



Article Underground Gas Storage Facilities in Ukraine: Current State and Future Prospects

Natalia Iwaszczuk ^{1,*}, Ivanna Zapukhliak ², Aleksander Iwaszczuk ³, Oleh Dzoba ⁴, and Oleksandra Romashko ⁵

- ¹ Faculty of Management, AGH University of Science and Technology, Mickiewicz Av. 30, 30-059 Krakow, Poland
- ² Department of Management and Administration, Ivano-Frankivsk National Technical University of Oil and Gas, Karpatska Str. 15, 76019 Ivano-Frankivsk, Ukraine
- ³ College of Social Sciences, Cracow University of Technology, Warszawska Str. 24, 31-155 Krakow, Poland
- ⁴ Department of Entrepreneurship and Marketing, Ivano-Frankivsk National Technical University of Oil and Gas, Karpatska Str. 15, 76019 Ivano-Frankivsk, Ukraine
- ⁵ Department of Finance, Ivano-Frankivsk National Technical University of Oil and Gas, Karpatska Str. 15, 76019 Ivano-Frankivsk, Ukraine
- * Correspondence: niwaszcz@zarz.agh.edu.pl

Abstract: The article considers the system of underground gas storage in Ukraine, the history of its development, the characteristics of regional gas storage complexes, and the current state and role of the gas group enterprises in the domestic gas market. The study also proves the significant role of Ukrainian UGS facilities in ensuring the energy security of Europe. However, their position in the European gas market depends significantly not only on the demand for gas storage services from foreign companies but also on the awareness at the state level of the importance of collective energy security manifested in energy policy regulations. To process forecasts for the development of the European gas market, an assessment of the environment of the gas storage operator of Ukraine was carried out using PESTEL and SWOT analysis. As a result, pessimistic, realistic, and optimistic scenarios for using underground gas storage facilities in Ukraine have been formed.

Keywords: underground gas storage (UGS); gas transmission system (GTS); gas storage operator; SWOT analysis; PESTEL analysis; scenario analysis

1. Introduction

The efficient functioning of enterprises of the fuel and energy complex of Ukraine (including enterprises of production, storage, and transportation of natural gas) is the basis of energy security, protection of national interests, and the success of the country's external integration processes. It is also a necessary condition for internal stabilization and development of the economy, that is, fully satisfying the population's needs and social production in energy resources. Natural gas is increasingly seen as the most acceptable energy source for two reasons:

- (1) improvement of gas production technologies;
- (2) recognition of gas as the most "clean" type of fossil fuel (its combustion entails a minimum emission of carbon dioxide and is consistent with decarbonization goals).

However, today there are several challenges and threats to the functioning of the gas transportation system (GTS) of Ukraine, among which the greatest threat is dependence on Russian gas supplies. To reduce this threat, it is necessary to:

- Make the most of internal traditional energy sources;
- Increase the share of energy received from domestic renewable sources;
- Diversify external suppliers of energy resources;
 - Use underground gas storage (UGS) facilities located on the country's territory more efficiently.



Citation: Iwaszczuk, N.; Zapukhliak, I.; Iwaszczuk, A.; Dzoba, O.; Romashko, O. Underground Gas Storage Facilities in Ukraine: Current State and Future Prospects. *Energies* 2022, *15*, 6604. https://doi.org/ 10.3390/en15186604

Academic Editor: Behnam Zakeri

Received: 14 August 2022 Accepted: 6 September 2022 Published: 9 September 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). To meet the domestic energy demand, Ukraine uses various sources: oil, natural gas, coal, nuclear energy, water, wind, sun, etc. The most demanded in Ukraine now are fossil resources—natural gas and coal. In 2020, primary energy production amounted to 57.0 million tons of oil equivalent, 5.7% less than the previous year. Nuclear energy (35.1%), natural gas (27.8%), and coal (22.4%) had the largest share in the structure of their own production. The total share of renewable energy (RE) sources was only 10.3%. Moreover, own production provided 66.0% of the total primary energy supply. In the structure of final consumption, the share of natural gas was the largest—27.6% [1], which remains one of the main types of energy resources. Therefore, it is so important to study the gas transportation system of Ukraine, which includes gas pipelines and underground storage facilities.

Until recently, the gas pipelines of Slovakia, Poland, Hungary, Romania, and Bulgaria were set up so that gas could be transported in only one direction—from the supplier (Gazprom PJSC, Russia [2]) to the consumer. For several years, these countries have built interstate gas pipelines (interconnectors), which were provided for by several EU documents, in particular, the Third Gas Directive. This made it possible to increase the security of gas supplies, including by purchasing gas on the "spot" market—gas "hubs". The purpose of the interconnectors was to connect all European gas facilities, which made it possible to pump gas from any point in any direction. The necessary investments for transferring gas transmission systems to the reverse mode are small compared to constructing new gas pipelines [3].

Imports of natural gas in 2020 amounted to 7.3 billion m³, which is 38.2% less than in the previous year, with more than 4.4 billion m³ Ukraine bought from Switzerland and Germany. Moreover, the volume of imports from Slovakia increased 6 times—up to 1.1 billion m³. Since November 2015, Ukraine has not bought gas from Russia [4]. For 10 months of 2021, Ukraine imported more than 2.5 billion m³ of natural gas [5].

To compensate for seasonal fluctuations in gas consumption, many countries accumulate gas reserves stored in underground storage facilities. In addition, UGS facilities ensure the reliability of gas supply in the event of an emergency in the GTS or an energy crisis (for example, the crisis associated with Russia's aggression against Ukraine).

For gas storage, cavities are most often used, which remain after the extraction of gas and oil. There are general requirements for the construction of such facilities:

- They should be located as close as possible to the route of the main gas pipeline;
- Their placement should be close to the largest consumer groups;
- the storage must be airtight (to avoid gas losses and prevent damage to the environment);
- Gas pressure that meets the operating conditions of the gas transportation and distribution system must be created and maintained in the storage facility.

There are not many scientific publications containing research on the gas market in Ukraine, although they started to appear more often in connection with the Ukraine–Russia crisis that began in 2014. Goldthau and Boersma [6] examined how this crisis influenced the energy market in political terms. The authors claim that "while the energy world is entering the next phase with a renewed emphasis on renewables and energy efficiency, and markets for energy becoming increasingly global and interconnected, a substantial number of politicians and foreign policy makers seem to be stuck in a Cold War paradigm". However, as the events of recent months show, they were right. Skalamera [7], in turn, believes that the gas factor (i.e., Ukraine's leading role in the transit of Russian gas to Europe) was one of the most important factors in the aforementioned crisis of 2014. Van de Graaf and Colgan [8] also devoted their research to this crisis, looking for answers to two questions: "How exactly did energy contribute to the crisis in the region? Can energy be wielded as a 'weapon' by Russia, the EU, or the US?" They stated that "Russian gas pricing played a crucial role as a context factor in igniting the Ukrainian crisis", but that was not the only cause of the crisis. In turn, Lee [9] returned in his research to the gas conflict between Russia and Ukraine in 2009, attempting to identify the causal mechanisms between their interdependence in the gas sphere and the gas conflict. The topic of the gas conflict in 2006–2009 and its impact on the energy security of European Union countries was also

investigated by Rodríguez-Fernandez, Carvajal, and Ruiz-Gomez [10]. The gas market in the context of the Russian-Ukrainian crisis was also the subject of research by Stulberg [11], who examined strategic limitations in gas relations between Europe and Russia.

As the Ukrainian gas market underwent reform, Goncharuk and Storto [12] compared it with the gas reform in Italy regarding natural gas distribution to end users. The authors stated that "both countries are low performing in terms of operators' technical and scale efficiency, and there is room to design more efficient market configurations". The study of the team of authors of the publication [13] concerned "the assessment of the ability of the Ukrainian economy and individual industries to ensure, in the conditions of economic growth, a stable reduction in natural gas consumption and reduce dependence on its import" (assess the ability of the Ukrainian economy and its individual industries to ensure, in the conditions of economic growth, a stable reduction of natural gas consumption and to reduce dependence on its imports). However, since 24 February 2022, geopolitical conditions have changed drastically.

Yakovenko and Mišík [14] studied the political discourse on transit and the role of natural gas in Ukraine and Slovakia in the context of energy security and compliance with the idea of the European Green Deal. Sauvageot [15] examined the issues of energy security of the European Union in the context of its dependence on Russia as a gas supplier and Ukraine as the main transit country. The author also considered the issue of increasing LNG supplies as an alternative to gas delivered via pipelines.

Teichmann, Falker, and Sergi [16], in turn, conducted a qualitative study of the impact of corruption in Ukraine on the extractive industries. The authors have proved that eliminating corruption is desirable for both governments and corporations. Bocse [17] analyzed the impact of the unrest in Ukraine and Russia's annexation of Crimea in 2014 on EU–US energy relations. The author stated that "strategic considerations played a more important role in thinking about energy security, not only in the EU but also in the US, and securitization characterizes the US response to the crisis".

Alberini, Khymych, and Milan Scasný [18] examined the price elasticity of demand for natural gas, using the example of Ukrainian households' response to an increase in the price of this raw material. Such studies are important for determining the appropriate tariff policy in the country and for implementing reforms in the gas sector. Ukrainian households were also the subject of research for Goncharuk and Cirella [19], who focused their attention on the impact of the government's "gas tax" on the economic and social aspects of consumers' lives. According to the authors, he "has significantly increased inflation, reduced domestic consumption, reduced profitability of local businesses, reduced the size of the middle class and increased stratification of society, concealed real income and escaladed a shadow economy and enhanced injustice and an outmigration of labor". However, due to the dynamic changes taking place in the economy of Ukraine, including the gas sector, a researcher's gap has arisen regarding the prospects for its development, including the use of underground gas storage.

On the other hand, there are many studies on the use of underground gas storage, but without reference to the Ukrainian gas market. Almeidaa et al. [20] assessed the main barriers to developing underground natural gas storage facilities in Brazil. They indicated what conditions should be met for implementing UGS projects to become effective. The authors proved that "there is an important economic value associated with the storage of gas in periods of low power prices and its consumption in a period of high power prices". Chen et al. [21] proposed a viable variant model to analyze the optimal investment strategy for UGS in the context of the ongoing reform of the natural gas market in China. Yu et al. [22] have developed an integrated methodology for assessing the reliability of gas supplies in a pipeline system involving underground gas storage.

Matar and Shabaneh [23] assessed the geological and economic viability of UGS in Saudi Arabia "under different scenarios: with and without LNG imports allowed, and low and high domestic gas production". Zhang et al. [24] investigated the natural gas market and the possibilities of developing underground gas storage in China. They paid particular attention to the imbalance between supply and demand in the domestic gas market, resulting from both regional and seasonal differences, as well as imported gas supplies. The authors emphasized the unique role of UGS in solving the above problem. Skrzyński [25] examined the role of UGS in the continuity of natural gas supplies to customers from the Visegrad Group countries (Poland, the Czech Republic, Hungary, and Slovakia). Syed and Lawryshyn [26] developed a quantitative model to test the operational reliability risk of an underground gas storage facility.

Tongwen et al. [27] focused on the technical issues of using UGS; namely, they proposed an integrated technology for constructing crude oil displacement tanks and underground gas storage. The authors described the advantages of this technology as well as technical connotations, rules for selecting a location, and the process of optimizing the operating parameters of gas storage facilities. Similarly, Thanh et al. [28] presented the machine learning method "to develop a series of unique deliverability smart models for underground natural gas storage in different types of target formations" to help forecast the above-mentioned deliverability. The authors believe that this approach will contribute to cleaner production and the implementation of the principles of sustainable development. Sadeghi and Sedaee [29] applied a mechanistic numerical simulation method to study the effects of molecular diffusion, operating conditions, and bed and rock properties on pillow gas replacement in conventional reservoirs. In the second article [30], the authors focused on the problem of fractures in the mixing of cushion and working gases during underground gas storage. Zhang et al. [31] focused on the issues of ensuring the safety and integrity of the UGS infrastructure, which is undoubtedly important for energy reliability. According to the authors, advanced monitoring and simulation of the risk management of underground gas storage may contribute to this.

