marcogaz
TECHNICAL ASSOCIATION
OF THE EUROPEAN NATURAL GAS INDUSTRY

WG-ME-17-19

SURVEY METHANE EMISSIONS FOR UNDERGROUND GAS STORAGE (UGS) FACILITIES IN EUROPE

FEBRUARY 8, 2018

MARCOGAZ – THE TECHNICAL ASSOCIATION OF THE EUROPEAN GAS INDUSTRY
Avenue Palmerston 4, B-1000 Brussels, Belgium
+32 2 237 11 39

Table of Contents

Figures

Tables

Appendix

1. SUMMARY

The impact of Greenhouse Gases on climate change has been recognized for some time which has led to measures aimed to reduce global warming. Methane (CH_4) which is the major component of Natural Gas is identified as a Greenhouse Gas.
As Natural Gas is a major source of energy for the society, it is the role of the gas network operators to deliver continuous and safe service whilst managing responsibly the impacts on the environment.

MARCOGAZ, the Technical Association of the European Gas Industry, considers that it is important for the Gas Industry to understand and quantify its emissions of Natural Gas. It is also important to be transparent about the methodology used to calculate the emissions and to demonstrate that best practices are used across the European Gas Industry.

This study is a first attempt to make an estimation of the total methane emission from underground gas storage facilities in the EU28. All the above ground installations are considered in this study. Together with the MARCOGAZ reports already published for transmission, distribution-grids and LNG terminals this report aims at estimating the total methane emission along the so called mid-stream sector of natural gas.

For this study several underground storage companies were asked to deliver their emission data of the year 2015 according to a method which was developed by MARCOGAZ. In this survey, 34 % of the total storage capacity in the EU28 was included in the dataset.

Based on this study, the average emission of underground gas storage facilities in the EU is estimated to be:

347 kg CH_4/ million m^3_n storage capacity

From this emission factor the following emissions are calculated:

- ✓ The total calculated amount of methane emissions from the underground storage facilities in EU28 (2017) is in the range of **38 kT CH_4.**
- ✓ On that base the methane emissions, expressed in CO2 equivalent, from underground storage facilities are estimated per year at:

  1.064 kT CO_2eq [1].

- ✓ The methane losses of the underground storage facilities will be approximately **0,05% of the total storage capacity in the EU28**[2] on a yearly basis.

---

[1] GWP: Global Warming Potential; GWP_{100} of CH_4 (= 28) is used according to the Fifth Assessment Report (AR5) - IPCC.

[2] Gas Infrastructure Europe (GIE), GIE Storage maps 2015 version April 2015

- ✓ Considering these figures, based on global European gas sales[3], the methane losses of underground storage facilities are calculated to be in the range of **0,01%.** This a ratio is representative only at a European level and not comparable at countries level.
- ✓ The total amount of GHG emissions caused by the methane emissions from underground storage facilities is estimated to be:

0,02% of the total of anthropogenic[4] GHG emission in Europe (EU28).

3 Source: EU28 inland gas sales: EUROGAS Statistical report 2015

4 Approximated European Union greenhouse gas inventory: Proxy GHG emission estimates for 2015, EEA report No 23/2016, page 76

2. INTRODUCTION

In the past five years an increasing number of reports from reputable institutions have highlighted the environmental impact of global warming and the accelerating effect that the continued release of Greenhouse Gases to atmosphere is having on this phenomenon.
This changing attitude of governments, regulatory bodies and the general public has resulted in increasing attention being paid to the methane releases from the gas networks across Europe.

Especially in the Unites States several publications have been published about the emission of underground gas storage facilities.

Although some data is available it is not easy to interpret the results from these studies to perform a technical analyse.

A literature review in Europe on the emission of underground storage facilities learned that on a European level no detailed emission studies were available.

This was the reason for MARCOGAZ and GIE[5] to invoke a study for methane emissions on underground gas storage facilities in Europe.

[5] GIE: Gas Infrastructure Europe

3. LIST OF DEFINITIONS

In order to obtain comparable objective emission calculations or estimations, the use of identical definitions is necessary. For this reason, a number of definitions are given below.

