Introduction GSE

Robert Jan Maaskant, Vice-Executive Secretary
Workshop with DG ENER, 15 July 2015
Gas Infrastructure Europe (GIE) is an European non-profit lobbying association representing the sole interest of the infrastructure industry in the natural gas business.

GIE was formally established on 10 March 2005 as a legally independent and non-profit lobbying association with official statutes.

GIE has currently 67 members in 25 European countries.

GIE voices the views of its members vis-à-vis the European institutions, regulators and other stakeholders.

GIE mission is to actively contribute to the construction of a single, sustainable and competitive gas market in Europe underpinned by a stable and predictable regulatory framework as well as by a sound investment climate.
Gas Infrastructure Europe

67 member companies
4 observers
25 countries
GIE is the umbrella organization for its three subdivisions:

- **GTE – Gas Transmission Europe** representing Transmission System Operators (TSO)
- **GSE – Gas Storage Europe** representing Storage System Operators (SSO)
- **GLE – Gas LNG Europe** representing LNG Terminal System Operators (LSO)
Gas Storage Europe
30 member companies
16 countries
2 observers
GIE President and GIE Board members as of June 2014

Jean-Claude Depail
GIE President
GDF Suez
*GIE President is Chairman of the GIE Board and GIE General Assembly*

GIE Board members

Stephan Kamphues
Open Grid Europe

Jean-Marc Leroy
Storengy

Francisco de la Flor
Enagás

Lubor Veleba
RWE Gas Storage

Gaetano Mazzitelli
Stogit

Nicole Otterberg
E.ON Gas Storage

Wim Groenendijk
Gate Terminal

Torben Brabo
Energinet.dk

Pascal De Buck
Fluxys

Denitsa Beyazova
Bulgartransgaz

Aidan O’Sullivan
Gaslink
The Secretariat is in charge of the daily management, and facilitates the co-ordination between the Working Groups and other activities on behalf of GIE, GTE, GSE and GLE

The Secretariat is based in:
Avenue de Cortenbergh 100
1000 Brussels
BELGUM
Web: www.gie.eu
mail: gie@gie.eu
<table>
<thead>
<tr>
<th>GIE activities</th>
<th>Transmission System Operators</th>
<th>Storage System Operators</th>
<th>LNG Terminal System Operators</th>
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Enabling a single European Market
GIE contributes to develop the regulatory framework for natural gas in Europe in a transparent and proactive manner. Our main objective is regulatory stability and predictability; the essential prerequisites for a sound investment climate.

Ensuring a backbone for secure supplies
Gas infrastructure is the backbone of the energy supply chain from producer to end-user. Transmission pipelines, storage facilities and LNG regasification terminals are among the physical elements of the gas system which ensure that gas is delivered to customers where and whenever needed.

Building the EU energy future
Competition, security of supply and sustainability, main lines of the EU’s energy policy. GIE members adhere to the EU energy objectives and continuously pursue technologically advanced solutions to achieve energy policy goals with the highest safety and efficiency.

Contributing to a competitive low-carbon European Union
Natural gas has proven to be the cleanest fossil fuel. Gas utilization can reduce CO₂ emissions and therefore to contribute to the “20-20-20” policy. As the past decade has shown, the increased share of natural gas in the European energy mix has led to a significant CO₂ reduction in Europe.
GIE is regularly publishing Maps & Data and providing Aggregated Inventory data of Storage operators and LNG terminals (AGSI and ALSI)
AGSI – Aggregated Gas Storage Inventory

GIE members have agreed on a voluntary basis to publish storage inventory as per Regional Energy Market project areas. This initiative is beyond that required by the GGPSSO and Gas Directive and will help provide the information the market needs to operate efficiently and effectively. This information is provided in an aggregated format to guarantee that commercially sensitivity information is not disclosed.
### Storage Investment Database May 2015

