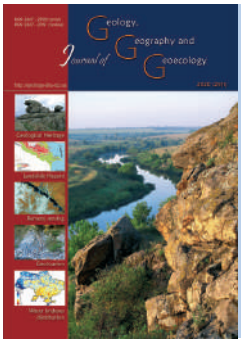

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu-dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ.Geol.Geograph. Geology, 29(2), 398–405.
doi: 10.15421/112035

Geospatial distribution of gas storage facilities within the East European gas hub

Ivan I. Rovenchak, Mariia A. Yaroshevych

Ivan Franko National University of Lviv, Lviv, Ukraine, maryana-ya@ukr.net

Received: 10.10.2019
Received in revised form: 04.11.2019
Accepted: 24.02.2020

Abstract. The purpose of this article is to elucidate the existing surplus of underground gas storage facilities of the Western region of Ukraine and to substantiate the possibilities of using gas storages not only for the state domestic needs but also for the needs of foreign importers. The gas storage system of the Western region of Ukraine consists of five gas storage facilities and is the basis for forming the future Eastern European gas hub. To better understand the impact of the geographical factor on the formation of the hub, a mapping method is used, which not only depicts the primary information on the position of the main gas storages but also provides an opportunity to analyze the effect of the location of an individual gas storage as it is used during a particular gas year. In order to evaluate the occupation degree of gas storage facilities, as well as to evaluate the possibilities of maximal use, the article analyzes each gas storage facility separately. There were used such methods as the comparative-geographical method, the idealization method, and the principle of causality in this article. The last is an important tool in the study because it allows the cause-and-effect relationship to be traced between the position of the gas storage and its fullness. Using the comparative-geographical method, two principles are taken into account: the similarity principle and the distinction principle. Using the principle of similarity, the article reveals similar characteristics of individual gas storage facilities, and using the distinction principle - on the contrary, highlights the differences. The core of the gas storage system of the Western region is the Bilche-Volyzko-Uherske gas storage facility - the largest gas storage with the total capacity of 17.050 million m³. It should be the core of the future Eastern European gas hub, as its capacity allows to pump the largest volumes of imported gas. The region's second-largest gas storage facility, Bohorodchanske, at the time of peak gas pumping for the past gas year, was filled by 65% of its total capacity. The third-largest gas storage facility – Dashawske had the highest percentage of usage for the last gas year. If necessary, this gas storage could be filled up by another 207 million m³ (about 10% of the total capacity) according to the conditions of the previous gas year. Oparske and Uherske gas storage facilities were hardly used for the domestic needs of the previous gas year. The total capacity of these gas storage facilities amounted to 2857 million m³ (1710 million m³ Uherske and 1117 million m³ Oparske) in the past gas year.

Key words: gas hub, gas storage, gas pipeline, natural gas market

Геопросторовий розподіл потужностей зберігання газу в межах Східноєвропейського газового хабу

Ровенчак І.І., Ярошевич М.А.

Львівський національний університет ім. І.Франка, Львів, Україна, maryana-ya@ukr.net

Анотація. Метою даної статті є висвітлення наявного профіциту потужностей підземних сховищ газу (ПСГ) Західного регіону України (ЗРУ) та обгрунтування можливостей використання ПСГ не тільки для внутрішніх потреб держави, але й для потреб іноземних імпортерів. Система ПСГ ЗРУ складається із п'яти газових сховищ і є базою для формування майбутнього Східноєвропейського газового хабу (СЄГХ). Для кращого розуміння впливу географічного фактора на формування хабу використовується картографічний метод, який дозволяє не тільки зобразити первинну інформацію про положення головних ПСГ, але й дає можливість проаналізувати вплив розташування окремого ПСГ на міру його використання протягом окремого газового року. Для того, щоб оцінити ступінь наповненості газових сховищ, а також оцінити можливості максимального використання, у статті проаналізовано кожне газове сховище окремо. При цьому використовуються такі методи, як порівняльно-географічний метод, метод ідеалізації, а також застосовується принцип причинності. Останній є важливим інструментом у дослідженні, оскільки дозволяє відслідковувати причинно-наслідковий зв'язок між положенням газового сховища та його наповненістю. Із застосуванням порівняльно-географічного методу беруться під увагу два принципи: принцип подібності та принцип розрізнення. За допомогою принципу подібності у статті розкриваються подібні характеристики окремих газових сховищ, а за допомогою принципу розрізнення – навпаки, висвітлюються відмінності. Ядром системи ПСГ ЗРУ є Більче-Волицько-Угерське газосховище – найбільше газосховище із загальною потужністю 17 050 млн м³. Саме воно повинно стати