3.1. Emissions: sources of methane

- *Fugitive emissions*: All residual leaks from flanges, pipe equipment's, valves, joints, seals and seal gas systems etc. that are more or less continuous sources.

- *Pneumatic emissions:* All emissions caused by gas operating valves, continuous as well as intermittent emissions.

- *Vented emissions:*
    - *Maintenance vents:* Methane emissions from planned operating conditions where significant volumes of Natural Gas can be released to atmosphere from the gas network for maintenance purposes.
    - *Incident vents:* Methane emissions from unplanned events. This will normally be from failures of the system due to third party activity and external factors normally outside of the control of the gas company.
    - *Operation vents*: i.e. starting and stopping of the compressors.

- *Incomplete combustion emissions:* Unburned methane in the exhaust gases from gas turbines, gas engines and combustion facilities and flares.

3.2. Gas system

- *Underground storage*; Gas storage in gas fields, aquifers or salt and other domes including gas compressor station on the UGS facilities, treatment plants and a variety of above-ground facilities to support the overall system.

3.3. Emissions measurement methodology

The underground gas storage (UGS) operators in Europe underline the importance of measuring and reducing methane emissions. They have accumulated extensive knowledge and experience in recent decades around methane emissions quantification and mitigating. They monitor their own emissions and maintain intensive programs to reduce methane emissions.

Monitoring of the emissions are typically done by measurement in case of fugitive emissions. In some cases, the whole population of a specific kind of asset is measured, in other cases the fugitive emissions are calculate from a population sample, depending of course of the size of the asset population. For the measurement of fugitive emissions, the EN15446 measurement method offers an approach to determine emissions from equipment leaks by providing an equation to predict mass emission rate (in kg/hr) as a function of screening value (ppm-mol) for a particular equipment type. The correlation factors are empirical equations based on field data and were developed for the Synthetic Organic Chemical Manufacturing Industry (SOCMI) and for the petroleum industry (PI). The Air Flow Method (Hi Flow Sampler device – HFS) offers an approach to measure emissions from equipment leaks in specific situation.

Calculation is often performed in case of vented emissions. In this situation the total mass of methane is calculated from the length of the pipeline, the pressure, diameter and the composition of the gas.

For pneumatic emissions, both measurement and estimation are used.

3.4. Geographical boundaries

The estimations for methane in this report for transmission companies in Europe are based on the list of Countries given in APPENDIX III.

4. RESULTS

4.1. Data collection

MARCOGAZ and GIE started a survey among its Members in November 2016 with the question to fill in the form of the MARCOGAZ method (see §7.1). The form was returned by 10 MARCOGAZ / GIE members operating a UGS facility.

Operators were asked to fill in the emission of the different parts of their installation and to give activity data where available.

The corresponding operators represents about 34 % of the total capacity of the European UGS facilities. The total number of UGS facilities in the EU28 is approximately 149[6].

4.2. Description of the method

The evaluation of total emissions is based on the following equation:

$$\boldsymbol{Methane\ emission} = \sum(\boldsymbol{AF} \times \boldsymbol{EF})$$

Where:

AF = activity factor
EF = emission factor

The **activity factors** are the population of emitting equipment's such as maximum send-out of the terminal in $m^3{}_n/h$, length of pipelines, number and type of valves, number and type of pneumatic devices, or the frequency of emitting events such as number of operating vents

The **emission factors** are defined as the quantity of methane emitted from each emitting source or for each emitting event. Some emissions are known, such as the gas released for operating reasons or for maintenance, some others can be evaluated on the basis of the characteristics of components and their emission factors, the emission from the operation of a pneumatic device. Other emission factors are difficult to measure such as those deriving from fugitive emissions. For fugitive emissions several measurements methods exist.