<table>
<thead>
<tr>
<th>Country</th>
<th>Facility/Location</th>
<th>Operator</th>
<th>Investment</th>
<th>Status</th>
<th>Start-up</th>
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<td>2020</td>
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<td>Moldova</td>
<td>Romgaz</td>
<td>new facility</td>
<td>planned</td>
<td>2018</td>
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<td>Târgu Mureș</td>
<td>Depomures</td>
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<td>Srbijagas</td>
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<td>Láb complex</td>
<td>Nafta</td>
<td>expansion</td>
<td>planned</td>
<td>2019</td>
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<td>Slovakia</td>
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<td>new facility</td>
<td>planned</td>
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<td>Spain</td>
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<td>Gas Natural Fenosa</td>
<td>new facility</td>
<td>planned</td>
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<td>Turkey</td>
<td>Silivri (Marmara)</td>
<td>TPAO</td>
<td>expansion</td>
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<td>2017</td>
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<td>Turkey</td>
<td>Tuz Gölü</td>
<td>BotaS</td>
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<td>BotaS</td>
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<td>planned</td>
<td>2019</td>
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<td>UK</td>
<td>Hill Top Farm (Cheshire)</td>
<td>EDF Energy</td>
<td>new facility</td>
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<td>2015</td>
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Source: GSE investment database, screenshot, detail of database
Transparency platform

For links to the GSE members' Transparency Template related websites, please check the list below:

<table>
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<tr>
<th>SSO logo</th>
<th>Country</th>
<th>Publication links</th>
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<td>BG</td>
<td>Publication Link</td>
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<td>centrica storage</td>
<td>UK</td>
<td>Publication Link</td>
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<td>IT</td>
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<td>ES</td>
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<td>ENERGINET/DK</td>
<td>DK</td>
<td>Publication Link</td>
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Source: GSE transparency platform, screenshot, detail of database
ALSI – Aggregated LNG Storage Inventory

GSE members have agreed on a voluntary basis to publish aggregated operational data regarding the operation of the EU LNG terminals on a daily basis, grouped by country areas. This information is provided in an aggregated format to guarantee that commercially sensitivity information is not disclosed.
GIE is a proud organizer of GIE Annual Conference. Each year top level representatives from the European Institutions, regulatory authorities, international organizations and the natural gas industry meet

- 13th GIE Annual Conference in Dublin
- 380 delegates
- “The” annual meeting of gas infrastructure industry in Europe
Introduction Gas Storage

Robert Jan Maaskant, Vice-Executive Secretary
Workshop with DG ENER, 15 July 2015
Overview market
Energy: supply and demand

Demand: consumption per sector

- Households: 26.8%
- Industry: 25.1%
- Transport: 31.6%
- Agriculture and forestry: 2.2%
- Other: 0.6%

Supply: energy mix

- Petroleum and Products: 34%
- Gas: 23%
- Solid Fuels: 17%
- Nuclear Heat: 14%
- Renewables: 11%
- Wastes, Non-Renewable: 1%

EU-28 Gross Inland Consumption – Energy Mix (%) – Primary Products Only

Total Primary 2012: 1.682 Mtoe
(Total Primary and Secondary 2012: 1.683 Mtoe)

Source: Eurostat
Energy mix varies significantly per Member State

Source: Eurostat
Gas demand per sector differs significantly per Member State

Source: Eurogas, statistical report 2014
Gas storage capacity also varies significantly

Source: GIE map 2015
### Energy units

**Conversion factors**

<table>
<thead>
<tr>
<th>Units glossary</th>
<th>Conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>bcm</td>
<td>billion cubic metres</td>
</tr>
<tr>
<td>GJ</td>
<td>gigajoule</td>
</tr>
<tr>
<td>GWh</td>
<td>gigawatt hour</td>
</tr>
<tr>
<td>kWh</td>
<td>kilowatt hour</td>
</tr>
<tr>
<td>MMBtu</td>
<td>million British thermal units</td>
</tr>
<tr>
<td>mcube</td>
<td>million cubic metres</td>
</tr>
<tr>
<td>Mtce</td>
<td>million tonnes of oil equivalent</td>
</tr>
<tr>
<td>MWh</td>
<td>megawatt hour</td>
</tr>
<tr>
<td>m³</td>
<td>cubic metres</td>
</tr>
<tr>
<td>Pcal</td>
<td>petacalories</td>
</tr>
<tr>
<td>Pj</td>
<td>petajoule</td>
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<tr>
<td>TWh</td>
<td>terawatt hour</td>
</tr>
<tr>
<td>toe</td>
<td>tonnes of oil equivalent</td>
</tr>
<tr>
<td>tcm</td>
<td>trillion cubic metres</td>
</tr>
</tbody>
</table>

