not meet performance requirement any more
Current evolution trends

- Improvements in emissions management (collection and reinjection of gas emissions)
- Improvements in compressors technology (e.g. magnetic bearings)
- Improvement in gas dehydration units (molecular sieves e.g.) to increase efficiency and reduce safety distances
- Quick switch from injection to emission and vice versa (currently less than 15’ for salt caverns UGS)
- Evolution of metering technology
- Improvement in maintenance practice.
- Consideration of fully automated, remotely operated facilities
- Inventing new technology to answer specific needs (Lined Rock Caverns to cope with geology unsuitable for conventional UGS, underground storage of LNG in lined rock caverns…)

6th Gas Centre Task Force on Supply, Infrastructure & Markets. UNECE. Paris, April 26th, 2012
Lined rock caverns for LNG storage
Enhancement of the overall safety of UGS progresses on two distinct lines:

- Implementation of state of the art design and equipment:
  - Application of the “double integrity or double barrier principle”
  - Implementation of (Surface Controlled) Subsurface Safety Valves,

- Improvement of operating practice
  - Safety studies, safety audits and emergency response planning within a strict regulatory frame (e.g. SEVESO 2)
  - Close monitoring of the storage and of its environment
  - Elaboration of best practice, common rules etc... promoted by operators associations (IGU, SMRI etc…) or at regulatory level.
The integration of the UGS sites (mainly onshore facilities) into their societal environment has triggered a breakthrough of human sciences into the UGS industry:

- Enhanced, transparent communication with the public (during permitting process, but ongoing during operation)
- Enhanced education and training schemes for the personnel
- Concerns for improved Knowledge Capture and Knowledge Management (KM). This aspect is particularly essential if a generation of engineers is due to go shortly into retirement.
Aquifer Storage LOENHOUT (Belgium)  
Client: Fluxys

General information:
- Location: Onshore, North Belgium
- Aquifer storage
- Project status: Gas storage operation since 1985

Reservoir information:
- Reservoir: Highly karstified & fissured carbonates
- Seal: Shales

GK involvement:
- Wide involvement since 35 years (Exploration works, Preliminary/feasibility studies, Basic design, Wells design, procurement, construction supervision, Assistance to surface facilities construction, Supervision of acceptance tests, Commissioning and start-up, Assistance to administrative authorizations).
- Training of operators and preparation of operating documents. Assistance to operation and follow-up.
- Supervision of expansion phases (volume and flow-rate increases).
- Continuous involvement in all kind of G&G, reservoir, wells and drilling studies.
Aquifer Storage LOENHOUT (Belgium)
Client: Fluxys
PHASE A – CONVENTIONAL DRILLING

(Rig COFOR MR7000)
Case History: Drilling of live gas wells in Loenhout

PHASE B – Snub-drilling and completion
(Halliburton HWO Unit)
Case History: Drilling of live gas wells in Loenhout
Case History: Drilling of live gas wells in Loenhout

PHASE C – Perforations and injectivity tests
(Halliburton)

INJECTIVITY TESTS ON DZH110 & DZH111

\[ y = 65.66x \]
\[ R^2 = 1.00 \]

\[ y = 335.08x \]
\[ R^2 = 0.9405 \]

Surface Water Injection Flowrate (m³/h)

BHP Flowing - BHP Static (bar)
Owner: TPAO
Depleted Gas Field for Natural Gas

- Main features:
  Production wells: 11 + 9
  Working gas: 1 600 + 300 - 10^6 Nm^3/d
  Max. injection rate: 9,5 + 2,3 - 10^6 Nm^3/d
  Max. withdrawal rate: 11,5 + 3,5 - 10^6 Nm^3/d

Remarks:
- 2 different fields for one shared gas station
- 3 production platforms: one offshore, 2 onshore

- Our scope of work:
  Basic Engineering for surface facilities
  Assistance to tendering and contracting for EPC contract
  Surface facilities construction supervision
CASTOR (Spain)  
Client: Escal UGS

General information:
- Location: 21km Offshore Mediterranean sea (Vinaroz – Province of Castellon)
- Water depth 60m
- Depleted oil field
- Project status: development drilling completed
Reservoir information:
- Reservoir: fissured and karstified carbonate
- Seal: Castellon alternance clay / siltstones / sands
- Depth: 1720 - 1940m
- Working Gas capacity: 1.3 Billion m3

Well information:
- 16 abandoned wells
- 8 planned injection / production wells (slanted wells from Castor platform)
- 4 planned observation wells (3 in storage reservoir, 1 in above-lying Castellon reservoir)
- 1 water disposal well

GEOSTOCK scope of work:
- Involvement in subsurface aspects, mainly Geology, Geophysics and Reservoir engineering
- Assistance to preparation and supervision of the drilling campaign
- Geological follow-up of the drilling campaign, petrophysical interpretations, 3D static and dynamic model
Owner: TRANSGAS
Natural gas

- **Main features:**
  Number of caverns: 4
  Unit volume of caverns: 300,000 m³
  Working gas: 144,0 - 10^6 Nm³/d
  Max. injection rate: 1,92 - 10^6 Nm³/d
  Max. withdrawal rate: 14,4 - 10^6 Nm³/d

- **Our scope of work:**
  Feasibility Study
  Exploration
  FEED
  Assistance to tendering and contracting
  Construction supervision
GEOMETHANE MANOSQUE (France)

Owner: GEOMETHANE
300 M Nm$^3$ Natural Gas

- **Main features:**
  - 7 caverns
  - Depth: - top: from 930 to 1240 m
    - bottom: from 1263 to 1555 m
  - Height: from 189 to 333 m
  - Volume: from 220 000 to 500 000 m$^3$
  - Capacity: - total: 450 M Nm$^3$
    - working gas: 300 M Nm$^3$
  - Inlet flowrate: 400 000 Nm$^3$/h
  - Outlet flowrate: 600 000 Nm$^3$/h
  - Pipeline between storage facility and Aix (70 km long, diameter 750 mm)
  - Construction: 1996 - 1999

- **Our scope of work:**
  - Caverns engineering, leaching, sonar control, acceptance tests and commissioning of the facility
  - Assistance to administrative authorizations
  - Assistance to operation
GEOMETHANE MANOSQUE (France)