To establish emission factors for either the whole UGS facility, but also for parts of UGS facilities, MARCOGAZ introduces a breakdown of the installations into:

- **Injection**: the process where gas is injected into the UGS.
- **Extraction**: the process where gas is extracted from the UGS facility.
- **Wells**: the emissions from the well itself (including X-tree and casing of the well)

[6] Gas Infrastructure Europe (GIE), GIE Storage maps 2015 version April 2015

- **Common**: other emissions (i.e. quality measurement)

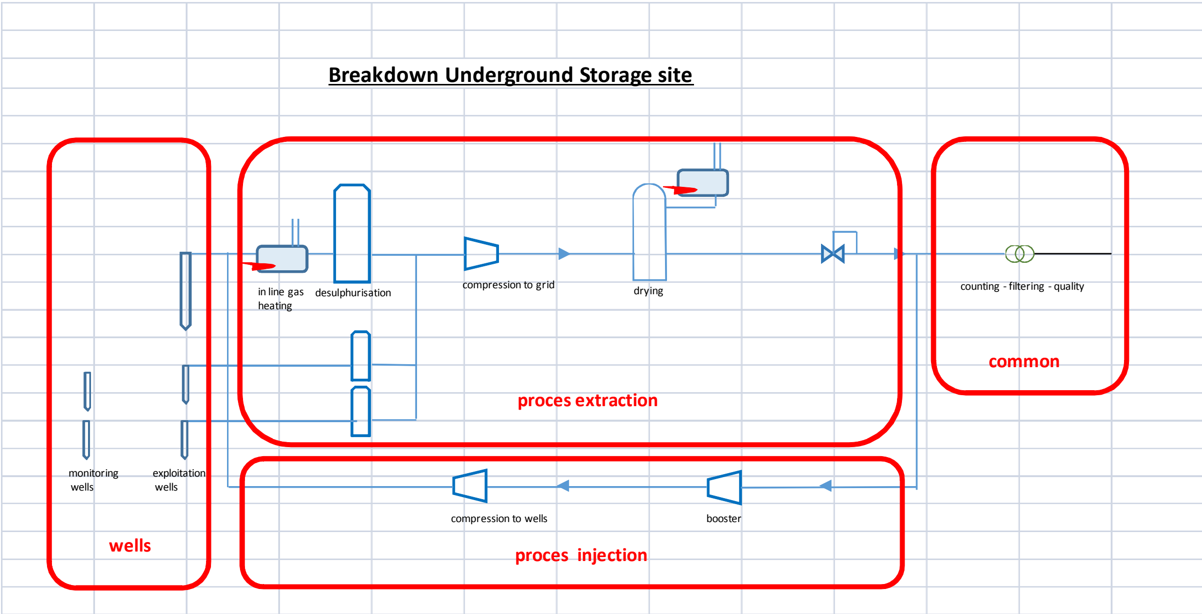

Figure 1: Breakdown of underground storage facilities

MARCOGAZ developed a questionnaire (see §7.1) were for all parts of the above ground installations of the underground gas storage: fugitive emissions, vented emissions and pneumatic emissions are asked for.

4.3. Evaluation of the quality of the data set

10 UGS companies provided data for 2015. Nevertheless, the data were not always sent according to MARCOGAZ format and some important information (such as origin of the data, or data for all emission sources) was not provided. In some cases, data was mixed between different subjects of the MARCOGAZ form. For example, many companies do measure fugitive emissions, vents and pneumatic emissions but following their methods, they do not make any distinction between injection, extraction or well-emissions.

The next table gives an overview of the data delivered by the UGS operators.

Legend:

Data not provided
Data provided

Operator	Type of emission			
	fugitive	pneumatic	vents	combustion
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				

Table 1: Datasets UGS

Although it seems that the data of 2 companies did not specify sub-data, this companies did deliver a total for the facility. It is remarked that the data completeness for the UGS facilities can be approved in future studies. Because sub-data was not always provided, conclusions of this report are based on Tier 1 approaches and must be seen as indicative estimates of the emissions from the above ground installations of UGS facilities in the EU28.