The article aims to analyze the current state of UGS facilities in Ukraine, to study their role and potential for ensuring the reliable functioning of the European natural gas market, and to model possible scenarios for the use of Ukrainian underground gas storage facilities by the EU countries to increase the level of energy security. The relevance of the article is also due to the change in the conditions for the functioning of the European gas market, caused by the aggressive energy policy of the Russian Federation and the need to attract new alternative sources of gas supplies from other regions of the world, including through the use of LNG technologies. All of this will require a revision of the strategies for the formation of natural gas reserves and the balancing of the European gas market and, consequently, a more active and systematic involvement in the use of Ukrainian UGS facilities.

The article reviews the information available in the scientific literature and regulations, as well as on internet pages. PESTEL and SWOT analyses were applied to the processing of the collected information, which made it possible to formulate scenarios for developing the gas industry in Ukraine, in particular, the underground gas storage sector.

2. General Overview of Underground Gas Storage Facilities in Ukraine

2.1. The Country's Underground Gas Storage System—A History of Development

The emergence of UGS facilities in Ukraine was associated with the development of gas production in the Precarpathian region and the Kyiv region. In the overwhelming majority of cases, depleted gas and oil fields have been adapted for gas storage. The development of the underground gas storage system in Ukraine can be divided into three periods: 1964–1969, 1970–1985, and 1986 up to the present (Table 1).

Period	Period Features	Commissioned Facilities
1964–1969	The period coincides with the global trend in underground storage in the design and development of large gas supply systems in the USA, France, and Russia.	- Olyshivske UGS facility and Chervonopartyzanske UGS facility (in aquifers) were created for the needs of gas supply to the city of Kyiv and the region.
1969–1985	The creation of gas storage facilities in depleted deposits of gas fields has begun.	 In 1969 for the first time, a pilot gas injection was carried out into the production horizons No. XIV-XV of the Uherske gas field (using the existing well stock and equipment). In parallel, design work was carried out to create an underground storage facility at the Oparske gas field. In 1973 construction of the Dashavske UGS facility and the Krasnopopivske UGS facility started. 30 April 1979, pilot operation of the Bohorodchanske UGS facility (created based on a depleted gas field of the same name, using residual reserves as a buffer gas) began. In 1983 Hlibovske UGS facility in Crimea was commissioned.
The mid- 80's—until now	The period is characterized by an increase in UGS capacity and the achievement of maximum daily productivity during gas extraction.	 In 1987 Solokhivske UGS facility in the Poltava region was commissioned. In 1988 Pilot operation of the Proletarske UGS facility in the Dnepropetrovsk region started. In 1989 Pilot operation of the Verhunske UGSF in the Luhansk region started.

Table 1. Periods of development of underground gas storage in Ukraine.

Source: developed by the authors of [32].

The outstanding achievement of the third period was the creation of the Bilche-Volytsko-Uherske UGS facility (with a capacity of over 17 billion m³ of natural gas), the second largest gas storage facility in Europe. Its pilot operation began in 1983 and was completed by the commissioning of the 4th compressor shop in 1992. Since then, the UGS has been functioning all the time.

In total, 13 UGS facilities (with a total capacity of 31.95 billion m³) are located on the territory of Ukraine. 11 of them were created in depleted gas and gas condensate fields, and 2 (Olyshivske and Chervonopartyzanske) in aquifers. The largest number of and largest capacity UGS facilities are concentrated in the Western part of Ukraine. This location was due to the need for uninterrupted gas supplies from the Soviet Union to European countries. The purpose of UGS facilities in other regions of Ukraine was to supply gas to local consumers and compensate for seasonal (and daily) fluctuations in gas demand. All gas storage in Ukraine is divided into 4 complexes: western; central; eastern; and southern (Table 2).

	The Name of the Complex					
Characteristic	Western Complex	Central Complex	Eastern Complex	Southern Complex		
Place of creation of the complex	The complex was created in the Precarpathian region, in the system of transcontinental, interstate, and intrastate gas pipelines	The complex was created in the Kyiv system of main gas pipelines	The complex was created in the Donetsk gas pipeline system	The complex was created in the Dnieper region and the Autonomous Republic of Crimea		
Purpose of the complex	 reliability of gas supplies for consumers in Western Ukraine, gas export via "Soyuz", Urengoy-Pomary- Uzhhorod, and "Progress" gas pipelines (transit supplies through Slovakia, Hungary, and Romania to European countries) 	Ensure the reliability of gas supplies for consumers in the city of Kyiv, as well as Kyiv, Khmelnytskyi, Vinnytsia, Zhytomyr, Kirovohrad, Cherkasy, Chernihiv, Poltava, Sumy, and Kharkiv regions	Ensure reliable gas supplies for Donbass consumers	 Ensure reliability of: gas supplies to domestic consumers, transit gas supplies (through the southern regions of Ukraine) to Moldova, the countries of the Balkans, and Turkey 		
List of gas storage facilities	 Five gas storage facilities: Bilche-Volytsko—Uherske; Uherske; Oparske; Dashavske; Bohorodchanske 	 Four gas storage facilities: Olyshivske (no injection since 2012); Chervonopartyzanske; Solokhivske; Kehychivske. 	Two gas storage facilities: - Krasnopopivske; - Verhunske (no injection since 2012, is located in the uncontrolled territory of Luhansk region)	 Two gas storage facilities: Proletarske; Hlibovske (located in the occupied territory of the Autonomous Republic of Crimea) 		
Achieved capacity	about 81% the to	11.5% otal amount of active gas in the	2.5% gas storage of the country	5%		

 Table 2. Characteristics of underground gas storage complexes in Ukraine.

Source: developed by the authors based on [33].

UGS facilities in Ukraine perform several important functions for the economy, namely:

- Reliable, uninterrupted, and rational supply of Ukrainian consumers with natural gas;
- Ensuring reliable gas transit through the territory of Ukraine to European countries;
- Creation of long-term gas reserves to equalize seasonal fluctuations in gas consumption and in case of emergencies.

2.2. Current State of Ukraine's UGS

Reforming energy markets towards liberalization is part of the overall policy of the European Union (EU) aimed at creating a single market with clear, understandable, and transparent rules of the game. To achieve these goals, the EU has created an appropriate regulatory framework, combined as part of the Second and Third Energy Packages. The Second Energy Package includes the Directives 2003/55/EU "On the fundamentals of the functioning of the internal market of natural gas" [34], as well as natural gas Regulation 1775/2005 "On conditions for access to the natural gas transmission networks" [35]. The Third Energy Package includes Directive 2009/73/EU, "On the general principles of functioning of the internal natural gas market" [36], and Regulation 715/2009, "On conditions for access to the transmission networks" [37].

Having chosen the European vector of development and trying to integrate into the European energy market, Ukraine has pledged to implement European directives and regulations and is purposefully moving in this direction. A significant step towards integration with the European gas market was the adoption in 2015 of the Law of Ukraine "On the natural gas market" [38]. The basic components of the process of liberalization of the Ukrainian gas market (in accordance with the mentioned directives) were:

- Renunciation of state regulation of producers' selling prices and prices on the wholesale gas market;
- Privatization of state holdings and separation of natural monopoly and potentially competitive activities of energy companies;
- Providing consumers with the right to choose a supplier;

- Stimulating (in various forms) the entry of new participants into potentially competitive market segments;
- Creation of conditions conducive to the expansion of secondary trade in transport capacities and capacities of underground gas storage facilities;
- Achieving market transparency by providing public access to information on supply volumes, demand, availability of transport capacities, tariff structure, etc.

The success of Ukraine's gas market reforms is today confirmed by the international community. According to the conclusions of the EU Energy Community, Ukraine in 2020 demonstrated the most significant progress among the contracting countries in the development of the gas sector [39].

An important stage of market transformation was also the fact that from January 1, 2020, the functions of transporting gas through the territory of Ukraine instead of JSC Ukrtransgaz (a subsidiary of NJSC "Naftogaz of Ukraine") are carried out by a specially created company—LLC Transmission System Operator of Ukraine. Unbundling was implemented according to the ISO model, so the gas transmission system remained the property of the state. A separate ministry, endowed with a certain autonomy, became the body for managing this property—to eliminate unwanted political influence on the management of the GTS [40].

In reforming the market, Ukraine ensured the implementation of the principle of third-party access, which operates in the EU member states. Its main task is to ensure transparent and non-discriminatory access of third parties to the capacities of the GTS. This is a prerequisite for creating a competitive natural gas market, where capacity is distributed among participants according to transparent, non-discriminatory, and market-based rules. To do this, in 2020, the GTS Operator of Ukraine initiated the relevant amendments to the GTS Code on the rules for capacity allocation and introduced the auction distribution of capacities at interstate connections through auctions on certified platforms, in particular, the information system of the GTS Operator of Ukraine.

In addition, in accordance with European requirements and practices, the GTS Operator of Ukraine launched the Transparency Platform [41], where all interested parties can access aggregated information on: physical and commercial gas flows through interstate connection points and UGS facilities; custom capacities; production and consumption of natural gas; imbalances; other performance indicators of the GTS. Thus, access to information has been created for all customers and traders who would like to use the services of the GTS [42].

The adoption by the Verkhovna Rada of Ukraine of amendments [38] on the possibility of GTS Operators, gas distribution networks, and UGS facilities entering the stock exchange was an important and positive step toward the creation of a liquid gas market that meets EU standards.

In 2020, the main provisions for the development of a liquid gas market were laid down—household consumers were allowed to choose a gas supplier, and short-term products were launched at LLC "Ukrainian Energy Exchange".

The Ukrainian Energy Exchange was established in 2010 to organize and conduct exchange trading in energy resources. Today it is the leader of exchange trading in Ukraine and the only centralized platform where the greatest liquidity and trading of all types of energy resources is concentrated. Both small market participants and international companies, large global traders, and state-owned enterprises, in particular Trafigura, MET Group, SOCAR Trading, JKX Oil&Gas, JSC Ukrgasvydobuvannya, JSC Ukrtransnafta, PJSC Centerenergo, the DTEK group of companies, NNEGC Energoatom, PJSC Ukrhydroenergo, NPC Ukrenergo, LLC Naftogaz Trading, and others, take part in exchange trading. In total, there are more than 1100 participants, of which about 300 are in the Natural Gas direction [42]. To bring energy exchange in Ukraine closer to European standards, the Ukrainian Energy Exchange has become a member of all-Ukrainian and European associations: the European Business Association, the "Exchange and Electronic Platforms" Association, and the Association of European Energy Exchanges Europex.

2.3. Naftogaz Group and Its Role in the Ukrainian Gas Market

The structure of Naftogaz Group includes the National Joint Stock Company "Naftogaz of Ukraine", as well as 7 joint stock companies, 9 subsidiaries, 7 representative offices and affiliates that are 100%-owned by the Company, as well as 5 companies whose share capital is 40–100% owned by National Joint Stock Company "Naftogaz of Ukraine". In addition, the National Joint Stock Company "Naftogaz of Ukraine" owns shares in 39 joint stock companies dealing with gas distribution and gasification. It operates in all regions of Ukraine, as well as in the Arab Republic of Egypt. Naftogaz also has representative offices in Turkmenistan and the Kingdom of Belgium [43].

NJSC "Naftogaz" is a vertically integrated group covering the gas business from production to sales. Companies in which Naftogaz owns stakes are major players in the gas and oil market in Ukraine. About 90% of the Group's asset value and sales volumes are accounted for by the gas business. Each line of business is served by separate companies [44]. The business areas of NJSC "Naftogaz" are shown in Figure 1.



Figure 1. Naftogaz's operations are managed by business divisions. Source: [43].

The gas storage operator of Ukraine, JSC Ukrtransgaz, manages the Ukrainian system of underground gas storage. It started working as an independent operator on 1 January 2020, after the completion of one of the largest reforms in the gas industry of Ukraine—the separation of gas transportation activities. Structural changes in the Ukrainian gas market from 1998–2020 are shown in Table 3.