**General conversion for units of energy and volume**

- 1 Mtoe = 10 Pcal
- 1 cubic metre (m³) = 0.001 m³ of natural gas
- 1 m³ of LNG = 593 mcm of gas

**Eurogas conversion factors from volume to energy units**

- 92.3 mcm gas = 1 TWh (GCV)
- 1 m³ of natural gas = 39 MJ (GCV) = 10.83 kWh (GCV)

**Common conversion factors from gross to net calorific value**

- Natural gas: NCV
- Oil: NCV
- Solid fossil fuels: NCV

**Equivalents**

- 1 gigawatt hour = 10⁶ kWh (GWh)
- 1 megawatt hour = 10⁵ kWh (MWh)
- 1 petawatt hour = 10⁴ kWh (PWh)
- 1 terawatt hour = 10³ kWh (TWh)

**Heat unit equivalents**

<table>
<thead>
<tr>
<th>Energy unit</th>
<th>GJ</th>
<th>kWh</th>
<th>MBtu</th>
<th>th</th>
<th>therm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Gigajoule (GJ)</td>
<td>1</td>
<td>277.8</td>
<td>0.948</td>
<td>238.9</td>
<td>9.479</td>
</tr>
<tr>
<td>1 kilowatt-hour (kWh)</td>
<td>3.6 x 10⁹</td>
<td>1</td>
<td>3.411 x 10⁹</td>
<td>0.86</td>
<td>3.411 x 10²</td>
</tr>
<tr>
<td>1 Million British thermal units (MBtu)</td>
<td>1.055</td>
<td>293.2</td>
<td>1</td>
<td>252</td>
<td>10</td>
</tr>
<tr>
<td>1 thermie (th)</td>
<td>4.186 x 10⁹</td>
<td>1.162</td>
<td>3.968 x 10⁹</td>
<td>1</td>
<td>3.968 x 10²</td>
</tr>
<tr>
<td>1 therm</td>
<td>0.1055</td>
<td>29.33</td>
<td>10¹</td>
<td>25.2</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Eurogas, statistical report 2014

Source: [http://www.gasstoragebergermeer.com/econverter/](http://www.gasstoragebergermeer.com/econverter/)
Introduction to gas storage
Why does the gas need to be stored?

The following functions are currently fulfilled by underground gas storage facilities:

• Create strategic reserve in case of interruption of supply (particularly applicable to countries with strong imports dependency)
• Provide seasonal load balancing to meet peak demand (gas is injected to storage between April and October and usually withdrawn between November and March)
• Enable optimised and economic production of natural gas
• Enable daily balancing
• Enable arbitration of gas prices, i.e. commercial optimisation of gas price fluctuations
• Ensure overall optimisation of system functioning, including facilitation of swap transactions
• Sustain transmission by eliminating local system bottlenecks or critical pressure constraint

Source: GSE knowledge center, screenshot FAQ
http://www.gie.eu/KC/faq_C.html
Typical gas demand profile

Fig. 1. Typical gas demand profile.

Source: Hans Plaat, Underground gas storage: Why and how
Use of gas storage 2013-2014

Source: ENTSOG data

MILD WINTER

SUMMER
Injection period

WINTER
Withdrawal period
Use of gas storage 2012-2013

LONG AND LATE WINTER

Source: ENTSOG data
Use of gas storage 2011-2012

COLD SPELL

SUMMER
Injection period

WINTER
Withdrawal period

Source: ENTSOG data
Gas storage levels (beginning and end of heating season)

- **2011/12**: Cold spell
- **2012/13**: Long/late winter
- **2013/14**: Mild winter
- **2014/15**: Normal winter
Another way of presenting:
Load Duration Curve (LDC)

Load duration curve: hours are ordered from peak demand to low demand
Peak demand is generally covered by the fastest flexibility source