4.4. Emission factor and derived EU28 UGS emissions.

4.4.1. Correlations

Considering that the MARCOGAZ data questionnaire is covering 4 main fields of emissions:

- Fugitive emissions
- Pneumatic emissions
- Vented emissions[7]
- Unburned emissions

A correlation check has been made between the declared amount of CH_4 emitted and the useful stored capacity of the UGS facilities:

Type of emission	Correlation with stored useful capacity
Fugitives	98%
Pneumatic	99%
Vents	97%
Combustion	51%
Total emissions	96%

Table 2: Correlation of several types of methane emissions with diverse factors.

Table 2**Error! Reference source not found.** shows a good correlation between the useful stored capacity and the different types of methane emissions. As expected, this is not the case for combustion emissions because these emissions will be more correlated with the injection volume. Because unburned combustion emissions are small the correlation with the total emission is still good.

In this report it was decided to make a Tier 1 approach for estimating the total amount of the methane for UGS facilities. As mentioned in the previous paragraph, the total methane emission has a good correlation with the storage useful capacity. The polynomial fit of this Tier 1 approach can be seen in Figure 2.

[7] The amount of unburned methane is not significant in comparison with the other type of emissions.

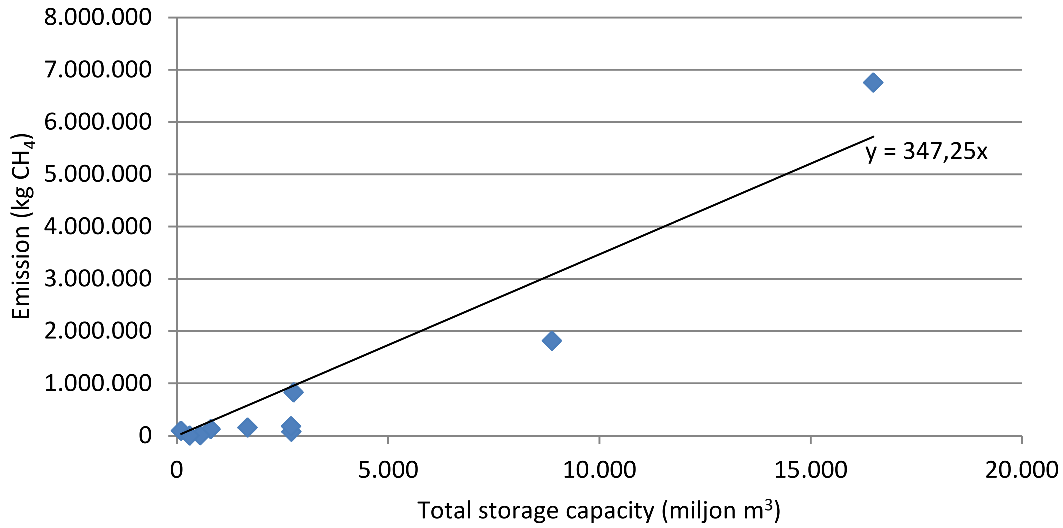

Figure 2: Correlation between storage capacity and the total UGS methane emissions.

The average coefficient is defining the emission factor (*EF)*:

EF = 347 kg CH_4/ million m^3_n storage capacity

4.4.2. Total methane emissions of UGS in the EU28

In this paragraph, MARCOGAZ makes an estimate of the total CH_4 emissions of the above ground installations of UGS facilities in the EU28 using this emission factor.

The total methane emissions from UGS facilities is estimated to be:

38 kT CH_4 per year

To estimate the EU28 UGS emission the total storage capacity was derived from a dataset from Gas Infrastructure Europe[8].

Reference	EU28	Unit	CH_4 UGS in EU28	Unit	Percentage UGS relative to reference
Storage capacity	108.100	Million m^3_n	38	kT CH_4	0,048%
Sales	289.700	kT CH_4	38	kT CH_4	0,013%
Anthropogenic CO_2	4.329.539	kT CH_4	1051	kT CO_2eq	0,024%

Table 3: Expression of EU28 UGS emission against several parameters.

[8] Gas Infrastructure Europe (GIE), GIE Storage maps 2015 version April 2015

Table 3 depicts the total CH_4 emissions from the underground gas storage facilities in the EU28 relative to the: EU28 UGS storage capacity, the EU28 gas sales and the EU28 anthropogenic CH_4 emissions.

