Factors determining the construction and location of underground gas storage facilities

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The growing demand for earth gas results in need for storing proper volumes of this fuel to ensure national energy security. Poland has its own earth gas reservoirs, but their exploitation cannot fully cover the constantly increasing demand. Most of the required volumes are covered by gas import, mainly from the Russian Federation. However, long-term agreements do not envisage seasonal variations, which causes that surplus volumes must be stored at underground storage facilities. Additionally, Poland's National Energy Policy imposes an obligation to store the reserves of this fuel. All of these factors determine the construction and development of underground gas storage facilities.

In recent years, a growing trend in building new and extending the existing gas storage facilities has been noticeable in the European Union. Most often, depleted gas and oil reservoirs, salt caverns and aquifers are used for that purpose. The most suitable locations of these types of storage facilities are areas near urban centres that are the final gas recipients. The construction of underground gas storage facilities is also related to the development of the gas transmission system. EU countries, including Poland, continue development of UGS facilities, aiming at diversification of gas supplies. It is also related to other activities, such as launching the LNG terminal in Świnoujście and searching for alternative gas suppliers.

Creating an efficient system of underground gas storage facilities should be focused on securing strategic reserves, balancing seasonal demand variability and optimising the transmission system throughout the country. In order to ensure the undisturbed function of the entire economy, countries maintain gas reserves in case of a failure or an interruption in the continuity of supplies. Additionally, continuous development allows using underground gas storage facilities commercially.

Keywords: *underground gas storage, location, geological structure, energy security*

Introduction

According to the BP Statistical Review of World Energy 2016, world demand for energy is rapidly growing. That growth is expected to stay around 34% in the period from 2015 to 2035, with an average yearly rate of 1.4% (PGI, 2017). Current forecasts indicate that fossil fuels should remain the major sources of energy until 2035. They are believed to constitute up to 80% of the world power supplies, covering 60% of the expected demand increase (Charun, 2004).

The demand for earth gas grows most rapidly when compared to other fossil fuels (IEA, 2014). This fuel is used in many branches of economy, in the industry, services sector, in households, as well as in the electric energy production sector (Mokrzycki, Szurlej, 2003).

Considering the world forecasts presented above, as well as earth gas exploitation in Poland, which covers 28.5% of the total usage, according to the data of 2015 (PGI, 2017), the efforts made to guarantee sufficient gas reserves in the following years seem understandable. Currently, the remaining gas volume is imported. The major earth gas supplier, not only for Poland but also for other European countries, is the Russian Federation.

Taking into account the need to ensure energy security of the country, reliability of gas supplies must be guaranteed through diversification of sources and become less dependent from a single major supplier. The document signed in 2009, "Poland's Energy Policy until 2030" envisaged the construction of the infrastructure allowing to reorganise gas import using the geographical situation of Poland with access to the Baltic Sea. This goal has been reached, and the LNG terminal in Świnoujście was launched in 2015. It has become a major gas hub in the north-east of Europe, performing transfer procedures and regasification of liquefied earth gas, offering the possibility to import gas from Norway or the USA (Egging, Holz, 2016). It is worth considering the various options for building natural gas storage facilities. Rehabilitation of abandoned mines makes it possible to implement new ways of use of closed mines and improve the economic and ecological situation in "mining cities" (Migaleva et al., 2018). An important element is also a way to obtain information from the stakeholders and take them into account when making decisions (Hąbek et al., 2019).

Considering the energy security of Poland, another important aspect can be distinguished, related with securing gas reserves based on extensive storage facilities, to allow to respond to the changes in demand/supply

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and fluctuation of prices. One of the instruments allowing to fulfil these assumptions, by encouraging competition on the gas market and improving the energy security of Poland, is increasing the working volumes of underground gas storage facilities (UGS). Additionally, the amendment to the Polish Energy Law of July 2005 contained a provision concerning the obligation to store imported gas. The legal aspect, as well as the internal policy, lead to searching solutions in this area (Kochanek, 2007). The purpose of this paper is to present the factors determining the construction and location of underground gas storage facilities, as well as to provide an outline of the principles of UGS functioning, using the example of the Strachocina USG.

Based on the forecast of the need to create natural gas underground gas reserves in Poland in 2035 and possible current locations for natural gas storage and the construction of new gas storage, it depends on a number of different economic, environmental, capacity, time, investment, policy, security. The problem can be defined as the role of multi-criteria assessment. The article proposes a methodology and a solution to how to use individual locations to increase the USG's need to cover the gradually rising level of natural gas reserves.

Methodology and theory background of solution

Deciding on serious strategic investments requires a scientific approach to decision making, decision making on a wide range of factors, and the various areas between which it is difficult to describe relationships. Such issues are addressed by multi-criterion decision-making methods as Weighted Method, AHP Method, Scoring Method, etc. (Malindžák et al., 2015). For the solution of the problem, a weighted sum method was applied.