ядром майбутнього СЄГХ, оскільки його потужності дозволяють закачувати у перспективі найбільші об'єми імпортованого газу. Друге за величиною газове сховище регіону – Богородчанське на момент пікового закачування за минулий газовий рік було заповнено на 65% від своєї загальної потужності. Найбільший відсоток використання за минулий газовий рік у третього за величиною газового сховища – Дашавського. При необхідності дане газове сховище можна було б наповнити ще на 207 млн м³ (близько 10% від загальної потужності) відповідно до умов попереднього газового року. Опарське та Угерське газові сховища у попередньому газовому році практично не використовувались для внутрішніх потреб країни. Сумарно вільні потужності даних газових сховищ становили у минулому газовому році становили 2857 млн м³ (1710 млн м³ Угерського та 1117 млн м³ Опарського).

Ключові слова: газовий хаб, підземне сховище газу, газопровід, ринок природного газу

Introduction. The problem of gas storage and transportation is mainly studied in economics and geography. Scientific articles of national and foreign scientists in transport and energy fields became the information base for this research. This article elaborates and generalizes research on specialized economic publications as well as the author's own research. It is based on data from information systems in energy as well as the work of scientists from the Oxford Institute for Energy Research. They are engaged in research gas hubs formation and operation problems. The purpose of this work is to characterize the surplus of underground gas storage facilities, to identify regularities of the spatial distribution of underground gas reserves, and to find out the possibilities of maximizing the use of underground gas storage facilities.

Materials and methods of research. The methodological basis of this article is the general scientific and special methods, which were selected based on the purpose and objectives of this study. In particular, induction and deduction methods are used to characterize the operation of underground gas storage facilities and the prospects for systematic storage of natural gas; graphical and tabular methods - for visual presentation of research results, for statistical information, for theoretical and methodological provisions, which are substantiated in the work. The article uses a cartographic method to describe the influence of the geographical factor on the formation of a gas hub. It is not only possible to represent the available information on the location of gas storage facilities, but also to analyze the impact of localization on its occupation and subsequent use. The information obtained through the cartographic method overlaps with the results obtained by applying the comparative geographical method. Using the comparative-geographical method, two principles are taken into account: the similarity principle and the distinction principle. Using the principle of similarity, the article reveals similar characteristics of individual gas storage facilities, and using the principle of distinction - on the contrary, highlights the differences The method of idealization is also among the methods used in the article. This method is used to describe each gas storage facility. Its application makes it possible to compare the maximal (ideal) occupation of the gas storage with the available indicators of occupation.

Results and their analysis. The European Union has traditionally paid great attention to the development of the underground gas storage sector, assessing it as one of the key contributors to its energy security in a highly import-dependent environment. To date, there are 124 gas storage facilities across the EU with a total capacity of over 98 billion m³ (Heather, 2012). It is sufficient to cover about 35-40% of total daily consumption over 10 days to cover peak demand for underground gas storage or 43 days in the conditions of high demand taking into account the maximum technical possibilities of gas extraction (Formuwannja ta wykorystannja strateghicnych zapasiw, 2012).

In recent years, there has been a trend of changing the structure of natural gas imports from the European side. In 2013-2017, the import of natural gas to Ukraine decreased significantly (by almost 50%): from 28 billion to 14 billion m³, the segment was opened to more importers. In 2017, there were more than 60 natural gas suppliers, and the market continues increasing in the share of leading European companies in the import structure. It is important to note that there is a surplus of underground gas storage facilities (UGS) in the region. Despite this, in times of cold snaps, European storage facilities may not fully fulfill their direct purpose - regulating the unevenness of gas consumption and covering peak demand levels. This is caused by the relatively low technical level of possible daily takeoff. According to the Gas Infrastructure Europe (GIE) platform, the level of gas reserves in gas storages across Europe has fallen by more than a half over the last period - up to 49.5 billion m³ as of January 22, 2016 (UGS occupation level is 48.9%). (Hazowa Infrastruktura Jewropy, 2019). According to the GIE, this level is the lowest in the current decade. Increasing gas consumption from storage facilities increases the importance of supplying gas from the outside to the European market. Besides, high gas costs create additional gas demand in summer - the season of pumping gas into UGS to restore gas used during the winter. Ukraine has the most

powerful underground gas storage network in Europe. Today, the total UGS capacity of Ukraine is over 30 billion m^3, or almost a third of the EU UGS volume.