The contribution of the UGS facilities in the EU28 are estimated to be **1064 kT CO_2eq**. This is smaller than **0,02%** in comparison to the EU28 anthropogenic methane emissions.

4.5. Further analysis

Based on the 2015 UGS datasets, the repartition of methane emissions per type of emission is given for:

- Pneumatic emissions
- Vented emissions
- Fugitive emissions
- Combustion emissions

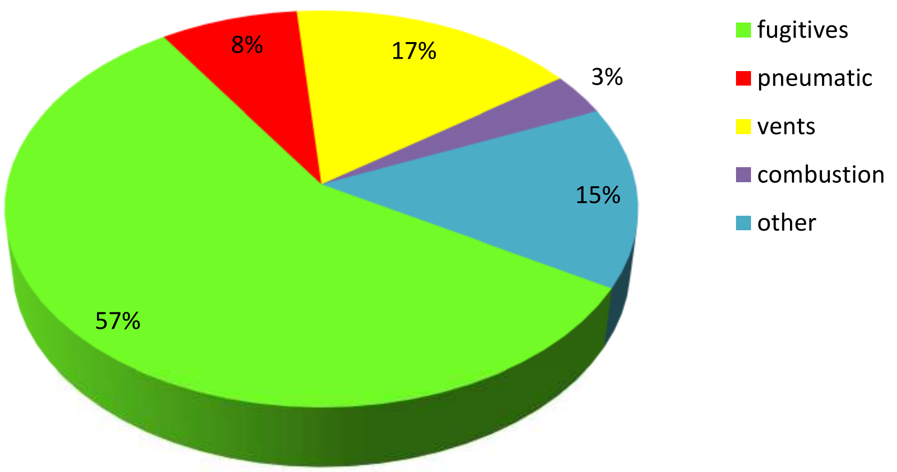

Figure 3: Type of methane emissions

Figure 3 shows that it is expected that fugitive emissions contributes for the largest part of the UGS facilities.

5. CONCLUSION

This study is a first attempt to make an estimation of the total methane emission for above ground installations of underground gas storage facilities in the EU28. Together with the MARCOGAZ reports already published for transmission, distribution-grids and LNG terminals, this report aims at estimating the total methane emission along the so called mid-stream sector of natural gas.

For this study, several underground gas storage companies were asked to deliver emission data of the year 2015 according a method which was developed by MARCOGAZ. In this survey, **34%** of the total storage capacity in the EU28 was included in the dataset.

Based on this study, the average emission of the above ground installations of underground gas storage facilities in the EU is estimated to be:

347 kg CH_4/ million $m^3{}_n$ storage capacity

From this emission factor, the following emissions are calculated:

- ✓ The total calculated amount of methane emissions from the underground gas storage facilities in EU28 (Gas Infrastructure Europe (GIE), 2017) is in the range of **38 kT CH_4.**

On that base the methane emissions from underground storage facilities are estimated per year at:

1.064 kT CO_2eq [9].

- ✓ The methane losses of the underground gas storage facilities will be approximately **0,05% of the total storage capacity in the EU28**[10] on a yearly basis.
- ✓ Considering the figures, based on global European gas sales[11], the methane losses of underground gas storage facilities are calculated to be in the range of **0,01%.** Such a ratio is representative only at a European level and not comparable at countries level.
- ✓ The total amount of GHG emissions caused by the methane emissions from underground gas storage facilities is estimated to be:

0,02% of the total of anthropogenic[12] GHG emission in Europe (EU28).

Although the dataset was not complete, the numbers can be used to make a first step to estimate the total amount of methane emissions from UGS facilities. It is recommended to perform an extended survey in the coming years to make the dataset more complete and reliable.