Table 3. Evolution of organizational forms of enterprises in the gas market of Ukraine.

Date	The Company Name	The Essence of Changes	Activities
25 February 1998	National Joint Stock Company "Naftogaz"	Establishment of "Naftogaz"	 full cycle of operations on exploration and development of deposits, production, and exploration drilling; transportation and storage of oil and gas; supply of natural and liquefied gas to consumers

Date	The Company Name	The Essence of Changes	Activities
24 July 1998	Ukrtransgaz subsidiary	Establishment of a subsidiary company "Ukrtransgaz" of NJSC "Naftogaz"	 transportation and storage of oil and gas; supply of natural and liquefied gas to consumers
18 July 2012	PJSC "Ukrtransgaz"	Reorganization of the company by turning into a public joint-stock company	 transportation and storage of oil and gas; supply of natural and liquefied gas to consumers
21 May 2018	JSC "Ukrtransgaz"	Changing the type of company from a public joint stock company to a private joint stock company	 transportation and storage of oil and gas; supply of natural and liquefied gas to consumers
2 November 2018	Branch "Operator of Gas Storages of Ukraine" as a structural unit within JSC "Ukrtransgaz", without separation into a separate legal entity	Separation of gas transportation and storage activities	 natural gas storage; ensuring efficient and uninterrupted operation of UGS facilities in Ukraine
1 January 2020	Gas storage operator JSC "Ukrtransgaz"	Separation of natural gas transportation activities	 natural gas storage; ensuring efficient and uninterrupted operation of UGS facilities in Ukraine

Table 3. Cont.

Source: developed by the authors based on [39].

According to the charter of JSC "Ukrtransgaz" [45], the main types of activity of the gas storage operator of Ukraine include:

- Provision of natural gas storage services, including accounting for natural gas, in particular in the regime of a customs warehouse;
- Management of gas storage facilities;
- ensuring reliable, safe, and efficient operation of gas storage and its long-term capacity;
- Planning commercial activities for the storage of natural gas in gas storage facilities;
 - Elaboration of gas storage development programs;
- Implementation of foreign economic activity and work with clients;
- Ensuring the creation and proper functioning of an open-type customs warehouse and customs control zones at the Company's gas storage facilities;
- Provision of services for customs clearance of natural gas in the customs regime of a customs warehouse.

The gas storage operator of Ukraine provides the following basic services [46]: storage (injection, withdrawal); natural gas transmission administration; customs warehouse, customs warehouse, and short haul. It also provides a number of additional services, incl. monitoring of pledged gas and exchange trading in gas stored in UGS facilities. At the same time, package services are provided (provided for 1 year of storage) and individual services (for 1 month, 1 day ahead).

The organizational structure of the Ukrainian gas storage operator is represented by six production departments of underground gas storage (PDUGS), the Uhersko production department of repair and maintenance services, and other structural divisions (Figure 2).



Figure 2. Structure of the Gas storage operator JSC "Ukrtransgaz" as of 1 January 2022. Source: [32].

The Gas storage operator manages 12 underground gas storage facilities in mainland Ukraine. The Verhunske UGS facility (with a storage capacity of 0.4 billion m³) has been located in the temporarily uncontrolled territory of Ukraine in the Luhansk region since March 2015. The total capacity of all gas storage on mainland Ukraine is 30.95 billion m³ and is the largest in Europe. Ukraine also owned the Hlibovske gas storage facility (with a capacity of about 1 billion m³), operated by Chornomornaftogaz, located in the occupied Crimea (Figure 3).



Figure 3. Characteristics of UGS of Ukraine (capacity in million m³). Source: [46].

The total capacity of exit points to the gas transmission system for gas storage (withdrawal) is 260.1 million m³ per day, and the capacity of entry points (injection) is 252.4 million m³ per day [32]. The capacity of individual gas storage is shown in Figure 4.



Figure 4. Characteristics of the maximum capacity of UGS of Ukraine during gas injection/withdrawal. Source: [32].

The Bilche-Volytske UGS facility is the largest not only in Ukraine but also in Europe and can hold 17 billion m³ of gas, while the total capacity of other fields in Western Ukraine is about 2 billion m³. As for the daily capacity, the Bilche-Volytske UGSF has 18 million m³ more injection than the withdrawal, while Bohorodchanske UGS, on the contrary, has a daily withdrawal that exceeds the injection volume by 24 million m³. In Chervonopartyzanske, Solokhivske, and Kehychivske UGS facilities, the daily withdrawal volume exceeds the injection volume, and vice versa in Krasnopopivske and Verhunske UGS facilities. In other Ukrainian UGS facilities, injection and withdrawal volumes are the same.

As of 1 September 2021, there are 1679 wells in Ukraine, of which 1366 are production and injection production wells (including 134 wells awaiting connection), and 313 are monitoring and special wells (Table 4). All wells are owned by the gas storage operator of Ukraine.

N°	The Name of the UGS	Design Indicator Capacity (Mil	Fund of Production Wells (Units)		
		Total Volume	Active	Project	Fact
1	Uherske	3850	1900	88	88
2	Bilche-Volytsko—Uherske	33,450	17,050	341	341
3	Oparske	4570	1920	76	76
4	Dashavske	5265	2150	100	100
5	Bohorodchanske	3420	2300	156	156
6	Olyshivske	660	310	40	40
7	Chervonopartyzanske	2973.8	1500	67	67
8	Solokhivske	2100	1300	81	81
9	Kehychivske	1300	700	53	53
10	Proletarske	2980.3	1000	100	251
11	Krasnopopivske	800	420	40	40
12	Verhunske	951	400	73	73
	Total	62,320.1	30,950	1215	1366

Table 4. UGS structure by capacity and fund of production wells.

Source: [46].

Most of the Operator's gas storage facilities are located near the western border of Ukraine. The proximity of UGS facilities to the countries of the European Union and the convenience of logistics processes make underground gas storage profitable for both foreign traders and Ukrainian companies providing services related to cross-border gas transportation and storage.

3. SWOT and PESTEL Analysis

3.1. Environment of the Gas Storage Operator of Ukraine

The main task of the Gas Storage Operator of Ukraine is the effective management of underground gas storage facilities, accumulation of gas reserves necessary for the uninterrupted passage of heating seasons, as well as the development of the gas storage business with customers in Ukraine and abroad. Subdivisions of the Business Unit are part of JSC "Ukrtransgaz". The Business Unit manages 12 gas storage facilities located in mainland Ukraine. The portfolio also includes another underground storage facility located in the temporarily occupied territory of the Luhansk Region. The network of UGS facilities is an important element of the Ukrainian energy system. Their steady and uninterrupted operation is necessary for the passing heating seasons, operation of industrial enterprises, and fulfilling obligations towards foreign partners. Europe's largest capacity and gas market reform create considerable opportunities for Ukrainian UGS facilities to attract foreign customers. This approach allows for commercializing available resources and reinforcing the country's energy independence [47].

Transformation processes in the economy of Ukraine and changes in the national strategy aimed at deepening European integration processes require studying the external environment in which business entities operate. The external environment can be divided into several levels:

- Global level;
- Level of macroenvironment;
- Level of microenvironment.

When examining the operating environment of the gas storage operator of Ukraine, it is necessary to identify global factors in the hierarchy of levels of the external environment that will influence the formation of the strategy of the gas storage operator of Ukraine:

- Situation in the global gas market;
- Changes in the natural resource potential of the regions of the world;
- Formation of the global communication and information space;
- Ukraine's access to this space;
- International regulation of relations in the global gas market;
- Development of transnational companies;
- Aggravation of global and geopolitical problems.

Macroenvironment factors are related to the general conditions for the functioning of the national economy. At the same time, microenvironment factors are associated with the immediate environment of the enterprise (suppliers, buyers, competitors, and partners). Figure 5 shows the interaction diagram of the three components of the external environment and the gas storage operator of Ukraine.

Until recently, the style of interaction between UGS facilities in Ukraine and global factors was reactive, but today it is acquiring the character of an analytical style. The same style is the optimal style of their interaction with macro factors since it is characterized by an attempt to adapt the elements of the external environment to their activities to mitigate or enhance their action. As for the micro factors, UGS facilities interact with the subjects of the near environment mainly in a proactive style, which is reflected in the ability to predict and prevent their action or even influence the surrounding economic entities and try to adapt their activities to achieve their goals. The result of a conscious and competent interaction of an enterprise with the external environment is the stability of its functionality and the possibility of future development. At the same time, ignoring or not being able to



take into account the signals coming from the external environment can have a devastating effect on the enterprise and lead to its degradation.

Figure 5. Conceptual scheme of interaction between the components of the external environment and the Gas Storage Operator of Ukraine. Source: improved based on [48,49].

Systematization of theoretical knowledge on the essence and composition of the external environment of enterprises, taking into account the peculiarities of the operation of UGS facilities in Ukraine, made it possible to decompose environmental factors, consider the establishments, organizations, and institutions through which the interaction between the external environment and UGS facilities is carried out, as well as identify the nature of such interaction.

Therefore, the question arises of choosing methods for assessing the influence of factors on the functioning of Ukrainian UGS facilities and the possibilities of using their capacities. In such cases, the tools and capabilities of expert research methods are usually used, using an individual or collective assessment of experts. Among the methods of individual expert assessment, the most common methods in practice are questionnaires, interviews, analytical, and written scripts. Among the collective expert methods, one can single out the Delphi method, matrix methods (PEST, SLEPT, STEEPLE, and SWOT analysis), and methods of collective generation of ideas (brainstorming). In our study, to form scenarios for the use of Ukrainian UGS facilities in the future, in the process of analyzing the UGS environment, we will apply PESTEL and SWOT analysis.

3.2. PESTEL and SWOT-Analysis of the Prospects for the Use of UGS Facilities in Ukraine

One of the common methods for assessing the environment to identify the strengths and weaknesses of an object while simultaneously identifying the opportunities and threats inherent in the external environment is the methodology for conducting a SWOT analysis. The essence of this analysis is the division of factors and phenomena that affect the functioning and development of enterprises into four categories: strengths, weaknesses, opportunities, and threats.

The preparation of a SWOT analysis is preceded by such stages of the strategic management process as an analysis of the internal and external environment. Analysis of the external environment allows one to identify both factors that are external opportunities for the enterprise and factors that can negatively affect it. Analysis of the internal environment is aimed at identifying the strengths and weaknesses of the company's activities, which allows one to place values and make the best development strategy. This method can be used to determine the development prospects for business entities and industries, regions, or countries.

To assess the magnitude of the influence of the external environment on the possibilities of using Ukrainian UGS facilities and form scenarios for their use, we use PESTEL analysis, a matrix analysis method involving the study of components of the environment such as political, economic, socio-cultural, technological, legal, and environmental (natural factors, including geographic ones). PESTEL analysis will start by identifying trends for each component and assessing their potential impact on UGS facilities. The next step will be to predict the consequences of such an impact, allowing us to substantiate strategic hypotheses (scenarios). Based on these scenarios, UGS facilities in Ukraine will be able to build their own development strategies that provide various options for changes in the external environment.

4. PESTEL-Analysis

Let us consider the trends of changes among the components of the external environment and their possible impact on UGS facilities in Ukraine, divided into groups of factors:

- Political;
- Economic;
- Social;
- Technological;
- Environmental;
- Legal.

In each country, a group of political factors has a significant impact on the formation of the stability of the macro-environment of enterprises. Effective political actions and a stable political situation in the country create the appropriate foundation for the calm planning of economic activity. Above all, it allows one to create long-term investment strategies.

The constituent factors of the economic component reflect both the state of the economy as a whole and its individual aspects that affect this type of economic activity. In particular, important factors for UGS facilities in Ukraine are effective regulation of tariff formation for gas storage services, access to investment and credit resources, the level of state funding for programs to modernize UGS facilities, and state support for research and development in the oil and gas industry.

Among a significant number of factors of the social component, of great importance are the educational level of the population, the level of labor and intellectual migration, the level of quality and training of personnel, and personal attitudes to work and leisure. They reflect the social structure and social stratification of the population, as well as the presence of an economically active group of people within it. It is the social component that largely forms informal public institutions, the influence of which is reflected in the formation of common values, the level of education and skills of workers, manifestations of their creativity, etc.