In case we want to concentrate all factors or criteria into one decision – into one indicator, we use this method:

- Factors have a different character from quantification and casualness point of view,
- Factors are from different areas – business, manufacturing, distribution, etc.
- They have different significance related to the analysis objective.

Algorithm of such method follows:

a) Factor and criteria selection for the evaluation and decision F_1, F_2, ... F_n.

b) Evaluation of important factors contributing to a fulfillment of the main objective – assigning of factors' weights w_i. It is advised to select the factors and define the weights by an expert. Weights wi express factor's importance but at the same time, express the proportion of significance among the factors. From a practical point of view, it is advised to make the sum of weights equal to number 1. (It is related to a visual dividing of a "unit circle cake"). Figure 1 shows evaluation according to the Ratio-index method.

$$\sum_{i=1}^{n} w_i = 1$$

In case this is not valid, factors are normalised.

$$w_{ij} = \frac{w_i}{\sum_{i=1}^{n} w_i}, \quad i = 1, 2, ... n,$$

And the sum is $\sum_{i=1}^{n} w_{ii} = 1$.

Particular variants V_j are evaluated with the help of selected factors (HV_j – variant evaluation V_j).
We evaluate particular factors F_i – (HF_{ij}) for each variant V_j. Factors are evaluated according to a pre-defined interval, so-called potency rate – K

$$HF_{ij} \in \langle 1, K \rangle$$

Potency rate value means the evaluation interval and defines the sensitivity of the method. The larger the amount of variants and factors is the larger interval, and higher potency rate becomes.

Variant evaluation $$HV_j = \sum_{i=1}^{n} HF_{ij} * w_i$$

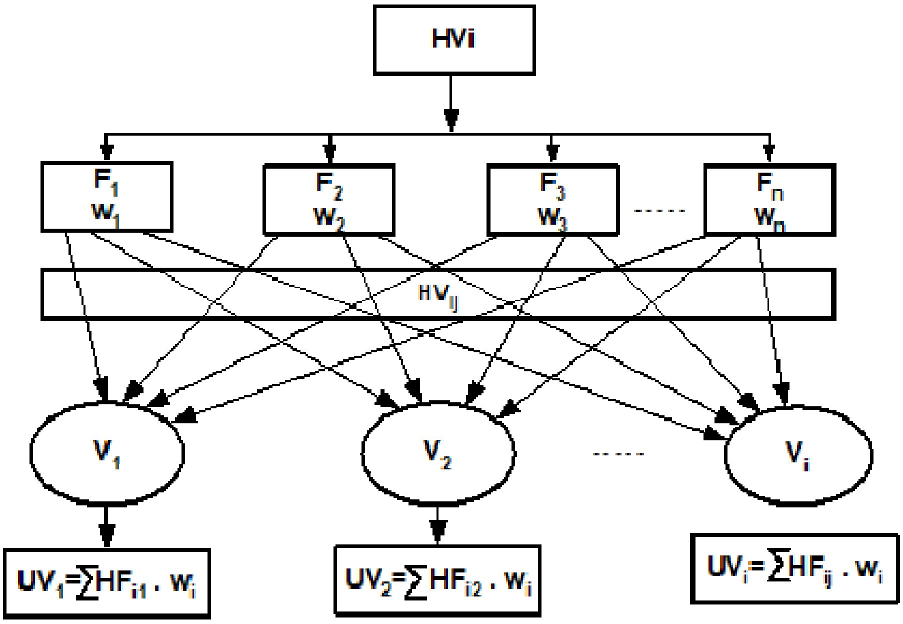

Fig. 1. Evaluation according to Ratio-index method

Factors are evaluated according to a pre-defined interval, so-called potency rate – *K*

$HF_{ij} \in \langle 1, K \rangle$

Potency rate value means an evaluation interval and defines the sensitivity of the method. The larger the amount of variants and factors is the larger interval, and higher potency rate becomes.

$$HV_j = \sum_{i=1}^{n} HF_{ij} * w_i$$

Variant evaluation

Analysis can be defined by minimalisation, meaning that the smaller evaluation HF_{ij} is the better, respectively vice versa by maximisation. The higher HF_{ij} is, the better and the same is valid for the weights *w*.

The solution then is

$$V_j(optim) = \min_j \langle HV_j \rangle$$

In the case of company analysis and evaluation, then we are talking about the evaluation of only one variant.

It is necessary to formulate both negative and positive factors in one form so they will become the same – either positive or negative. For example, in the case of evaluation of suppliers:

for example, F_1 – the amount of distribution per month (the bigger, the better)

F_2 – the time from the order till delivery (the smaller, the better)

In the case, for example, F_1 will be re-formulated – intervals between distribution (the smaller, the better) in case of a minimalisation task.