---

9 GWP: Global Warming Potential; GWP_{100} of CH_4 (= 28) is used according to the Fifth Assessment Report (AR5) - IPCC.

10 Gas Infrastructure Europe (GIE), GIE Storage maps 2015 version April 2015

11 Source: EU28 inland gas sales: EUROGAS Statistical report 2015

12 Approximated European Union greenhouse gas inventory: Proxy GHG emission estimates for 2015, EEA report No 23/2016, page 76

6. BIBLIOGRAPHY

- California E. (2016, 11 16). California Environmental Protection Agency. Opgehaald van Methane Emission Leak Survey of Natural Gas Storage Facilities: https://www.arb.ca.gov/research/methane/natural_gas_storage_survey.htm

- D.L. Massart, B. V. (1988). Chemometrix a textbook, Data handling in Science and Technology. Elsevier Science Publishers B.V.

- European Environment Agency. (2016). Approximated European Union greenhouse gas inventory (EEA Report No 23/2016). EEA.

- Gas Infrastructure Europe (GIE). (2017). http://www.gie.eu/index.php/maps-data/gse-storage-map. Opgehaald van GIE Storage maps 2015 version April 2015.

- R. Subramanian, L. L. (2015, February 10). Methane Emissions from Natural Gas Compressor Stations in the Transmission and Storage Sector: Measurements and Comparisons with the EPA Greenhouse Gas Reporting Program Protocol. Environmental. Science. Technology., pp. 3252-3261.

7. APPENDIX

7.1. APPENDIX I: MARCOGAZ form for Underground Storage

METHANE EMISSION Calculation for Storage

Organisation	
Company:	
Emissions for the Year:	2015
Responsible Person:	

Natural Gas Composition		
Average Methane Content of Natural Gas:	80,00%	% (Vol.)
Density of Methane:	0,7175	kg/m³ $_0$
Conversion Factor from m³ Nat.gas to g CH4:	574,00	gram CH_4 / m^3_0 Gas