Fig. 7. Position of UGS in the load duration curve.
Types of gas storage in EU-28

**Porous rock**

Depleted gas field:
Total working volume **70 bcm**
Average working volume 1 bcm

Aquifer
Total working volume **17 bcm**
Average working volume 600 mcm

**Salt cavern**

Salt cavern:
Total working volume **16 bcm**
Size: 40 – 100 mcm per cavern (often operated in clusters)
Average working volume 350 mcm

Deliverability: fast
(less pressure loss than in porous rock)

Source: Eon Gas Storage, GSE map 2015
Technical aspects of gas storage

Storage

Gas is injected and stored in underground reservoirs to be withdrawn from and re-injected into the transmission system according to gas demand.

- **Reservoir**: Natural gas can be stored in aquifers, salt caverns and depleted gas reservoirs.
- **Wells**: Gas is injected into the underground reservoir or withdrawn to the surface by wells drilled in the ground.
- **Grid connection**: Connection to the transmission system where natural gas is metered.
- **Compressors**: Engines used to increase the pressure of natural gas allowing it to be injected into the underground storage.
- **Gas treatment**: Process used to eliminate residual water, sulphur or other impurities from gas withdrawn from underground storages.


Source: Hans Plaat, Underground gas storage: Why and how (metering station added by RJM)
Some more terminology

**Working volume** (working gas) – max volume available for withdrawal

**Cushion gas** (base gas) – gas that stays in reservoir, required for minimum pressure to provide deliverability

**Inventory** – sum of working volume and cushion gas

**Deliverability** – amount of gas that can be delivered (withdrawn) in a period. Deliverability decreases when amount of gas in storage decreases (see next page for deliverability curve). Duration is working volume/ deliverability

**Injectability** – amount of gas that can be injected in a period. Also a curve applies. Duration is working volume/ injectability

**Capacity** – can refer to working volume and/ or deliverability and injectability (no commonly accepted definition)

Source: Hans Plaat, Underground gas storage: Why and how
Deliverability curve

Fig. 11. UGS withdrawal profile.

Source: Hans Plaat, Underground gas storage: Why and how
Commercial aspects of gas storage
The **Value of Storage** is like an iceberg ...

**THE VISIBLE**

**Market values**
- Intrinsic
- Extrinsic

**THE INVISIBLE**

- System value
- Insurance value

...with the greater part remaining invisible
“Market values” of Storage

Intrinsic Value

- Based on difference between gas price in summer (injection) and winter (withdrawal).
- Reflects seasonal demand pattern.
- “Static view” of the seasonal forward curve.

Extrinsic value

- Based on shorter-term price differentials: day-ahead, weekend, month ahead etc.
- Dynamic and complex function of price volatility, asset flexibility, optimization strategies.
- Potentially high value from small price variations but limited price visibility.
“System value” of Storage

- Avoided investment in wells and surface facilities (up to 80% of avoided CAPEX).
- Optimized operations and maintenance (plateau vs. swing).
- Maximization of gas production (up to 15% of volume).

Optimized gas production

- Avoided investment thanks to lower peak load requirement (avoided CAPEX of 9%-16%*).
- Reduced operating and maintenance costs thanks to optimized gas compression.
- Reduction of local bottlenecks.

Cost-efficient gas transport

Storage is 5-7 times less expensive than the extraction of the corresponding reserve and construction of transmission facilities (source: Gazprom)
“Insurance value” of Storage

- Timely response to demand at all times: prolonged periods of high demand, cold peaks; back-up for renewables integration etc.
- Safeguard against unexpected high impact events: technical failures (production, pipeline), geopolitical risk.
- Lesser vulnerability and higher bargaining power in politically sensitive situations.
- Avoidance of high social welfare costs.