The study of the factors of the technological component has an impact on the search for priority areas for the technical and technological renewal of facilities (in particular, UGS facilities in Ukraine), the intensification of innovation activities, the improvement of the mechanism of institutions for monitoring the quality and safety of services (including natural gas storage), the development of various levels of programs and projects in the scientific and technical industry. The constituent factors of the technological component are the presence in the country and access to advanced technologies, the technical and technological level of partner enterprises, equipment suppliers and other stakeholders, the development of information and communication technologies, the use of energy resources, etc.

Factors of the environmental component are determined by the characteristics of the ecological environment and the natural and geographical conditions of the location of economic facilities. Concerning UGS facilities in Ukraine, such factors are: the state of the environment and environmental safety; climatic conditions for the functioning of UGSF facilities and the complexity of passing routes that directly affect the operation parameters of UGSF facilities and the formation of final costs for natural gas transportation; degree of exploration and development of national oil and gas deposits, geographical location of UGSF facilities by markets and sources of natural gas, which will influence the formation of scenarios for their use.

The factors of the legal component include transparency and stability of the national energy legislation, the level of adaptation of the regulatory and legal framework to European integration energy processes, legal support for standardization and certification of natural gas storage services, protection of intellectual property, transparency, and the possibility of obtaining licenses to carry out activities. The presence of legal institutions that are legally enshrined in laws, decrees, regulations, clarifications, nationwide concepts, and development strategies and their effective interaction and mutual agreement is a necessary condition for improving the efficiency of the function and development of UGS facilities and their successful European integration. These institutions are also mechanisms for controlling the quality and safety of natural gas storage services and eliminating shortcomings in their functioning as a subject of natural monopolies.

Let us consider in more detail the main environmental factors (in the context of individual components) and the nature of their interaction with UGS facilities in Ukraine (Table 5).

External Environment Component	Factors Reflecting the Components of the External Environment for Underground Storage Facilities	Institutes, Organizations, and Institutions through Which Influence Occurs	Consequences for UGS Facilities
Political	 political stability; political climate; euro focus on UGS customers 	Verkhovna Rada of Ukraine, Cabinet of Ministers, President of Ukraine, political forces and confidence in them; authorities at different levels of government. International organizations, world legislation, transnational companies, and multinational corporations.	 unstable political situation in the country, lack of a consolidated position of the authorities on the strategy of reconstruction and modernization of the GTS. Reorientation of part of gas flows from the Russian Federation to the countries of the Asia-Pacific region, which reduces the demand for GTS services (including UGS facilities). The intensified efforts of European countries to diversify sources and routes of gas supplies to domestic markets, as well as their rejection of Russian gas (sanctions due to the war), reduce gas transit through Ukraine and its storage in underground storage facilities.

Table 5. Main environmental factors and the nature of their interaction with UGS facilities in Ukraine.

Table 5. Cont.

External Environment Component	Factors Reflecting the Components of the External Environment for Underground Storage Facilities	Institutes, Organizations, and Institutions through Which Influence Occurs	Consequences for UGS Facilities
Economic	 changes in natural gas prices; support for innovation processes and government policy; credit, tax, protectionist and depreciation policy; capacity of commodity markets; exactingness of consumers; state of banking and insurance services; availability of commercial funds, trade organizations. 	National Bank, State Fiscal Service, Antimonopoly Committee, State Audit Service, Ministry of Fuel and Energy, NJSC "Naftogaz", National Commission for State Regulation of Energy and Public Utilities (NEURC), Oil and gas companies, gas distribution enterprises, infrastructure enterprises, industrial enterprises, stock exchanges, banks, financial and credit intermediaries, commercial funds, insurance agencies, employment services, trade, and other organizations.	 monopolization of gas supply, lack of competition in the gas market, dependence on one supplier of natural gas, slowdown in the development and operation of domestic oil and gas fields; creation of new pipeline gas transportation routes bypassing the territory of Ukraine; increased demand for natural gas storage services due to higher natural gas prices and the energy crisis; high inflation rate, low level of information communications, unsatisfactory state of banking and insurance services, insufficiency of intermediary, financial, insurance, and advisory organizations.
Social	 cultural level of society development; formation of consumer protection groups; compliance with the ethics of cooperation with partners; focus on strategic partners; educational level; age structure; income level of the population; unemployment; labor and intellectual migration. 	Public organizations, international partners, relations with the population, national traditions, cultural and educational institutions; communication networks; information and library network. Research institutes, higher education institutions, postgraduate education, international specialists and organizations in the oil and gas industry, trade unions, employment services, etc.	 lack of ethics of cooperation, especially with Eastern partners, unfair struggle in the gas market, low level of technical awareness of the population, which hinders the change in the structure of personnel in accordance with the achievements of scientific and technical progress. sufficient educational and professional qualification level of oil and gas specialists, providing postgraduate education, development of distance learning, low level of international exchange of experience and information, the need for professional development, passivity of trade unions and various associations.
Technological	 Availability and access to advanced technologies; modern systems and methods of management and organization of the production process; technical and technological level of domestic engineering and pipe plants; technical level of information communications. 	Research institutes, higher educational institutions, international specialists and organizations in the oil and gas industry, organizations, enterprises, and institutions that ensure the functioning of oil and gas transportation enterprises.	 limited access and investment opportunities for the implementation of advanced technologies; presence in Ukraine of its capacities for the production of gas pumping units, pipes, and other oil and gas equipment; creation of new technologies for the transportation of liquefied gas.

External Environment Component	Factors Reflecting the Components of the External Environment for Underground Storage Facilities	Institutes, Organizations, and Institutions through Which Influence Occurs	Consequences for UGS Facilities
Environmental	 spatial conditions; geographical location in relation to sales markets; geographic location in relation to sources of natural gas; availability of water supply; the difficulty of passing the routes; climatic conditions. 	Environment components; population.	 restriction of certain areas of development through possible damage to the environment; loss over time of the necessary useful properties of UGS facilities, in particular, due to damage to the insulation of pipelines; impact on gas transportation and storage parameters; advantageous geographical location of the gas pipeline system and gas storage facilities.
Legal	 patenting of inventions; State control over the quality and safety of the provision of gas storage services; regulation of pricing for gas storage services; licensing of activities. 	National Bank, State Fiscal Service, Antimonopoly Committee, State Audit Service, Ministry of Fuel and Energy, NJSC "Naftogaz", NEURC, and other central authorities involved in the operation of the Ukrainian gas sector. Laws, regulations, orders, programs, strategies, and projects.	 low level of support for innovation processes and modernization of UGS facilities; ill-conceived tax, depreciation, and credit policy; contradictions in the legislation; low level of support for the interests of the domestic UGS system in the international market; elimination of monopolists, in particular, restructuring of NJSC "Naftogaz"; creation of an independent regulator in the gas market.

Table 5. Cont.

The current situation in Ukraine and Europe testifies to a deep energy crisis, inability to ensure energy security, high dependence on the monopoly gas supplier (Russia), and lack of sufficient gas reserves in underground gas storage facilities (to ensure the alignment of seasonal fluctuations in gas consumption and prevent the consequences of a crisis that has arisen). The environmental factors that formed the crisis in the European energy market emphasized the competitiveness of Ukrainian UGS facilities and the need to use their capacities to maintain Europe's energy security.

5. SWOT Analysis of Ukraine's Competitive Position in the Field of Natural Gas Storage

Conducting a SWOT analysis includes such steps as assessing the factors of the internal environment and identifying and analyzing external opportunities and threats.

5.1. Strengths

UGS facilities in Ukraine create significant strategic opportunities for gas storage not only for the whole of Europe but for the whole world. They are the largest on the European continent and the third largest in the world, and in recent years have become a significant element of the EU energy balance. The active capacity of Ukrainian UGS facilities is approximately 20% of the total capacity of gas storage facilities in European countries. The total capacity of all gas storage on mainland Ukraine is 30.95 billion m³ and is the largest in this part of the world. Ukraine has the biggest working storage capacity in Europe and amounts to a third of the combined storage capacity of the EU28 [50]. Ukrainian gas storage facilities are the third largest in the world, after the US and Russia [51].

As of September 1, 2021, the total active capacity of UGS facilities in European countries was about 138 billion m³, of which 30.95 billion m³ (i.e., 22.43%) was in Ukraine (Table 6).

More than 71% of all gas storage capacities are concentrated in six European countries— Ukraine, Germany, Italy, the Netherlands, France, and Austria. The latest GlobalData report "Underground Gas Storage Industry Outlook in Europe, North America, and Former Soviet Union (FSU) to 2025—Capacity and Capital Expenditure Outlook with Details of All Operating and Planned Storage Sites" shows that as of September 2021, 151 underground gas storage facilities were operating in Europe [52].

\mathbf{N}°	Country	Storage Volume, Million m ³	The Share of Gas Storage Facilities in UGS in Europe,%
1	Ukraine	30,950	22.43
2	Germany	21,881	15.86
3	Italy	18,904	13.70
4	Netherlands	13,748	9.96
5	France	12,640	9.16
6	Austria	9128	6.62
7	Hungary	6657	4.82
8	Slovakia	4068	2.95
9	Czech Republic	3441	2.49
10	Poland	3421	2.48
11	Spain	3274	2.37
12	Romania	3150	2.28
13	Latvia	2310	1.67
14	Great Britain	1115	0.81
15	Denmark	1000	0.72
16	Belgium	861	0.62
17	Bulgaria	599	0.43
18	Croatia	499	0.36
19	Portugal	341	0.25
	Total	137,987	100.00

Table 6. Capacities of underground gas storage of European countries as of 1 September 2021.

Source: [52].

An additional strength of Ukrainian UGS facilities is their territorial location—about 80% of them are located near the western border of Ukraine. It is the significant active volume of UGS facilities in the Western region of Ukraine (located closest to other European countries), a wide range of possibilities for extracting natural gas from UGS facilities (providing extraordinary flexibility in gas flows), optimization of operating modes, and convenience of logistics processes that create a fairly profitable infrastructure for the use of Ukrainian underground storage facilities not only for storing operational and strategic gas reserves but also for its uninterrupted supply to European countries.

As of mid-January 2022, the number of customers using the services of Ukrainian UGS facilities was 1003, incl. 111 foreign companies from 27 countries located on three continents—Europe, North America, and Asia. Among them are companies from the Czech Republic, Switzerland, USA, Canada, United Arab Emirates, Hong Kong, and Singapore. The Gas storage operator provides gas storage services to both suppliers of this energy resource and its consumers. Daily operational information on the operation of gas storage facilities in Ukraine can be found on the transparency platform [53], launched in 2015. Since 2014, similar data has also been published on the European Transparency Platform AGSI+ [54]. Ukraine was the first country outside the EU to join the AGSI+ transparent data display system according to the standards of the Association of European Underground Gas Storage Operators (GSE) [55].

Until June 2019, the gas storage operator of Ukraine created its own IT environment and a unified database (of process parameters), as well as set up its own dispatching system. Operational dispatching of UGS operation is currently carried out from Lviv, not far from several major storage facilities, where a central control room has been set up. In August 2019, an information platform was launched to interact with UGS customers, significantly increasing its efficiency. We are constantly working on expanding the functionality of the platform. To account for gas transferred between two operators, counting equipment installed at connection points is used. To improve the accuracy of gas metering, by 2023, equipping new metering units is planned [55].

In November 2020, the gas storage operator of Ukraine introduced a new service that allowed banks to track transactions with natural gas in UGS facilities. Clients use this gas as collateral for loans [56]. Since 21 May 2020, Ukrtransgaz customers have had the opportunity to submit separate nominations and renominations [57] for volumes of natural gas submitted for injection and/or withdrawal to/from gas storage facilities using the short-haul service. The essence of the short-haul service is to issue trade notices identifying that the natural gas to be transferred has been supplied to the exit point in the gas storage or group of gas storage facilities under the terms of capacity use with restrictions. The new service is most in demand by Ukrainian and foreign gas traders who use Ukrainian UGS facilities for seasonal gas storage [58]. Currently, Ukrtransgaz is implementing a program to prepare for the transition to gas accounting in energy units, scheduled for 1 May 2022. The advantages of gas storage facilities in Ukraine include competitive tariffs for the storage of natural gas, as shown in Table 7 (as of 1 October 2021).