Calculation

No.	System Category	Total Emissions: Nat.Gas m$^3_0$/yr	Methane gram/yr	Quality*: method (M,L,E, NA, U)	part of total (X)	not applicable (X)	not known (X)	Activity Factors: System Category	Data	Unit	method (M,L,E, NA, U)	Emission Factors: Marcogaz Range: Minimum	Maximum	method (M,L,E, NA, U)	Company: Data	Unit	method (M,L,E, NA, U)	Source for own factor (specify method)	Remarks
0.	**Plant information**																		
0.0.1								Type of storage plant				to be evaluated	to be evaluated						field/salt/aquifier/other
0.0.2								Stored usefull capacity		m_0^3		to be evaluated	to be evaluated						
0.0.3								Average yearly utility factor (last		m_0^3		to be evaluated	to be evaluated						
0.0.4								Other specify											
1.	**Compressor Stations - Injection**																		
1.1.	**Fugitive Emissions**																		
1.1.1	Injected gas volume							Avg Yearly gas volume injected		m_0^3	1	to be evaluated	to be evaluated						
1.1.2	Gas turbines (including fug. from seals)	0	0					Thermal power input		MW		to be evaluated	to be evaluated			m_0^3/MW/yr			
1.1.3	Gas engines (including fug. from seals)	0	0					Thermal power input		MW		to be evaluated	to be evaluated			m_0^3/MW/yr			
1.1.4	Electrical drives (including fug. from seals)	0	0					Power input		MW		to be evaluated	to be evaluated			m_0^3/MW/yr			
1.1.5	Safety relief valves	0	0					Number of safety release valves		No		to be evaluated	to be evaluated			m_0^3/No/yr			
1.1.6	Valves (injection pipeline /flanges / spindles of valves)	0	0					Pipeline lenght		km		to be evaluated	to be evaluated			m_0^3/km/yr			
1.1.7	Other issues	0	0					Other issues				to be evaluated	to be evaluated						
1.1.8	Other issues	0	0					Other issues				to be evaluated	to be evaluated						
1.1	**Subtotal**	0	0																
1.2.	**Pneumatic Emissions**																		
1.2.1	Pneumatic(gasdriven) actuators	0	0					Number of valves with pneumatic operation		No.		to be evaluated	to be evaluated			m_0^3/No/yr			
1.2.2	Gas seals	0	0					Gas seals		No.		to be evaluated	to be evaluated			m_0^3/No/yr			
1.2	**Subtotal**		0																
1.3.	**Vents**																		
1.3.1	Maintenance	0	0																
1.3.2	Normal operation (start up /stops)	0	0																
1.3.3	Incident	0	0																
1.3.4	Flares	0	0																
1.3.5	Other specify	0	0																
1.3	**Subtotal**	0	0																
1.4.	**Combustion (Waste gas)**																		
1.4.1	Methane in waste gas turbiness	0	0					Fuel gas consumption turbines		m_0^3		to be evaluated	to be evaluated			g/m_0^3			
1.4.2	Methane in waste gas engines	0	0					Fuel gas consumption engines		m_0^3		to be evaluated	to be evaluated			g/m_0^3			
1.4.3	Other specify	0	0					Other issues				to be evaluated	to be evaluated						
1.4.4	Other specify	0	0					Other issues				to be evaluated	to be evaluated						
1.4	**Subtotal**		0																
1	**Total injection**		0																
2	**Extraction**																		
2.1.	**Fugitive Emissions**																		
2.1.1	Extracted gas volume							Gas volume extracted		m_0^3/yr		to be evaluated	to be evaluated						
2.1.2	Gas turbines (including fug. from seals)	0	0							MW		to be evaluated	to be evaluated			m30/MW/yr			
2.1.3	Gas engines (including fug. from seals)	0	0							MW		to be evaluated	to be evaluated			m03/km/yr			
2.1.4	Electrical drives (including fug. from seals)	0	0							MW		to be evaluated	to be evaluated			m30/No/yr			
2.1.5	Safety relief valves	0	0							No		to be evaluated	to be evaluated			m30/No/yr			
2.1.6	Drying and treatment units	0	0					Number of towers/tanks		No		to be evaluated	to be evaluated			m30/No/yr			
2.1.7	Other specify	0	0					Other issues				to be evaluated	to be evaluated						
2.1.8	Other specify	0	0					Other issues				to be evaluated	to be evaluated						
2.1	**Subtotal**	**0**	**0**																
2.2	**Pneumatic Emissions**																		
2.2.1	Pneumatic valves	0	0					Number of valves with pneumatic operation		No.		to be evaluated	to be evaluated			m^3_0/No/yr			
2.2.2	Gas seals (only in case of compression)	0	0					Gas seals		No.		to be evaluated	to be evaluated			m^3_0/No/yr			
2.2.3	Drying and treatment units	0	0					Number of towers/tanks		No.		to be evaluated	to be evaluated			m^3_0/No/yr			
2.2	**Subtotal**		0																
2.3	**Vents**																		
2.3.1	Maintenance	0	0																
2.3.2	Normal operation (start up /stops)	0	0																
2.3.3	Incident	0	0																
2.3.4	Flares	0	0																
2.3.5	Other specify	0	0																
2.3	**Subtotal**		0																
2.4	**Combustion (waste gas)**																		
2.4.1	Methane in waste gas turbiness (in case of compression)		0					Fuel gas consumption turbines		m_0^3		to be evaluated	to be evaluated			g/m_0^3			
2.4.2	Methane in waste gas engines (in case of compression)		0					Fuel gas consumption engines		m_0^3		to be evaluated	to be evaluated			g/m_0^3			
2.4.3	Other specify		0					Other issues				to be evaluated	to be evaluated						
2.4.4	Other specify		0					Other issues				to be evaluated	to be evaluated						
2.4	**Subtotal**		0																
2	**Total extraction**		0																
3	**Wells**																		
3.1	**Fugitive Emissions**																		
3.1.1	Wells (leakage)	0	0					No of wells		No		to be evaluated	to be evaluated			m^3_0/No/yr			
3.1.2	Storage capacity	0	0					Storage capacity		No		to be evaluated	to be evaluated			m^3_0/No/yr			
3.2	**Pneumatic Emissions**																		
3.2.1	Pneumatic valves	0	0					Number of valves		No		to be evaluated	to be evaluated			m^3_0/No/yr			
3.3	**Vents**																		
3.3.1.	Mantenance	0	0																
3.3.2	Start up operation	0	0																
3.3.3	Incidents	0	0																
3.3	**Subtotal**		**0**																
3	**Total wells**		0																
4	**Common (please specify)**																		
4.1	**Vents**																		
4.1.1	Measurement	0	0					Measurements		No.		to be evaluated	to be evaluated			m^3_0/No/yr			
4.1.2	Maintenance (not specifiedf at 1.3, 2.3, 3.3)	0	0																
4.1.3	Start up operation (not specified at 1.3., 2.3, 3.3)	0	0																
4.1.4	Incidents (not specified at 1.3, 2.3, 3.3)	0	0																
4.1.5	Flares (not specified at 1.3, 2.3, 3.3)	0	0																
4.1.6	Other specify	0	0																
4.1.7	Other specify	0	0																
4	**Total common**		0																
	Total Emissions		0																