From a practical point of view, it is necessary to create the following evaluation table 1:

Tab. 1. Example evaluation table

Title of factor i	Factor I weight	Variant 1		Variant 2		...	Variant j	
F_1 F_2 F_3 F_4	w_1 w_2 w_3	HF_{11} HF_{12}	$HF_{11}.w_1$ $HF_{12}.w_2$.	HF_{21} HF_{22}	$HF_{21}.w_1$ $HF_{22}.w_2$.	...	HF_{j1} HF_{j2}	$HF_{j1}.w_1$ $HF_{j2}.w_2$
F_n	w_n	HF_{1n}	$HF_{1n}.w_n$	HF_{2n}	$HF_{2n}.w_n$		HF_{jn}	$HF_{jn}.w_n$
Total variant evaluation			HV1		HV2			HVj

Characteristics of usage and reasons behind earth gas storing

Earth gas belongs to the group of energy carriers with growing market participation due to economic and ecological considerations. It consists of a mixture of hydrocarbons (methane, ethane) and small portions of hydrogen, nitrogen, oxygen, hydrogen sulfide, helium and carbon disulfide. Gaseous fuels are easy in transfer, storage and distribution. Their scope of application includes the generation of thermal and electric energy as well as powering combustion engines. In comparison with other fuels, gas combustion processes are characterised by lower emission of contaminants. Earth gas is useful in municipal services and in households. Furthermore, in the chemical industry, it allows reducing the power consumption of various processes (PGNiG, 2017).

Poland has 292 earth gas reservoirs, including 207 exploited and 53 unexploited reservoirs. The exploitation of 32 gas reservoirs has been ceased. The volume of exploitable gas resources was 125.04 billion cubic metres in 2015. Most of the documented gas resources are reservoirs located in the Polish Lowlands (66.5%). The largest high-methane earth gas reservoirs in that area include Paproć, Załęcze, Kościan, Brońsko, Baranówko-Mostno-Buszewo, Radlin and Żuchlów. Around 29.3% of the resources are located in the Carpathian Foothills area. The largest earth gas reservoir in Poland is Przemyśl, with over 86 million cubic metres of this fuel. Other areas where earth gas can be found are Pilzno, Jasionka, Leżajsk, Żołynia, Jarosław, Dzików and Lubaczów. Figure 2 presents earth gas reservoirs locations in Poland.

Fig.2. Gas fields in Poland (PGNiG, 2018)

The 2015 data indicate that gas in the volume of 4,447.9 million cubic metres was extracted from domestic sources in Poland. The remaining part of the demand (11,174.48 million cubic metres) was covered by gas imported from Russia (9,549.1 million cubic metres), Germany (1,625.16 million cubic metres) and Czech Republic (0.22 million cubic metres) (PGI, 18.12.2017). In Poland, earth gas is distributed by pipelines. The largest volumes of this fuel are supplied by Russian Gazprom, through the Yamal-Europe pipeline. The flow capacity of the first leg is 32.3 billion cubic metres.

The documented Polish earth gas reservoirs remain under control of the *Polskie Górnictwo Naftowe iGazownictwo* S.A. (PGNiG). Their capacity reaches 98 billion cubic metres. Currently, PGNiG supplies gas to 6.5 million customers, including households, companies - combined heat and power plants, steel mills and nitrogen compounds plants. Within the last few years, the volume of gas extracted by PGNiG increased from approx. 3.6 billion cubic metres in 1998 to approx. 4.3 billion cubic metres in 2015. Extraction of high-methane gas recorded by the Sanok branch of the company reached 1.9 billion cubic metres, while the facility in Zielona Góra delivered 2.4 billion cubic metres.

The dynamic economic growth of Poland requires controlling gas storage facilities located in every region. Due to the lack of natural reservoirs in central and north Poland, further development of the national gas supply system should be based on the underground gas storage facilities (UGS), built not only in depleted reservoirs but also in aquifers and salt caverns (Filar, Kwilosz, 2008).

Previously, the primary function of underground gas storage facilities was to maintain commercial reserves. Their primary goal is to secure gas supply continuity in emergency situations, or in case of an unexpected demand increase, and also to minimise the consequences of incidents threatening the national energy security. Long-term gas import agreements do not provide for seasonal consumption variations that are common in the European climatic zone. In summer months, surplus imported gas is stored at UGS facilities and covers peak demands during winter months, caused, among others, by increased gas consumption for heating. Additionally, underground gas storage facilities allow responding to increasing or decreasing blue fuel prices (Brzeziński and Wawrzynowicz, 2014).