Some examples:
⇒ 2009 Russia-Ukraine dispute: storage and reverse flows were the main mitigating measures.
⇒ 2012 cold snap: storage was key in covering high demand (up to 55% daily demand coverage)
⇒ 2013 prolonged winter end: prolonged draw-down and cross-border use of storage.
TPA: regulated, negotiated

Characteristics of contract (varies per jurisdiction)
- **Duration**: long-term, 1-3 year
- **Volume and speed**: working volume, deliverability and injectability
  - Depends on characteristics gas storage facility
  - Fast products higher priced, because more extrinsic value captured
- **Delivery point**: flange, hub (including transmission capacity)
- **Related to one storage versus group of sites (storage pool/ virtual storage)**
- **Price**:
  - **Working volume**: price for working volume (generally biggest chunk), can be fixed or indexed to summer-winter spread
  - **Fee for injection**
  - **Fee for withdrawal**
  - **Other fees**

Other relevant costs of using gas storage
- **Transmission tariffs**
  (hub: paid by gas storage operator, flange: paid by customer)
- **Opportunity/ financing cost of gas in storage**
How does customer decide to buy and use gas storage capacity?

Buyer must believe that benefits are larger than marginal costs
Marginal costs depend per situation

<table>
<thead>
<tr>
<th>Step 1: acquire storage contract</th>
<th>Gas storage contract</th>
<th>Working volume</th>
<th>Injection fee</th>
<th>Withdrawal fee</th>
<th>Transmission fees</th>
<th>Financing costs of gas in stock</th>
<th>'Option value'</th>
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Customer will only buy contract if total costs are lower than benefits
Current market conditions: either very low bids or unsold capacity

When customer owns contract, gas storage is likely to be filled
Exception: If transmission tariffs are marginal cost

<table>
<thead>
<tr>
<th>Step 2: inject gas</th>
<th>Gas storage contract</th>
<th>Working volume</th>
<th>Injection fee</th>
<th>Withdrawal fee</th>
<th>Transmission fees</th>
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Peak demand: gas in storage is likely to be used

<table>
<thead>
<tr>
<th>Step 3: withdraw gas</th>
<th>Gas storage contract</th>
<th>Working volume</th>
<th>Injection fee</th>
<th>Withdrawal fee</th>
<th>Transmission fees</th>
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Expenditure (cash-out)
Cost to be taken into account (cash-out later but unavoidable when using gas storage contract)
Probably no marginal transmission cost for injecting and withdrawing gas, depends on availability and price of short-term transmission capacity

Step 1: option value: see iceberg, Step 3: withdrawal of gas leads to end of financing cost
Option of waiting and buying when gas is cheaper (depending on expectations for price fluctuation and speed of facility)
Option of waiting and selling when gas is more expensive (idem)
Summer-winter spread is an important driver for gas storage use

Summer-winter spreads currently historically low

• AGSI+ and ENTSOG data show that gas storages are used, although willingness to pay is low
  – Low prices for indexed contracts
  – Unsold capacity (e.g. failed auctions)

• Market prices are low: risk of decommissioning/ mothballing, not a driver for investments

• Gas storages is key to ensure Security of Supply
Backup slides

Robert Jan Maaskant, Vice-Executive Secretary
Workshop with DG ENER, 15 July 2015
European Commission: LNG (33%) and storage (28%) play an important role in case of an interruption of gas supply in East

Short-term measures: use of existing infrastructure
Medium/long-term measures: building infrastructure

Source: European Commission, Stress test communication, 16 October 2014, COM(2014) 654 final, page 5
13 May 2015: gas in stock 28.3 bcm, 31.3% full
Lowest point on 9 April: 23.2 bcm in stock, 25.0% full

Source: GSE AGSI+ database
• High gas storage levels before start winter (>90%) due to high levels in March 2014

• Relatively warm winter, but significantly higher withdrawal rates

• Gas storage level vary from year to year significantly depending on various factors on the wholesale market
Gas storage projects 2015 – 2024 in EU-28

Source: GSE investment database 2015, ENTSOG TYNDP 2015, DG ENER, projects that will come online in 2015 – 2024

- GSE investment database: 20.3 billion m³
- TYNDP: 14.2 billion m³
- PCI: 3.9 billion m³
- CEF: 0.5 billion m³
Gas storage projects 2015 – 2024

Source: GSE investment database 2015, ENTSOG TYNDP 2015, projects that will come online in 2015 – 2024