Taking into account the data on the functioning of recent gas years, it is possible to trace certain regularities of gas storage (Yaroshevych, 2019). First, the maximal daily extraction of gas from underground storage facilities is steadily shifting annually by one calendar month: if in 2014-2015 the maximal daily extraction was at the beginning of December, then in the current gas year the maximum was reached at the beginning of March 2018. Secondly, the dynamics of pumping gas into the UGSs in summer becomes more stable and uniform every year. This could especially bee seen between the beginning of May and the end of September 2017, as well as from the beginning of May to the end of July 2018. In the previous selection did not exceed 92 million m³ within the day. Considering the gas year 2017-2018, the maximal daily value reached 116 million m³ (Pryrodnij gas u pidzemnych showyshcach Ukrainy, Skat trade, 2018).

Ukraine's gas storage potential significantly exceeds the country's domestic needs: only about a half of the gas tank facilities is used annually. The idea of gas storage for foreign traders has been existing for a long time. The gas storage facilities of the Western region of Ukraine are best suited for such purposes, as their geographical distance from other underground gas storage facilities not only strengthens logistical positions but also makes it possible to consider the aggregate of gas reservoirs as a European-style gas hub. As noted above, the potential of gas storage facilities is not fully utilized. Western region gas storage facilities are no exception (Fig. 1).

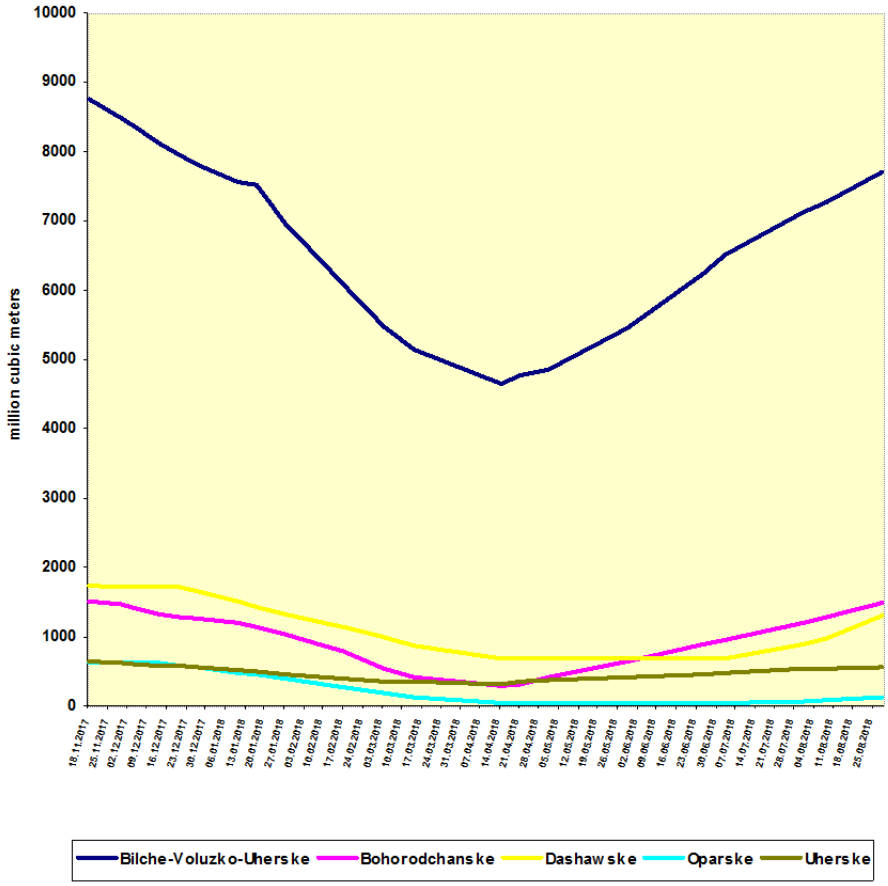

Fig. 1 Occupancy of gas storage facilities in the Western Region

two years, the dynamics of gas pumping was more variable - frequent changes in daily quantities are observed. Third, there is a clear tendency to reduce the maximal values of daily gas extraction from gas storage facilities. In winter of 2014-2015 gas year during the day more than 130 million m³ of natural gas could be extracted from underground storage facilities, in the same period of the gas year 2016-2017 the daily