The gas supply standard assumed in Poland is approx. 862 million cubic metres for 30 days of extra high earth gas consumption. Taking into account the expected increase in earth gas consumption in the power engineering sector, from 3.5% in 2013 to 30% in 2050, great emphasis is placed on ensuring the stability of the gas supply system and securing access to sufficient storage volumes (BiP, 2018). The total working capacity of UGS reached 2.5 billion cubic metres in 2014. Until 2021, that capacity should increase to 3.3 billion cubic metres, which would be 20% of the envisaged demand for gas during that period.

As far as the other EU member states are concerned, construction and development of underground gas storage facilities are related with energy policy priorities, the scale of gas consumption and the size of the existing gas transmission and distribution system, as well as the wealth of the country and its inhabitants. Table 2 presents the number of UGS facilities in individual countries, total working capacity and maximum deliverability in 2010 and 2015.

Table 2. Underground gas storage facilities (USG) in EU countries, 2010 and 2015 (Eurogas, 2014).

No.	Country	ISO 3166 sign	2010			2015		
			Number of UGS	Total working capacity [millions m3]	Maximum deliverability [millions m3/day]	Number of UGS	Total working capacity [millions m3]	Maximum deliverability [millions m3/day]
1.	Austria	AT	5	4,744	55	8	8,250	95
2.	Belgium	BE	1	600	25	2	1,085	57
3.	Bulgaria	BG	1	600	4	1	550	4
4.	Croatia	HR	0	0	0	1	553	6
5.	Czech Republic	CZ	8	3,127	52	8	3,517	59
6.	Denmark	DK	2	980	16	2	1,035	25
7.	France	FR	15	11,900	200	16	12,894	265
8.	Spain	ES	2	2,367	13	4	2,457	16
9.	Ireland	IE	1	230	3	1	230	3
10.	Latvia	LV	1	2,325	24	1	2,300	30
11.	Netherlands	NL	3	5,000	145	6	12,078	305
12.	Germany	DE	47	20,804	494	51	24,588	637
13.	Poland	PL	7	1,640	32	9	2,915	41
14.	Portugal	PT	1	175	2	6	333	8
15.	Romania	RO	8	3,110	28	7	3,050	28
16.	Slovakia	SK	6	2,770	34	2	3,156	46
17.	Slovenia	SL	0	0	0	1	2,300	30
18.	Sweden	SE	1	9	1	1	9	1
19.	Hungary	HU	5	4,340	55	5	6,330	74
20.	Great Britain	GB	6	4,480	86	8	4,528	154
21.	Italy	IT	10	14,336	152	13	16,696	332
∑			130	78,793	-	153	108,854	-

Underground gas storage facilities secure the operation of gas transmission systems in individual countries (Bergman, 2006; Hill, 2006). The data presented in Table 2 indicates a growing trend in launching new UGS facilities. From 2010 to 2015, 23 UGS facilities were built, which resulted in an increase in the working capacity by 30,061 million cubic metres. Poland was in the 11th place in this ranking in terms of working capacity. The largest number of USG facilities operated in Germany.

Gas storage capabilities characteristics

Building an appropriate network of USG facilities in Poland should secure the basic functions related with maintaining strategic reserves, balancing seasonal gas consumption variability and optimising the gas transmission system in terms of estimation of gas volume to be imported (Ciechanowska, 2016). In Poland, it is both possible to develop the existing storage infrastructure and build new facilities. Suitable geological structures can be found and staff experienced in designing and building USG facilities is available. The development of underground gas storage facilities is followed by the necessity to extend the transmission pipelines.

Storing gas underground is much safer and more advantageous than constructing gas storages on the ground, which require a lot of space and are more vulnerable to acts of terrorism. Due to strict safety standards that must be met, the costs of construction and maintenance of that type of storage facilities is higher (Czapowski, 2006). The basic requirements for underground storage facilities are complete tightness and lack of any adverse reactions between gas and the surrounding rocks. Other desirable features include location in the vicinity of urban or industrial areas, closeness to existing gas pipelines and large capacity.

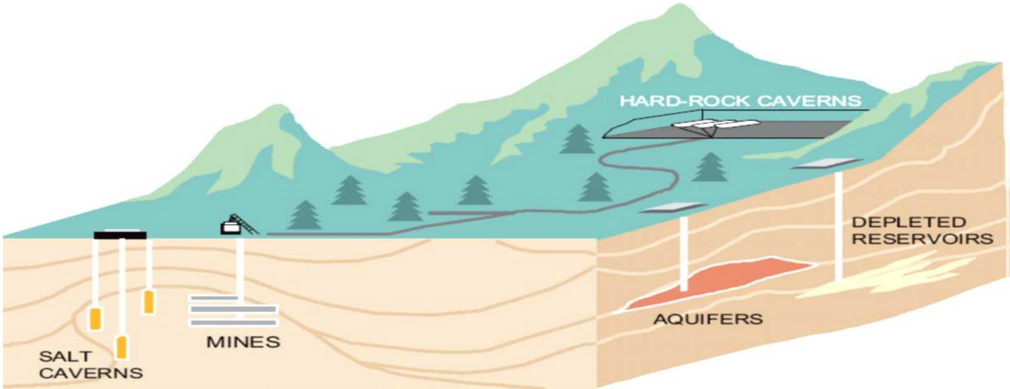

Fig.3. Gas storage using geological structures (AGH, 12 Feb 2017)

Hydrocarbons are stored underground in depleted gas and oil reservoirs, salt caverns and selected aquifers, and also in natural hard-rock caverns or old mines. Figure 3 presents all these types of structures.