Method	Type of storage plant
M = measured	field
L = literature	salt
E = estimated	aquifer
NA = not applicable	other
U = unknown	

7.2. APPENDIX II: List of technical working gas volume of UGS.

Gas Storage Europe

Storage Map April 2015

Technical working gas volume of underground gas storage facilities per country

billion m^3

	operational	under construction	planned
Austria	8,3		
Belgium	0,7		
Bulgaria	0,6		1,7
Croatia	0,6	0,0	
Czech Republic	3,5	0,5	0,2
Denmark	1,0		
France	12,0	0,1	0,7
Germany	24,3	2,0	0,7
Greece			0,4
Hungary	6,3		
Ireland	0,2		0,2
Italy	16,6	3,4	7,1
Latvia	2,3		2,8
Lithuania			0,5
Netherlands	12,9		
Poland	2,8	0,8	0,0
Portugal	0,3		
Romania	3,1		1,6
Serbia	0,5	0,4	
Slovakia	3,1		0,9
Spain	4,1		0,2
Sweden	0,0		
UK	5,0	0,2	12,5
EU-28	**108,1**	**7,4**	**29,3**
Albania			1,3
Belarus	1,1	1,0	
Turkey	4,2	0,2	1,4
Ukraine	32,0		
Europe	**145,3**	**8,5**	**31,9**

Technical working gas volume and number of underground gas storage facilities per type

	operational		under construction		planned	
	billion m^3	no.	billion m^3	no.	billion m^3	no.
EU-28						
Depleted field	73,1	71	4,5	5	20,7	16
Salt cavern	16,5	45	3,1	4	5,1	9
Aquifer	17,2	24	-0,2		3,3	1
Other	1,3	4			0,2	1
Total	**108,1**	**144**	**7,4**	**9**	**29,3**	**27**
Check sum		144		9		27

	operational		under construction		planned	
	billion m^3	no.	billion m^3	no.	billion m^3	no.
Europe						
Depleted field	106,4	84	4,8	5	20,7	17
Salt cavern	18,2	47	3,9	4	7,7	13
Aquifer	19,4	27	-0,2		3,3	1
Other	1,3	4			0,2	1
Total	**145,3**	**162**	**8,5**	**9**	**31,9**	**32**
Check sum		162		9		32

Check sum not to be published on the GSE Storage Map

Technical working gas volume of underground gas storage facilities per country

billion m^3

Operational	EU-28	108,1	
	GSE Members	89,8	83%
	Europe	145,3	
	GSE Members	89,8	62%
Under Construction	EU-28	7,4	
	Europe	8,5	
Planned	EU-28	29,3	
	Europe	31,9	

Table not to be published on the GSE Storage Map

7.3. APPENDIX III: List of countries included for calculations

Countries			
Belgium	France	Latvia	Romania
Bulgaria	Greece	Luxemburg	Slovenia
Cyprus	Hungary	Malta	Slovakia
Denmark	Ireland	Then Netherlands	Spain
Germany	Italy	Austria	Czech Republic
Estonia	Croatia	Poland	United Kingdom
Finland	Lithuania	Portugal	Switzerland