Table 7. Comparison of gas storage tariffs in Ukraine and nearby EU countries.

Directions	Tariff for Short-Haul Transportation and Storage in the "Customs Warehouse" Mode (EUR/MWh)			Country	Storage Tariff (EUR/MWh)	
-	Annual Lunar The Day before					
Ukraine—Poland Poland—Ukraine	1.55	1.64	1.70	Poland	3.2–3.7	
Ukraine—Hungary Hungary—Ukraine	1.52	1.60	1.66	Hungary	2.5	
Ukraine—Slovakia Slovakia—Ukraine	1.47	1.55	1.61	Slovakia	2.2–2.9	
Ukraine—Romania Romania—Ukraine	1.47	1.56	1.62	Romania	2.64	
	C [[]]					

Source: [53].

The proximity of Ukrainian UGS facilities to the border with the EU, favorable conditions, and competitive tariffs for storage and transportation of gas are several convincing arguments for gas traders from all over the world to choose these UGS facilities for storing their own natural gas reserves. This possibility is especially relevant during the period of instability in the gas market, which we are now witnessing in connection with Russia's attack on Ukraine. These strengths form the strategic attractiveness and importance of Ukraine's UGS facilities against the backdrop of growing demand for underground gas storage services.

5.2. Weaknesses

Weaknesses include the service life of UGS facilities and their associated technical condition, technological capabilities, and wear and tear of fixed assets. In general, the majority of gas compressor units (GCUs) in UGS facilities were put into operation in the 1970s and 1980s. Although the overall percentage of technical wear and tear is low (due to the short period of use of the main production equipment during the year), 102 gas compressor units (79.7% of their total number) have already been in operation for more than 30 years. More than 53% of gas compressor units have a service life of 31 to 40 years (68 out of 128). Most of them work at booster compressor stations (BCS) Dashava, BCS Opary-1, CS Kechyhivka, CS Solokha, and in some compressor shops (CC) CS Bohorodchany, CS Mryn, BCS Bilche-Volytsia. There is also a significant number of GPUs (34 in total) operated for more than 40 years, most of them installed at BCS Uhersko, CS Mryn, CS Olyshivka, and CS Krasnopopivka [32] (Figure 6).



Figure 6. The structure of the fleet of gas-pumping units of the storage system according to the service life by the production departments of the UGS facilities. Source: [32].

The transparent display of information on UGS facilities in Ukraine (using the AGSI+ data display system according to the standards of the Association of European Underground Gas Storage Operators (GSE)) is an important component of Europe's energy security. However, the full-scale entry of Ukrainian UGS facilities into the European gas market requires introducing digitalized information technologies. In particular, this concerns the processes of managing the client base of potential consumers of UGS services (both Ukrainian and foreign), the number of which is constantly growing. For example, in the 2020/2021 gas withdrawal season, the number of customers increased from 802 (as of 10 October 2020) to 901 (as of 30 April 2021). Over the past three years, from January 2019 to January 2022, the portfolio of customers of Ukrtransgaz services has more than doubled to 1003. And the number of non-resident companies in it has grown 8 times [59].

The enterprises of the gas transmission system (gas transmission, gas distribution, and gas storage), due to the specifics of their operation, are also monopolized in the state form of ownership. This complicates the development of strategic mechanisms for managing them [60]. In addition, the unpredictability of the state policy of Ukraine—in the field of gas storage and the formation of tariffs for the services of gas storing enterprises—complicates the work with potential customers. The problem is also the lack of investment attractiveness of the enterprise since UGS facilities are state-owned, and little funds are allocated from the budget for the renewal of fixed assets, which could increase the efficiency of these enterprises.

5.3. Opportunities

As already mentioned, most Ukrainian UGS facilities were created on the site of depleted fields. However, two of them—Chervonopartyzanske and Olyshivske—are based on aquifers [61]. Although each Ukrainian gas storage is located at a distance of 3–3.5 thousand km from the main areas of natural gas production, they are all interconnected through a system of gas pipelines, creating favorable conditions for the redistribution of gas flows and meeting the needs of local and remote consumers. The Ukrainian GTS is also closely connected with the gas pipeline systems of neighboring European countries—Russia, Belarus, Poland, Slovakia, Hungary, Romania, and Moldova. Thus, it is integrated with the European gas network and is also a bridge between the gas-producing regions in Russia and Central Asia and consumers in Europe [53]. In 2015, Ukraine proposed to Poland and Hungary that they use this powerful gas transmission hub, as well as the UGS

facilities located next to it, as the basis of the Eastern European gas hub. On 19 January 2015, NJSC Naftogaz and the Polish Gaz-System SA signed an agreement to construct an interconnector. On 29 May 2015, JSC Ukrtransgaz (gas storage operator of Ukraine) and the Hungarian operator FGSZ signed an agreement to unite the cross-border gas pipelines of the two countries. Moreover, in March 2020, the United States announced that it was ready to create a hub for its liquefied gas in Ukraine, but with the spread of COVID-19, this idea was put on hold. Unfortunately, the war further pushed these plans into the future.

According to the estimates of leading Ukrainian non-governmental organizations and government agencies, with the support of European structures and experts, the energy balance of Europe will undergo significant changes by 2028. Renewable energy sources (including biogas, biomethane, hydrogen, and other "environmental gases") and natural gas will significantly strengthen their positions. In Ukraine, the share of natural gas, according to the Energy Strategy of Ukraine until 2035, will not undergo significant changes, but the share of nuclear energy and renewable energy sources will increase significantly [62].

Ukraine does not use all the capacities of its UGS facilities. From 2013–2018, Ukraine had about 15 billion m³ of free capacity it could offer European consumers (Figure 7).





In 2019, the maximum gas injection volume increased to 21.8 billion m³, i.e., free capacity was 10 billion m³. The record year was 2020, when the highest level in the last 10 years in terms of injection volumes (28.3 billion m³) was reached. And a third of these stocks were created by foreign customers, most of whom were from EU countries [63]. This fact is convincing evidence that the most important elements of Ukraine's gas energy infrastructure are being successfully integrated into the energy space of the European Union. In addition, the gas storage operator of Ukraine is recognized as a reliable business partner in Europe, and Ukraine as a whole has significantly strengthened its position in its gas market.

In 2020, the gas storage operator and the GTS operator offered their customers a new service—storage of natural gas in the "Customs warehouse" mode and transportation of gas from entry/exit points to/from the GTS at interstate connections of UGS facilities at a reduced short-haul tariff. This provides special tariffs for transit transportation services,

that is, for capacities with limited access to the Ukrainian VTP (the virtual trading point where natural gas is transferred) and the domestic market. Accordingly, in 2020, Ukrainian gas storage facilities received 6.1 billion m³ of gas in the short-haul mode. The "Customs warehouse" service provides traders with the opportunity to store natural gas in 10 underground gas storage facilities in Ukraine for 1095 days without paying taxes and customs duties, subject to further transportation of natural gas from the territory of Ukraine or placing it in another customs regime. This service was introduced to the market back in 2017. In 2019, the customers of this service placed more than 8.1 billion m³ of natural gas in the customs warehouse regime (more than 30% of the total volume of gas storage), of which natural gas of residents (10 customers) amounted to 6.1 billion m³ (65%), and non-residents (19 customers)—2.0 billion m³ (35%) (Figure 8) [63].



Figure 8. Dynamics of the provision of the "Customs warehouse" service in 2017–2019. Source: [54] (p. 93).

In 2021, the injection of natural gas into UGS facilities in Ukraine amounted to 3.59 billion m³ (in 2020—16.8 billion m³), and withdrawal—13.62 billion m³ (in 2020—7.4 billion m³). Thus, in 2021, the total gas withdrawal from storage facilities exceeded its injection by 10.03 billion m³, while in 2020, injection exceeded the withdrawal by 9.4 billion m³. In the 2020/2021 withdrawal season, gas reserves in Ukrainian UGS facilities were unusually high compared to the previous decade, thanks in large part to foreign customers of services who actively used gas storage facilities to store their own reserves [64]. By the beginning of the 2021–2022 heating season, 19 billion m³ of gas had been accumulated in Ukrainian UGS facilities. The Gas storage operator of Ukraine entered 2022 with gas reserves in UGS facilities at the level of 13.5 billion m³ [65].

The potential of Ukrainian UGS facilities is much higher, as is the role of Ukraine in the European energy space. This is not only about the rational and efficient use of existing natural gas storage capacities but also reasonable prerequisites for expanding the UGS network in Ukraine and increasing the total active volume of storage facilities at the expense of depleted gas fields.

5.4. Threats

There are several threats to companies providing natural gas storage services. The most important of these is the significant influence of the political and regulatory environment, by which we mean laws, government institutions, and pressure groups that put pressure on and restrict the activities of enterprises. Another type of restriction on business activities is licensing, since some of the activities of the gas storage operator JSC "Ukrtransgaz"

are subject to state licensing. JSC "Ukrtransgaz" carries out its activities in the field of underground gas storage based on:

- 5 licenses of the National Commission of Ukraine (carrying out state regulation of energy and public utilities),
- 11 special permits of the State Service of Geology and Subsoil of Ukraine,
- 4 other permits.

These licenses and permits cover and regulate the activities of the gas storage operator and meet the requirements of the energy legislation of the European Union. At the same time, certain features require the continuation of work on harmonizing the energy legislation of Ukraine and the EU.

A characteristic feature of Ukraine is imperfect legislation, which also creates additional threats to the activities of market entities for underground gas storage services. After all, each enterprise must determine the permissible boundaries of economic activity, the boundaries of relationships with other entities, and methods for defending their interests.

In addition, the imperfection of the gas market and the incompleteness of structural reforms in the energy sector of Ukraine complicate their cooperation with European gas giants and pose a threat to the effective functioning of both UGS facilities and the GTS of Ukraine in the long term. At the same time, such threats are not critical and can be leveled quite easily by further improvement of the energy legislation of Ukraine. The need to create and operate a transparent gas market requires further reform of NJSC Naftogaz and its subsidiaries by turning them into a modern corporate business structure with a high level and quality of management.

The economic crisis, high inflation, rising unemployment, high-interest rates on loans in recent months, and now also the war (the worst that could befall the country and its inhabitants) have all negatively affected and will continue to affect the activities of underground gas storage companies in Ukraine.

The technological environment, which requires a separate systematic study in terms of limitations, trends, and opportunities for a particular enterprise, is of particular importance. Currently, Ukrainian gas storage facilities mainly use traditional technologies, which are quite reliable, but looking ahead, it is necessary to work now on the modernization of the gas industry in Ukraine.

During all 30 years of Ukraine's independence, the government of the Russian Federation has used natural gas as an instrument of political blackmail and diktat. The GTS of Ukraine has been developing technological and economic interconnection with the GTS of Russia and European countries for a long time, serving as a means of intercontinental natural gas transit from its production areas (located mainly in Western Siberia of the Russian Federation) to end consumers in Europe. The gas crises of 2004–2005, 2009–2010, and 2021–2022 have become clear evidence of the use by the Russian Federation of its monopoly position in the European gas market for political pressure and blackmail. At the same time, Ukraine's underground gas storage system also experienced a negative impact, as the reduction in the volume of Russian gas transit through the Ukrainian GTS reduced the level of workload and the use of Ukrainian UGS capacities to regulate seasonal fluctuations in gas consumption in European countries. Today, however, the biggest threat has been Russia's invasion of Ukraine, the destruction of its infrastructure, and massacres of civilians. Concerning UGS facilities, this is fraught with a loss of control over gas storage facilities located in war zones.