Storage in selected aquifers is very expensive due to the protection of groundwater reservoirs. Additionally, selecting a suitable structure requires a lot of exploration and identification work. When a suitable structure is selected, it might not be properly tight (Schafer et al., 1993). Therefore, no structures of this type have been used in Poland so far. The advantages of storing gas in aquifers include high deliverability rate, the possibility of performing a number of cycles during the season and the fact that they are usually located close to final recipients. Mesozoic, Jurassic and Cretaceous aquifers within the anticlines: around Łódź, Warsaw and Szczecin, are also expensive in use but offer quite convenient storage conditions (Polit et al., 2010). Table 3 presents financial outlays and average construction time of UGS facilities depending on the type of structure.

Table 3. Cost and time of construction of different types of UGS

Type of UGS	Average financial outlays [euro/m3]	Average construction time [years]
Aquifers	0.7-1	10-12
Depleted reservoir	0.6-1	5-8
Salt cavern	0.8-1.2	5-10

A relatively cheap and most common form of storage of gaseous hydrocarbons (75% of all facilities in the world), is injecting gas into the porous spaces of depleted gas and oil reservoirs. This method is very advantageous due to the available storage capacity reaching hundreds of millions up to several billion cubic metres of gas. Depleted reservoirs are usually connected with pipelines, there are already existing wells, and their structure is known due to performed seismic and geophysical analyses as well as exploitation records. It is reflected in lower costs of construction of this type of storage facility.

The most suitable rocks in terms of using porous space are sedimentary rocks, especially sandstones, characterised by permeability that allows migration and formation of natural accumulation zones. There are 7 earth gas storage facilities of this type in Poland: Husów, Strachocina, Swarzów, Brzeźnica, Wierzchowice, Bonikowo and Daszewo. They are mostly situated in the Meso–Cenozoic gas reservoirs. Figure 4 presents the location of underground gas storage facilities in Poland. The UGS facilities located in depleted reservoirs are usually capable of performing only a single injection/extraction cycle during a year.

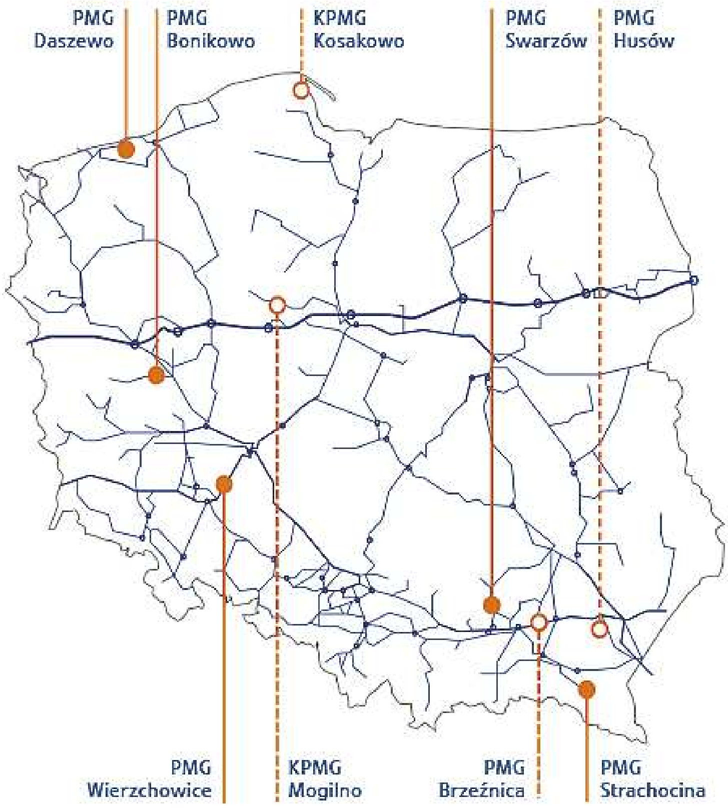

Fig.4. Gas storage facilities in Poland (PGNiG, 18 Dec 2012)

Caverns formed in halite deposits serve as underground storages of a special type. When compared with storage facilities in depleted oil and gas reservoirs, they are more expensive in construction but offer many advantages. This solution ensures complete and fast extraction of the injected medium and the structures can be used for waste disposal when they are no more used as gas storage facilities. These UGS facilities are characterised by very large injection and deliverability rate. They are also capable of being used in several injection/extraction cycles in a year, which enables balancing lower, for example, daily variations of earth gas demand and supply. The building of this type of storage facilities is related to high investment outlays and operating costs.