However, the main gas storage facilities are located in the western part of the country and are under the control of Ukraine. On the other hand, the need has become clear for:

- Refusal of European countries from the monopoly supply of natural gas from the Russian Federation;
- Diversification of sources of supply;
- Formation of large reserves of natural gas and its storage in UGS facilities.

An analysis of the development of the military conflict, and in fact, a full-scale war between Ukraine and the Russian Federation in the period from February to August 2022, testifies to the ability of Ukraine to defend its independence, and the aid of the countries of the European Union, the United States, and the United Kingdom allows us to draw an encouraging conclusion about a fairly quick end to hostilities, preservation of Ukraine's independence, and rapid integration into the European community. Under these conditions, the use of the potential of Ukrainian UGS facilities to ensure the reliable functioning of the European gas market becomes especially attractive and promising.

5.5. SWOT Conclusions

Summing up the analysis, Table 8 shows an extended SWOT matrix for underground gas storage facilities in Ukraine and, consequently, for Ukrainian companies engaged in underground gas storage in the context of identifying Ukraine's competitive position in the European gas market.

As seen from the above SWOT analysis, Ukrainian UGS facilities have several competitive advantages, which can be used to win in foreign markets. These include:

- Geographic location;
- Well-developed transport communications;
- Technical characteristics (a wide range of options for natural gas withdrawal from underground storage facilities, providing extraordinary flexibility of gas flows, optimization of operating modes, provision, and maintenance of reverse flows);
- Favorable conditions and competitive tariffs, data transparency.

Table 8. Matrix of SWOT analysis of the prospects for using UGS facilities in Ukraine.

	Strengths		Weaknesses
1.	The most powerful network of underground gas storage facilities in Europe, the volume of which is about 20% of the capacity of all UGS facilities in the EU countries.		
2.	The largest storage facilities are located near the western border of Ukraine, at the intersection of key gas pipelines connecting the GTS of Ukraine, Belarus, Poland, Slovakia, Hungary and Romania	1. 2.	Low innovation activity, focus mainly on the use of traditional technologies. A significant age of operation of UGS facilities and a high
3.	A positive business reputation among customers and a fairly high efficiency in promoting underground gas storage services and other related services to foreign markets (especially in the last 2–3 years).	3.	degree of depreciation of fixed assets, as well as the unsatisfactory technical condition and limited technological capabilities associated with these factors. Lack of working capital, hindering investment.
4.	Provision of gas storage services in UGS facilities to both suppliers and consumers of gas.	4. 5.	Low profitability of underground gas storage companies. Insufficient investment attractiveness of UGS facilities for commercial investments since UGS facilities are
5.	Data transparency and daily information about gas storage services on the European transparency platform ACSI+	6.	state-owned and are not subject to alienation. Sufficiently low activity of expanding the client base of
6.	Favorable conditions and competitive tariffs for storage, injection withdrawal and gas transportation	_	consumers of services provided by UGS facilities in Ukraine.
7.	Unique technical characteristics of gas storage facilities:	7.	Insufficient number of qualified personnel, specialists, and workers in the industry for the use and implementation of
	 a wide range of natural gas extraction options from UGS facilities, providing extraordinary gas flow flexibility, optimization of operating modes, provision, and maintenance of reverse flows. 	8.	digital technologies. Instability of state policy in the field of gas storage.
8.	High degree of compliance with contractual obligations.		

Table 8. Cont.

	Opportunities		Threats
1. 2.	High market potential for natural gas storage services for customers from Europe and other parts of the world. The high potential of existing storage facilities and significant opportunities to create the necessary operational and strategic gas reserves at the expense of	1.	The war launched by the Russian Federation against Ukraine destroyed the opportunities for the rapid development of the gas industry in Ukraine. Moreover, there is a threat of loss of control over UGS facilities and
3.	spare capacities. Attractive prospects for expanding the UGS network in Ukraine and increasing the total active volume of storage facilities by creating new UGS facilities based on depleted gas fields.	2. 3.	the impossibility of their intended use. The difficult political situation in the country and the frequently changing imperfect legislation do not contribute to long-term planning and investment. Socio-economic instability, which does not contribute to
4. 5. 6.	Improving approaches to forming tariffs for services for the injection, storage, and withdrawal of natural gas. Development of new services based on UGS. Compensation for seasonal fluctuations in gas consumption, since the nature of gas demand is seasonal	4. 5.	the development of both the country's economy as a whole and its sectors. High inflation, which creates difficulties for investments, since it is unrealistic to calculate their profitability. Absence or insufficiency of government measures to
7.	and cyclical. Availability of a program to improve the quality of service delivery through the digitalization of management, business, and production processes.	6. 7.	develop the gas transportation industry and the underground gas storage system. Imperfection of the gas market. Incompleteness of general structural reforms in the energy
8.	Attracting foreign investors on the terms of expanding access to active UGS facilities.	8.	sector of Ukraine. The use of natural gas by the Russian Federation as an
9.	Creation of an Eastern European gas hub based on UGS facilities in the Western region of Ukraine.	9.	instrument of political blackmail and diktat. Development of alternative energy, which, on the one
10.	Construction of terminals for LNG (e.g., in Odessa), with subsequent injection of gas into the GTS and UGS facilities.		hand, is beneficial for the environment (less impact on climate change and global warming), and on the other hand is competitive with fossil energy sources (including
11.	Possibility of adapting the GTS infrastructure to LNG transportation and storage; however, a gas port needs to be built.	10.	natural gas). The development of LNG reduces the share of capacity utilization of the GTS built for traditional gas
12.	Use of UGS facilities for storage of other substances (e.g., hydrogen and carbon dioxide).		transportation methods.

At the same time, the greatest advantages are the high capacity potential of UGS facilities in Ukraine and the high degree of compliance with contractual obligations for end users. However, most gas storages experience problems associated with the long service life of their production facilities. To ensure the competitiveness of Ukrainian UGS facilities, considerable attention should be paid to the construction, reconstruction, technical re-equipment, and overhaul of production facilities to ensure long-term performance. In addition, an insufficient number of qualified workers in the field of using the latest digital technologies leads certain consumers to be dissatisfied with the quality of service provision.

Clearly, political factors and the presence of monopolists in the market cannot be ignored, as evidenced by the events in the European natural gas market in the summer and autumn of 2021, as well as in March 2022. The events were accompanied by an astronomical increase in gas prices in spot markets and clearly demonstrated the vulnerabilities of the European energy security system (Figure 9).

However, the shortcomings mentioned can be overcome and threats prevented. Ukraine has all the possibilities to do this. The gas storage operator of Ukraine has the opportunity to expand its activities (due to the high potential of the European sales market), but for this, it is necessary to use strengths and eliminate weaknesses, as well as closely monitor changes in the external environment.



Figure 9. Dutch TTF European natural gas price dynamics in 2021–2022 (EUR/MWh). Source: [66].

6. The Role of UGS Facilities in Ensuring Energy Security in Europe

The growth of the role of Ukrainian UGS facilities in the European gas market significantly depends not only on the demand for gas storage services from foreign companies but also on the awareness at the state level of the importance of collective energy security manifested in energy policy regulations. An important role in this aspect is played by the problem of forming a single European energy space and its reliable and efficient function. At the same time, one should consider not only the availability and volume of storage facilities in different countries but also other infrastructure parameters, in particular their connection to existing gas pipelines, the development of pipeline networks, and their performance. All this ultimately creates opportunities for the rational use of storage capacities from the standpoint of national, regional, and European energy security.

To determine the role played by Ukrainian UGS facilities, we analyzed the available storage volumes in various European countries and domestic gas consumption in 2019 and 2020. We also assessed the level of UGS facilities supplying the internal needs of individual European countries (Table 9).

Country	Storage Volume, Billion m ³ -	Volume of Natural Gas Consumption, Billion m ³		Ratio of UGS Capacity for Domestic Needs	
		2019	2020	2019	2020
Ukraine	30.950	28.3	29.3	1.094	1.056
Germany	21.881	88.7	86.5	0.247	0.253
Italy	18.904	70.8	67.7	0.267	0.279
France	12.640	43.7	40.7	0.289	0.311
Netherlands	13.748	37.0	36.6	0.372	0.376
Austria	9.128	8.9	8.5	1.026	1.074
Hungary	6.657	9.8	10.2	0.679	0.653
Czech Republic	3.441	8.3	8.5	0.415	0.405
Poland	3.421	20.9	21.6	0.164	0.158
Spain	3.274	36.0	32.4	0.091	0.101

 Table 9. Provision of underground storage facilities to the domestic needs of individual European countries.

Country	Storage Volume, Billion m ³	Volume of Natural Gas Consumption, Billion m ³		Ratio of UGS Capacity for Domestic Needs	
		2019	2020	2019	2020
Romania	3.150	10.7	11.3	0.294	0.279
Great Britain	1.115	77.3	72.5	0.014	0.015
Belgium	0.861	17.4	17.0	0.049	0.051
Portugal	0.341	6.1	6.0	0.056	0.057

Table 9. Cont.

Source: compiled by the authors according to [61,67].

Based on the data (Table 9), we calculated the ratio of UGS capacities to meet gas consumption needs as the ratio of natural gas consumption to the active volume of gas storage facilities. We divided the results into five groups, characterizing the level of provision of each country with these capacities from the standpoint of internal energy security (Table 10).

Table 10. Levels of supply of countries with underground gas storage facilities.

Ratio Limits	≤ 20%	21–30%	31–40%	41–50%	>50%
The level of the ratio	critically low level	low level	average level	high level	ultra-high level
Country	Poland Spain Great Britain	Germany Italy Romania	Netherlands France	Czech Republic	Ukraine Austria Hungary

The level of supply of UGS capacities for domestic needs is an important component of the country's energy security. If UGS capacities are less than 20% of the annual volume of gas consumption, then this level is considered critically low. The availability of UGS facilities at the level of 21–30% of annual consumption corresponds to a low level, 31–40% to an average level, 41–50% to a high level, and more than 50% to an ultra-high level. Next, we ranked the European countries (from Table 9) according to the level of provision of domestic needs with underground gas storage facilities.

The results obtained allow for a more reasonable approach to creating strategies for improving the energy security of both individual European countries and the region. This approach contributes to the rationalization and optimization of the tasks of developing the network of underground gas storage facilities and allows minimizing the total costs of developing the UGS network from the standpoint of European energy security. Of course, this should take into account the peculiarities of the economic development of individual countries, the structure of gas consumption, the presence of industries with high gas consumption, and the possibility of alternative use of energy resources, including the replacement of natural gas with other energy resources, climatic conditions, environmental factors, the availability of pipeline infrastructure for cross-border movement of gas streams, etc.

7. Formation of Scenarios for the Use of UGS Facilities in Ukraine

Ukraine (according to the Association Agreement between Ukraine and the European Union [68]) is actively implementing measures aimed at further integration with the European energy market, in particular, the gas market. Therefore, when planning the development of the Ukrainian gas storage system, it is necessary to take into account the prospects for the consumption of energy resources in the EU countries. According to experts, the forecast energy balance of Europe and Ukraine in 2028 will have the following structure (Figures 10 and 11).



Figure 10. Forecast of energy balance in 2028 (Europe). Source: [55].



Figure 11. Forecast of energy balance in 2028 (Ukraine). Source: [55].

As we can see, both in Ukraine and in European countries, natural gas will continue to play a dominant role in the coming years (although the development of alternative energy sources will weaken its market position). Although forecasts up to 2050 may include a decrease in the share of gas in the global consumption of primary energy sources, they will remain significant in the future [69–71]. In this regard, it is important to forecast the production and consumption of this energy resource in the coming decades.

Based on the studies, we will consider three scenarios for using UGS facilities in Ukraine: pessimistic; realistic; optimistic (Figures 12–14).

Pessimistic scenario

Ukraine has not rebuilt its infrastructure due to a protracted war.

Dependence on natural gas in Europe is decreasing.

In Europe, renewable energy production is growing moderately.

The decline in demand from enterprises as a result of the economic and energy crisis, which are the result of two years of the pandemic and the aggression of the Russian Federation against Ukraine (including sanctions imposed on the exchange with the aggressor country).