Favourable conditions for building salt cavern gas storage facilities are in bedded salt deposits with simple and homogeneous structure as well as Zechstein halite structures in salt domes. There are two underground salt cavern gas storage facilities in Poland: Mogilno and Kosakowo (Czapowski, 2006; Kochanek, 2007). Salt-bearing rocks provide good storage conditions due to constant temperature and low humidity. Salt is impermeable and very suitable for storing earth gas, liquefied gas and chemical substances (Evants et al., 2009). Gas can be stored in old salt mines and salt caverns, or in specially designed and built storage chambers (Kunstman et al., 2009; Siemek, Nagy, 2007). Germany has the largest number of cavern storage facilities in use (32 storage facilities in 266 caverns with a total capacity of 19.98 million cubic metres) (EID, 2017).

Operation of the Strachocina underground gas storage facility and development plan

The Strachocina underground gas storage facility is located in south-east Poland, in the Sanok and Brzozów communes area. The geological fold in that region contains flysch rocks of the Lower Cretaceous period (Stasiowski, Wagner-Staszewska, 2010). Until the second half of the 19th century, that fold was a subject of geological and drilling analyses, due to the occurrence of gas exhalations and oil outflows. The gas reservoir was discovered in 1928 when the first wells were drilled. A decision to transform the reservoir into underground gas storage was made in the 1990s.

Gas pipelines are installed in directional wells made by horizontal drilling. The currently used drilling technology allows reducing the costs of exploitation of power resources, improving the availability of the reservoir. The purpose of the horizontal wells at the Strachocina UGS is to reduce turbulences and increase gas storage efficiency (Pielech, 2017). The working capacity of that UGS is 360 million cubic metres.

Taking national energy security into account, infrastructure development is another important factor besides building underground storage facilities. Currently, the transmission system of the Strachocina UGS is extended and modernised, along with the new Poland-Slovakia gas interconnector. 72 kilometres of gas pipeline Hermanowice-Strachocina shall be completed by 2018, including the execution of other related investment tasks. It is an important part of the implementation of the Central-European North-South Gas Corridor concept in Poland. The primary function of the new gas pipeline is the improvement of the technical conditions of gas transmission and improving the continuity and safety of gas supply to recipients. The planned investments in the national gas transmission system are presented in Figure 5.