The energy crisis continues because the energy infrastructure and supply chains of energy resources cannot be changed quickly.

The demand for natural gas in households is decreasing due to its high price.

Europe depends on the monopoly supply of natural gas. Gas reserves are not formed in sufficient quantity.

Gas production volumes are declining.

Figure 12. Pessimistic scenario.

Realistic scenario

Ukraine has not fully rebuilt its infrastructure, which was damaged during the war, but the GTS facilities are working normally.

Europe's dependence on natural gas remains high.

The volume of energy obtained from alternative sources is constantly growing, both in Ukraine and in Europe.

European countries are reducing gas consumption due to the introduction of energysaving technologies.

Industrial gas consumption is decreasing (both in Ukraine and in Europe) as a result of the economic and energy crisis

Demand for natural gas by households is declining due to sharp fluctuations in prices. Europe has abandoned the monopoly (Russian) gas supply.

Natural gas reserves have been formed in sufficient quantities.

Gas production volumes remain at the same level.

The UGS system of Ukraine is integrated with the European gas market, which simplifies gas storage procedures (as well as its injection and withdrawal) for customers from European countries.

Figure 13. Realistic scenario.

European energy companies take limited interest in gas storage services provided by Gas storage operator JSC «Ukrtransgaz»

European energy companies take high interest in natural gas storage services provided by Gas storage operator JSC «Ukrtransgaz» Ukraine has rebuilt its infrastructure, GTS facilities are operating at full capacity.

European countries still need large volumes of natural gas.

European countries are building new terminals for receiving and regasification of liquefied gas.

Energy companies from other parts of the world are interested in storing natural gas in Ukraine.

Ukraine is building its own LNG terminal, which simplifies the use of the Ukrainian GTS for the storage of liquefied natural gas.

The share of renewable energy sources in the energy supply of many countries of the world is growing significantly.

Gas supply is diversified in most countries dependent on gas supplies from the Russian Federation.

The price of natural gas is somewhat reduced and stabilized at an acceptable (for industry and households) level.

Hydrogen energy is developing in many countries of the world, including Europe.

Ukraine has adapted its underground storage facilities for hydrogen storage.

Foreign companies use UGS facilities in Ukraine to store hydrogen, which can be used as an energy source.

Ukraine has adapted its underground storage facilities for carbon dioxide storage.

Foreign companies use Ukraine's UGS facilities to harbor carbon dioxide, which will reduce its emissions into the atmosphere, and thereby limit the impact of economic activity on climate change and global warming.

Energy companies from different parts of the world use part of the potential of Ukrainian gas storage facilities to store natural gas and other gases (hydrogen, carbon dioxide). UGS facilities loading in Ukraine is maximum and diversified. At the same time, other facilities of the Ukrainian GTS are used

Figure 14. This is a figure. Schemes follow the same formatting.

Considering the pessimistic scenario, which provides for a long-term energy crisis, a slow change in the energy infrastructure, and an increase in the monopoly supply of natural gas to Europe, we can predict its implementation within the next five years at least. As for the optimistic scenario, which provides for a complete renewal of the energy infrastructure, maximum demonopolization, and diversification of gas supply services, it is obvious that the implementation of such a scenario involves large investments, powerful scientific developments, and requires a significant period for implementation, in particular, in our opinion, not less than 10 years. A realistic scenario for the use of UGS capacities in Ukraine, in our opinion, can be implemented in the next 3–5 years. Obviously, the implementation of the individual components of the realistic scenario has already begun.

Given the current situation, a realistic scenario for using UGS facilities in Ukraine is more likely to materialize. However, in the longer term, Ukraine should prepare for alternative uses of gas storage facilities, in particular for hydrogen [71] and carbon dioxide storage [72], and to expand its offer of GTS services outside of Europe.

8. Conclusions and Prospects for Further Research

Underground gas storage is important for meeting domestic demand for natural gas. Facilities are used to compensate for the uneven consumption of gas in countries with a distinct change of seasons, as well as to level the risks of undersupply of gas of various natures (including technological, political, economic, and environmental) that may threaten the energy security of national markets. Ukraine belongs to the group of such countries. In recent years, there have been significant changes in the functioning of Ukrainian UGS facilities, in particular:

Separation of the UGS operator from the gas transport operator;

- Access of European countries to UGS facilities has been expanded and facilitated;
- Natural gas storage regimes have been expanded;
- Gas storage tariffs have been diversified;
- Natural gas metering system has been improved.

However, in the future, it will be necessary to diversify the range of services, improve the quality of services already provided (including natural gas storage services), ensure the transparency of the activities of the underground gas storage operator, reduce the number of bureaucratic procedures, and eliminate the negative impact of monopolies that still operate in the gas market.

The studies prove the significant role of Ukrainian UGS facilities in ensuring the energy security of Europe. An important aspect of its improvement is regional cooperation aimed at increasing the level of energy security of countries that should unite in regional energy or exclusively gas clusters. The issue of forming a regional gas cluster, which could include Ukraine, Poland, Slovakia, Hungary, and some other countries interested in optimizing their energy balances, increasing the level of energy security and counteracting the gas expansion of the Russian Federation, deserves careful attention. The key infrastructure elements of such a gas cluster should be existing and potential underground gas storage facilities, an extensive gas transmission network, gas interconnector pipelines, LNG, and CNG terminals. In addition, gas storage facilities can be used to store hydrogen and carbon dioxide. The military invasion of Russia on the territory of Ukraine and the energy crisis caused by it will become an impetus for the development of hydrogen energy in European countries and the development of liquefied gas terminals, which will lead to demand for gas storage capacities in Ukraine.

As the study showed, UGS facilities in Ukraine have significant development opportunities, and the management of enterprises must use them correctly, utilizing their strengths. Of course, at the same time, there are many threats, but this requires effective management to foresee and avoid them in the future.

In further studies, we propose to deepen the study of the external environment of UGS facilities in Ukraine based on the already considered composition of factors within the political, economic, social, technological, and legal components; to determine the magnitude of the influence of each of the selected factors using the method of rating; to substantiate the reliability and consistency of the results of an expert survey using economic and mathematical criteria; and to carry out forecasting indicators of the functioning of UGS facilities in Ukraine. Our further studies will include: an analysis of the competitiveness of Ukrainian UGS facilities in the global gas market (taking into account macro-environment factors); identification of their role in the geopolitical aspect (taking into account global factors); forecasting demand for Ukrainian UGS services from foreign companies; analysis of alternative ways to use UGS facilities (in connection with the development of new achievements in science and technology).

Author Contributions: Conceptualization, N.I.; methodology, A.I. and I.Z.; validation, N.I. and O.D.; formal analysis, A.I.; investigation, A.I. and I.Z.; resources, O.D. and O.R.; data curation, O.D. and O.R.; writing—original draft preparation, I.Z. and O.R.; writing—review and editing, N.I. and A.I.; visualization, O.R.; supervision, N.I. and I.Z.; funding acquisition, N.I. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by AGH University of Science and Technology.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the authors.

Conflicts of Interest: The authors declare no conflict of interest.

References

- 1. Energy Balance of Ukraine for 2020. Available online: http://www.ukrstat.gov.ua/express/expr2021/11/147.pdf (accessed on 16 April 2022).
- Shvidky, E.A.; Bodnar, G.F. Retrospective Analysis of the Formation Process of the Gas Transport and Gas Distribution System of Ukraine as the Basis of the Identification and Solution of Their Main Problems Development. Available online: https: //core.ac.uk/download/pdf/84123072.pdf (accessed on 16 April 2022).
- Zapukhliak, I.B. Current State and Problems of Development of the Gas Transportation System of Ukraine in the Context of European Integration Processes. *East. Eur. Econ. Bus. Manag.* 2017, *3*, 47–52. Available online: http://easterneurope-ebm.in.ua (accessed on 3 May 2022).
- 4. Geography and Dynamics of Natural Gas Imports to Ukraine in 2020. Available online: https://ua-energy.org/uk/posts/zvidky-haz-heohrafiia-ta-dynamika-importu-pryrodnoho-hazu-ukrainoiu-u-2020-rotsi (accessed on 14 April 2022).
- TSOUA. Official Website of Ukrtransgaz. Available online: https://tsoua.com/news/za-pidsumkamy-10-misyacziv-importgazu-z-yes-v-ukrayinu-perevyshhuye-eksport/ (accessed on 17 April 2022).
- Goldthau, A.; Boersma, T. The 2014 Ukraine-Russia crisis: Implications for energy markets and scholarship. *Energy Res. Soc. Sci.* 2014, 3, 13–15. [CrossRef]
- 7. Skalamera, M. The Ukraine Crisis: The Neglected Gas Factor. Orbis 2015, 59, 397–410. [CrossRef]
- 8. Van de Graaf, T.; Colgan, J.D. Russian gas games or well-oiled conflict? Energy security and the 2014 Ukraine crisis. *Energy Res. Soc. Sci.* **2017**, *24*, 59–64. [CrossRef]
- 9. Lee, Y. Interdependence, issue importance, and the 2009 Russia-Ukraine gas conflict. Energy Policy 2017, 102, 199–209. [CrossRef]
- 10. RodrHguez-Fernandez, L.; Carvajal, A.B.F.; Ruiz-Gomez, L.M. Evolution of European Union's energy security in gas supply during Russia–Ukraine gas crisis (2006–2009). *Energy Strategy Rev.* **2020**, *30*, 100518. [CrossRef]
- 11. Stulberg, A.N. Natural gas and the Russia-Ukraine crisis: Strategic restraint and the emerging Europe-Eurasia gas network. *Energy Res. Soc. Sci.* 2017, 24, 71–85. [CrossRef]
- 12. Goncharuk, A.G.; lo Storto, C. Challenges and policy implications of gas reform in Italy and Ukraine: Evidence from a benchmarking analysis. *Energy Policy* **2017**, *101*, 456–466. [CrossRef]
- Yemelyanov, O.; Symak, A.; Petrushka, T.; Zahoretska, O.; Kusiy, M.; Lesyk, R.; Lesyk, L. Changes in Energy Consumption, Economic Growth and Aspirations for Energy Independence: Sectoral Analysis of Uses of Natural Gas in Ukrainian Economy. Energies 2019, 12, 4724. [CrossRef]
- 14. Yakovenko, K.; Міљнk, M. Cooperation and Security: Examining the Political Discourse on Natural Gas Transit in Ukraine and Slovakia. *Energies* **2020**, *13*, 5969. [CrossRef]
- 15. Sauvageot, E.P. Between Russia as producer and Ukraine as a transit country: EU dilemma of interdependence and energy security. *Energy Policy* **2020**, *145*, 111699. [CrossRef]
- 16. Teichmann, F.; Falker, M.-C.; Sergi, B.S. Extractive industries, corruption and potential solutions. The case of Ukraine. *Resour. Policy* **2020**, *69*, 101844. [CrossRef]
- 17. Bocse, A.-M. From the United States with shale gas: Ukraine, energy securitization, and the reshaping of transatlantic energy relations. *Energy Res. Soc. Sci.* 2020, *69*, 101553. [CrossRef]
- 18. Alberini, A.; Khymych, O.; Scasnə, M. Responsiveness to energy price changes when salience is high: Residential natural gas demand in Ukraine. *Energy Policy* **2020**, *144*, 111534. [CrossRef]
- 19. Goncharuk, A.G.; Cirella, G.T. A perspective on household natural gas consumption in Ukraine. *Extr. Ind. Soc.* **2020**, *7*, 587–592. [CrossRef]
- 20. Almeidaa, J.R.U.C.; De Almeida, E.L.F.; Torres, E.A.; Freires, F.G.M. Economic value of underground natural gas storage for the Brazilian power sector. *Energy Policy* **2018**, *121*, 488–497. [CrossRef]
- 21. Chen, S.; Zhang, Q.; Wang, G.; Zhu, L.; Li, Y. Investment strategy for underground gas storage facilities based on real option model considering gas market reform in China. *Energy Econ.* **2018**, *70*, 132–142. [CrossRef]
- 22. Yu, W.; Gonga, J.; Song, S.; Huang, W.; Li, Y.; Zhang, J.; Hong, B.; Zhang, Y.; Wen, K.; Duan, X. Gas supply reliability analysis of a natural gas pipeline system considering the effects of underground gas storages. *Appl. Energy* **2019**, 252, 113418. [CrossRef]
- 23. Matar, W.; Shabaneh, R. Viability of seasonal natural gas storage in the Saudi energy system. *Energy Strategy Rev.* 2020, 32, 100549. [CrossRef]
- 24. Zhang, J.; Tan, Y.; Zhang, T.; Yu, K.; Wang, X.; Zhao, Q. Natural gas market and underground gas storage development in China. *J. Energy Storage* **2020**, *29*, 101338. [CrossRef]
- 25. Skrzyński, T. The Role of Underground Gas Storage Facilities in the Continuous Supply of Natural Gas to Domestic Recipients Based on the Example of the Visegrad Group. *Energy Policy J.* **2020**, *23*, 21–40. [CrossRef]
- 26. Syed, Z.; Lawryshyn, Y. Risk analysis of an underground gas storage facility using a physics-based system performance model and Monte Carlo simulation. *Reliab. Eng. Syst. Saf.* **2020**, *199*, 106792. [CrossRef]
- 27. Tongwen, J.; Zhengmao, W.; Jinfang, W. Integrated construction technology for natural gas gravity drive and underground gas storage. *Petrol. Explor. Develop.* **2021**, *48*, 1227–1236.

- Thanh, H.V.; Safaei-Farouji, M.; Wei, N.; Band, S.S.; Mosavi, A. Knowledge-based rigorous machine learning techniques to predict the deliverability of underground natural gas storage sites for contributing to sustainable development goals. *Energy Rep.* 2022, *8*, 7643–7656. [CrossRef]
- 29. Sadeghi, S.; Sedaee, B. Mechanistic simulation of cushion gas and working gas mixing during underground natural gas storage. *J. Energy Storage* **2022**, *46*, 103885. [CrossRef]
- Sadeghi, S.; Sedaee, B. Cushion and working gases mixing during underground gas storage: Role of fractures. *J. Energy Storage* 2022, 55, 105530. [CrossRef]
- 31. Zhang, Y.; Oldenburg, C.M.; Zhou, Q.; Pan, L.; Freifeld, B.M.; Jeanne, P.; Tribaldos, V.R.; Vasco, D.W. Advanced monitoring and simulation for underground gas storage risk management. *J. Pet. Sci. Eng.* **2022**, *208*, 109763. [CrossRef]
- 32. Plan for the Development of Gas Storage Facilities of the Gas Storage Operator of the Joint Stock Company "Ukrtransgaz" for 2021–2030. Available online: https://utg.ua/img/menu/company/docs/2021/%D0%9F%D0%BB%D0%B0%D0%BD%20%D0%9F%D0%A1%D0%93%202021-2030.pdf (accessed on 14 April 2022).
- 33. Storchak, S.O.; Zaiets, V.O. Underground Gas Storages of Ukraine—A Reliable Basis for the Creation of the Eastern European gas hub. *Oil Gas Ind. Ukr.* **2016**, *3*, 24–25.
- Directive 2003/55/EC of the European Parliament and of the Council of the European Union on Common Rules for the Internal Market in Natural Gas, Which Repeals Directive 98/30/EC. Brussels. 2003. Available online: https://zakon.rada.gov.ua/laws/ show/994_380#Text (accessed on 22 December 2021).
- 35. Decision of the Commission Dated August 24, 2012 "Regarding Amendments to Annex I of Regulation (EC) No. 715/2009 of the European Parliament and of the Council on Conditions of Access to Gas Transmission Systems". Available online: https://zakon.rada.gov.ua/laws/show/984_012-12#Text (accessed on 22 December 2021).
- 36. Directive of the European Parliament and Council 2012/27/EU Dated October 25, 2012 "On Energy Efficiency, Amending Directives 2009/125/EU and 2010/30/EU and Repealing Directives 2004/8/EU and 2006/32/EU". Available online: https://zakon.rada.gov.ua/laws/show/984_017-12#Text (accessed on 22 December 2021).
- Regulation (EC) No. 715/2009 OF THE EUROPEAN PARLIAMENT AND COUNCIL Dated July 13, 2009 "On Conditions of Access to Natural Gas Transportation Networks and Which Repeals Regulation (EC)" No. 1775/2005. Available online: http://reform.energy/media/209/e8d7f3816b9d32188f2f454906fcfd0d.pdf (accessed on 22 December 2021).
- Law of Ukraine "On the Natural Gas Market". Available online: https://zakon.rada.gov.ua/laws/show/329-19#Text (accessed on 22 December 2021).
- 39. Official Website of NJSC Naftogaz. Available online: https://www.naftogaz.com/ (accessed on 22 December 2021).
- 40. Information Platform LLC "GTS Operator of Ukraine". Available online: https://iplatforma.tsoua.com/start (accessed on 22 December 2021).
- 41. Ukraine's Progress in the Development of the Gas Market. Ekonomichna Pravda, February 24. 2021. Available online: https://www.epravda.com.ua/columns/2021/02/24/671345/ (accessed on 22 December 2021).
- Official Website of LLC "Ukrainian Energy Exchange". Available online: https://www.ueex.com.ua/ (accessed on 12 December 2021).
- 43. About Naftogas. Official Website of NJSC Naftogaz. Available online: https://www.naftogaz.com/en/about-naftogaz (accessed on 20 December 2021).
- 44. Annual Report of Naftogaz of Ukraine for 2015. Available online: https://annualreport2015.naftogaz.com/ua/operacijnadijalnist/struktura-biznesu/ (accessed on 20 December 2021).
- 45. Charter of JSC "Ukrtransgaz". Available online: https://utg.ua/utg/media/news/2017/06/statut-utg-20-06-2017.html (accessed on 15 November 2021).
- 46. UTG Today. Official Website of Ukrtransgaz. Available online: https://utg.ua/utg/about-company/utg-today/ (accessed on 15 November 2021).
- 47. Natural Gas Storage. Available online: https://www.naftogaz.com/business/natural-gas-storage-business-unit (accessed on 25 November 2021).
- Zapukhliak, I.B. Development of Gas Transportation Enterprises in the Conditions of Instability of Their Operating Environment: Theory and Practice: Monograph; Publishing House of Ivano-Frankivsk National Technical University of Oil and Gas: Ivano-Frankivsk, Ukraine, 2016.
- 49. Zapukhliak, I.B. Institutional framework for the development of domestic gas transportation enterprises. *Econ. Ann.-XXI* **2016**, 158, 39–42. [CrossRef]
- 50. A Gas Hub for Ukraine. Available online: http://aei.pitt.edu/52449/1/JW_and__FG_A_Gas_Hub_For_UA.pdf (accessed on 5 September 2021).
- 51. Gas Storage Capacities. Available online: https://erdgasspeicher.de/en/gas-storage/gas-storage-capacities/ (accessed on 5 September 2021).
- 52. Underground Gas Storage Industry Outlook in Europe, North America, and Former Soviet Union (FSU) to 2025—Capacity and Capital Expenditure Outlook with Details of All Operating and Planned Storage Sites. Available online: https://www.giiresearch.com/report/gd1029385-underground-gas-storage-industry-outlook-europe.html (accessed on 5 September 2021).
- 53. Booklet of UGS Operator in Ukraine. Official Website of Ukrtransgaz Naftogaz. Available online: https://utg.ua/utg/psg/ underground-gas-storages.html (accessed on 25 November 2021).

- 54. JSC "Ukrtransgaz" Is an Information Platform of the Gas Storage Operator of Ukraine. Available online: https://iplatforma-ogu.utg.ua/start_en (accessed on 20 November 2021).
- Annual Report of Naftogaz of Ukraine for 2019. Available online: https://www.naftogaz.com/files/Zvity/Naftogaz_2019_UA. pdf (accessed on 5 September 2021).
- "Ukrtransgaz" Will Introduce Monitoring of Gas Transactions in UGS Facilities for Banks. Available online: https://ua-energy. org/uk/posts/operator-hazoskhovyshch-zaprovadzhuie-posluhu-monitorynhu-operatsii-z-hazom (accessed on 10 September 2021).
- 57. Nomination/Allocation at the Cross Border Interconnection Points. Available online: https://tsoua.com/kliyentam/komerciinyidyspetchyng/nominatcii/alokacia-na-mizhderzhavnyh-zyednannyah/ (accessed on 10 September 2021).
- 58. A New Service for Seasonal Storage of Gas in Storage Facilities will Appear in Ukraine. Available online: https://ua-energy.org/ uk/posts/informatsiini-platformy-ohts-ta-psh-obiednaiut-posluhy-short-haul-ta-mytnyi-sklad (accessed on 5 September 2021).
- The Number of Customers of Ukrainian UGS Services Exceeded One Thousand Companies. Available online: https://utg. ua/utg/media/news/2022/01/klkst-zamovnikv-poslug-ukranskix-psg-perevishhila-tisyachu-kompanj.html (accessed on 10 January 2022).
- 60. Doroshevych, V.I. The gas transportation system of Ukraine as a component of the security of the national economy. *Molod. Vchenyi* **2018**, *10*, 325–330. Available online: http://nbuv.gov.ua/UJRN/molv_2018_10(1)__79 (accessed on 10 January 2022).
- 61. Gas Balance in European Gas Storages. Available online: https://naftogaz-europe.com/article/ua/GasBalances (accessed on 12 January 2022).
- 62. On Approval of the Energy Strategy of Ukraine for the Period Up to 2035 "Security, Energy Efficiency, Competitiveness". Available online: https://zakon.rada.gov.ua/laws/show/605-2017-%D1%80#Text (accessed on 12 January 2022).
- 63. Storage. Available online: https://www.naftogaz.com/www/3/nakweb.nsf/0/C83CD1A84832AA46C2257F1D0023448E? OpenDocument&Expand=1.3& (accessed on 10 January 2022).
- 64. The Gas Storage Operator Started 2022 by Storing 13.5 Billion Cubic Meters of Gas in UGS Facilities. Available online: https://finbalance.com.ua/news/zapasi-hazu-v-psh-na-pochatok-2022-roku-znizilisya-do-135-mlrd-kubiv (accessed on 15 February 2022).
- Gas Reserves in Underground Storage Facilities by the Beginning of 2022 Decreased to 13.5 Billion Cubic Meters. Available online: https://utg.ua/utg/media/news/2022/01/operator-gazosxovishh-rozpochav-2022-rk-zbergayuchi-u-psg-135-mlrdkub.-m-gazu.html (accessed on 15 February 2022).
- 66. EU Natural Gas. Available online: https://tradingeconomics.com/commodity/eu-natural-gas (accessed on 8 September 2022).
- 67. BP. Official Website of British Petroleum. Statistical Review of World Energy—2021, 70th ed. 2021. Available online: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf (accessed on 10 September 2021).
- 68. The Verkhovna Rada of Ukraine, Legislation of Ukraine. Available online: https://zakon.rada.gov.ua/laws/show/984_011#Text (accessed on 6 March 2022).
- 69. Natural Gas Consumption Growth between 2020 and 2050 Is Concentrated in Two Areas: Exports and Industrial Use, EIA, U.S. Energy Information Administration. Available online: https://www.eia.gov/outlooks/aeo/production/sub-topic-03.php (accessed on 6 May 2022).
- Oil and Gas Forecast to 2050, Energy Transition Outlook 2017. Available online: https://eto.dnv.com/2017/oilgas (accessed on 6 May 2022).
- 71. Global Gas Demand to Rise 50% by 2050, Gas Export Group Says, S&P Global Market Intelligence. Available online: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/global-gas-demand-to-rise-50-by-2050-gas-export-group-says-62844254 (accessed on 6 May 2022).
- Dutch Energy Companies to Build Offshore CO2 Storage. Available online: https://ua-electro.com/ru/gasunie-z-niderlandivnakopichuye-voden-u-pidzemnij-solyanij-pecheri/ (accessed on 6 May 2022).