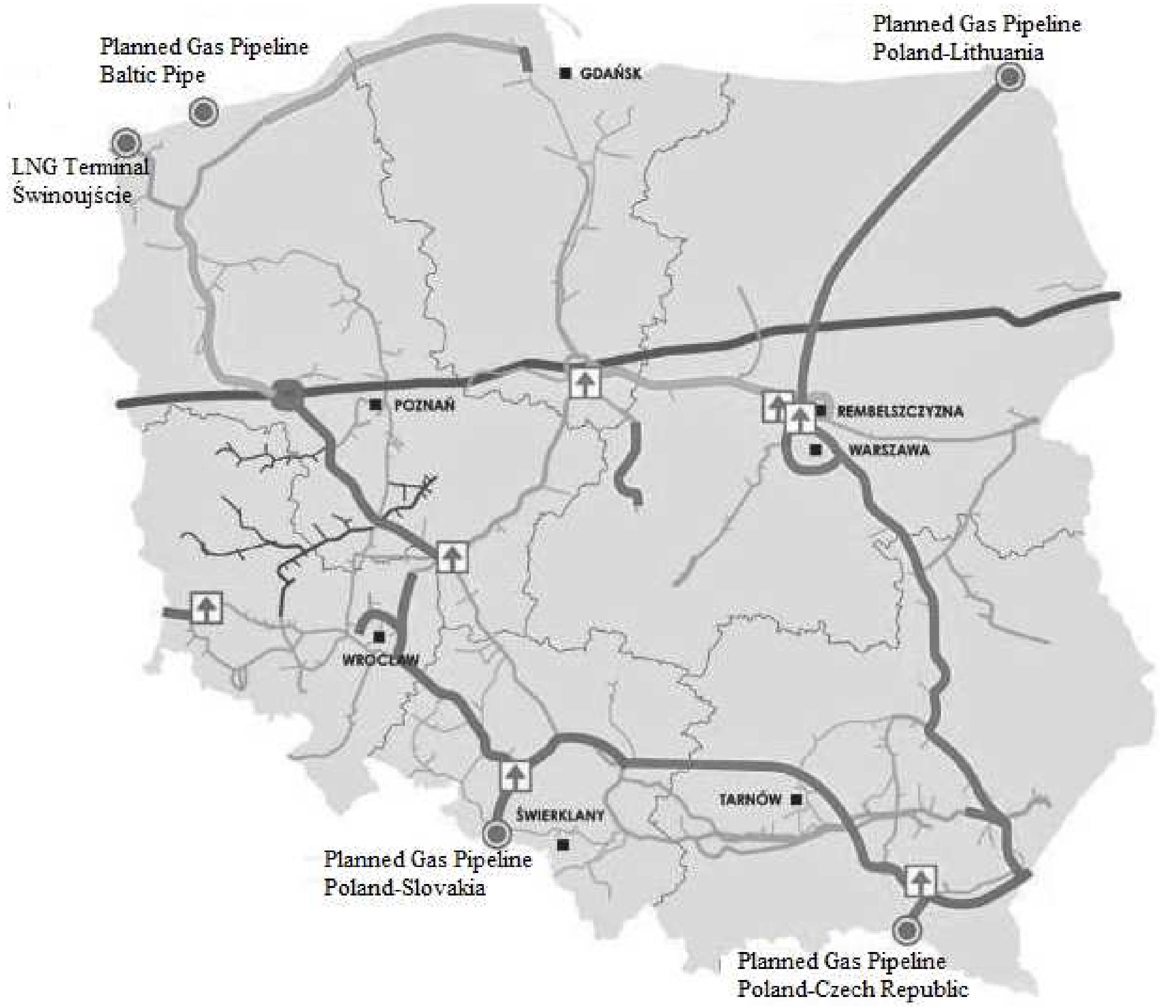

Fig. 5. Planned investments in the Polish gas transmission system until 2023 (Gaz-System, 2015)

Gas pipelines (for example, Poland-Lithuania, Poland-Czech Republic) are under development throughout Poland. It aims at building a well-functioning and uniform (in terms of operating parameters) main gas transmission network. Directions of physical gas supplies will be diversified, ensuring flexibility and continuity of supplies, and also creating conditions for the rapid growth of the national economy. It is envisaged that every client will have an option to buy gas from a selected source by 2023, getting better access to the global gas market through the LNG terminal in Świnoujście (Gaz-System, 2015).

Design of energy use capacity

For the case analysed, the authors selected exemplary criteria that can be taken into account when choosing gas storage facilities. The weights were assigned to individual criteria.

F1 - Economic - the cost of expanding the underground gas warehouse, $w_i = 0.3$;
F2 - Infrastructure - the distance from the agglomeration, $w_i = 0.15$;
F3 - Safety - the distance from other warehouses, $w_i = 0,2$;
F4 - Environmental – the distance from national parks, $w_i = 0,1$;
F5 - Technical – the injection capacity, $w_i = 0,25$.

For the criteria defined and the weights assigned to them, a list of variants for existing underground natural gas storages was developed. The development of options is an example of the development of a proposal, in what order underground storage facilities should be occupied or extended to cover the growing demand for natural gas consumption. The following table is an example of the order of selection of warehouses to be expanded; then it can be applied to potential new locations of underground gas storage facilities (Osieczko, Polaszczyk, 2018). The sum of the weights is 1. The scale of the assessment ranged from 1-5 points and was adjusted to the data concerning gas storage facilities located in Poland.

Table 4. Multicriteria model for the selection of underground gas storage facilities to be expanded

Title of factor i	weights	Variant 1		Variant 2		Variant 3		Variant 4		Variant 5		Variant 6		Variant 7		Variant 8		Variant 9	
		HF	HFw_i	HF	HFw_i	HF	HFw_i	HF	HFw_i	HF	HFw_i	HF	HFw_i	HF	HFw_i	HF	HFw_i	HF	HFw_i
F1	0,3	5	1,5	5	1,5	3	0,9	5	1,5	3	0,9	5	1,5	5	1,5	5	1,5	5	1,5
F2	0,15	2	0,3	5	0,75	5	0,75	4	0,6	4	0,6	5	0,75	2	0,3	3	0,45	2	0,3
F3	0,2	5	1	3	0,6	5	1	3	0,6	4	0,8	3	0,6	3	0,6	2	0,4	2	0,4
F4	0,1	5	0,5	4	0,4	5	0,5	5	0,5	5	0,5	5	0,5	5	0,5	5	0,5	5	0,5
F5	0,25	2	0,5	2	0,5	2	0,5	4	1	5	1,25	2	0,5	1	0,25	3	0,75	3	0,75
Total variant evaluation	1	3,8		3,75		3,65		4,2		4,05		3,85		3,15		3,6		3,45	

Variant 1 – Daszewo
Variant 2 – Bonikowo
Variant 3 – Kosakowo
Variant 4 – Wierzchowice
Variant 5 – Mogilno
Variant 6 – Brzeźnica
Variant 7 – Swarzów
Variant 8 – Husów
Variant 9 – Strachocina

The cost of expanding the warehouse:
5 - Depleted reservoir, Mines, 4- Aquifers, 3- Salt cavern.
Infrastructure - the distance from the agglomeration - (gas transmission infrastructure) - up to 50 km - 5, from 50 - 100 km - 4, from 100 - 200 km - 3, from 200-500 km - 2, over 500 km - 1. Adopted cities for agglomerations - Warsaw, Kraków, Katowice, Gdańsk, Wrocław, Łódź, Poznań.
Safety - the distance from other warehouses (nearest) - up to 50 km - 1, from 50 - 100 km - 2, from 100 - 150 km - 3, from 150 - 200 km - 4, over 200 km - 5.
Environmental - the distance from national parks - no national park in the area of 5 km - 1, from 5 - 10 km - 2, from 10 to 20 km - 3, from 30 to 50 km - 4, over 50 km - 5.
Technical - the injection capacity - up to 1 million m3/day - 1, from 1-2.5 million m3/day - 2, from 2.5 to 5 million m3/day - 3, from 5 -8.5 million m3/day - 4, above 8.5 million m3/day - 5.

Table 5. The proposal of the order of expansion of underground gas storages

No.	Variant number	Name	Total variant evaluation	Target capacity million m^3
1.	4	Wierzchowice	4,2	1200
2.	5	Mogilno	4,05	841
3.	6	Brzeźnica	3,85	100
4.	1	Daszewo	3,8	60
5.	2	Bonikowo	3,75	200
6.	3	Kosakowo	3,65	250
7.	8	Husów	3,6	500
8.	9	Strachocina	3,45	360
9.	7	Swarzów	3,15	90

Based on the information available on the pages of Polish Mining and Gas Extraction Company (Polskie Górnictwo Naftowe i Gazownictwo), a multi-criteria model for the development of existing gas storage facilities was developed. The results presented in Table 4 are an attempt to choose the order of expansion of warehouses in connection with the growing demand for natural gas in the coming years. The criteria should be adjusted accordingly to the requirements and expectations of underground gas storage facilities. Based on the criteria defined by the authors and the weights assigned to them, a certain sequence of extending existing warehouses was established along with the target capacity in a million cubic meters. The offer is presented in ***Table 5,*** along with the target capacity in a million cubic meters. The proposal is presented in Table 5.

The proposed use of the multicriteria model and determining the order of selecting individual objects is only an example that can be used to select new locations for underground gas storage. The authors, due to the lack of access to detailed information, chose the criteria allowing for the use of publicly available data. When selecting the location of gas storage, a number of factors related to technical aspects, construction costs, distance from main pipelines, expansion of the gas transmission installation, and distance from end users should be taken into account. It is also recommended to pay attention to safety-related aspects by considering topics related to the risk of explosion and fire.

Conclusion

Most EU countries rely on the import of earth gas. It is followed by the growing significance of underground gas storage facilities as the key part of the gas supply system. USG facilities ensure security against sudden supply interruptions and balance seasonal demand variations, optimising the operation of the gas supply system in a given country. As a strategic tool, underground gas storage facilities improve the energy security, but may also be operated as commercial undertakings, ensuring compensation of the financial outlays and providing profit from the fees charged for storing fuels for other countries.

Poland has proper geological structures, suitable for the development of underground gas storage facilities. Currently, Poland's energy policy is focused on ensuring energy independence of the country by the diversification of sources and directions of supplies. Certain projects aimed at the development and modernisation of the gas extraction and transmission infrastructure are being executed. Another essential factor is the development of underground gas storage facilities. A growing trend in the numbers and the capacity of UGS can be noticed in all EU countries.

Ensuring proper reserves of the blue fuel determines the energy security of a given country. Depleted gas and oil reservoirs, salt caverns and aquifers can be used as storages of fuel resources. Gas storage facilities should be situated over the entire area of the country, possibly closest to the recipients. Additionally, there is a need to extend the existing storage capacity, due to the obligation to maintain gas reserves in case of a failure or a sudden increase in consumption. The forecasts assume a fifty percent increase in gas consumption over the next few years. Therefore the analysis of the gas storage system indicated the necessity of further rapid development of the underground gas storage network, closely related to using gas as an energy carrier.

One of the elements facilitating the decision-making process may be an application of a multi-criteria model to the selection of a location and establishing the appropriate sequence of development of underground gas storage facilities. The selection of required criteria related to construction costs, depending on the type of warehouse, costs of infrastructure development, technical, environmental or security aspects and the allocation of appropriate weights, may facilitate decision making in the face of high investment expenditures and country security related to the growing natural gas demand. The proposed solution based on appropriate parameters important from the perspective of the strategic goals of the state may prove to be a helpful tool.

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