The total capacity of five gas storage facilities is 25.32 billion m³. This is almost 80% of the total capacity of all gas storage facilities in Ukraine (including the Glibove gas storage facility in the territory of the temporarily occupied Crimea). As stated in the Energy Strategy of Ukraine until 2035, gas production will have the following dynamics: 2020 - 22.9 billion m³, 2025 - 27.5 billion m³, 2030 - 33.8 billion

m³, 2035 - 42.1 billion m³ (Nowa enerhetychna stratehija Ukrainy do 2035 roku, 2017).

This means that for the next 10-15 years, the capacity of underground gas storage will be sufficient to store both our own and European gas. According to the Naftogaz annual report for 2017, the volume of gas pumped by third parties in UGS was 1.5 billion m³. This is 15% of the total gas amount in gas storage facilities. The volume of gas extraction by third parties was 1 billion m³. This is 13% of the total UGS gas extracted. These are very low indicators, given the characteristics of gas storage facilities. The largest gas storage facilities are located in Western Ukraine at the intersection of key gas pipelines connecting the gas pipelines of Belarus, Poland, Slovakia, Hungary and Romania (Fig. 2).

The major volumes of transit gas from Russia also pass through this gas transit route. The core of the future Eastern European Gas Hub is to become the largest gas storage facility in the region - Bilche-Volyzko-Uherske, with the capacity of 17 050 million m³. UGS is connected to the gas pipeline system of Ivatsevichi - Dolyna III, Kyiv - West of Ukraine-II, Bilche- Volyzko - Dolyna, which through its continu-

Fig. 2. Arrangement of gas storage facilities concerning the main gas pipelines

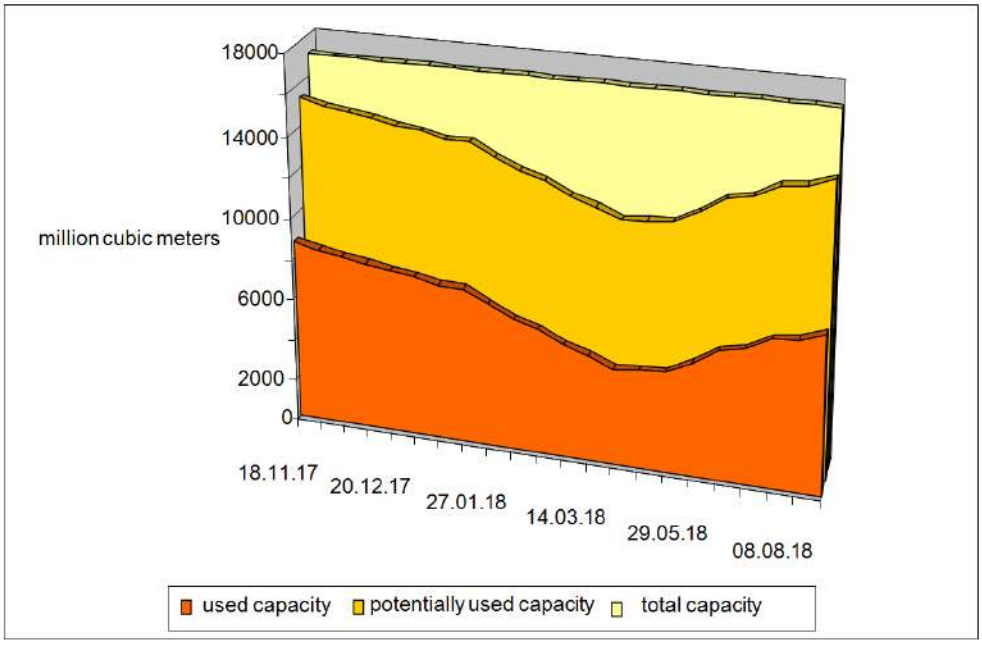

Fig. 3. Capacity of the Bilche-Volyzko-Uhersky gas storage facility

ation (gas pipeline Dolyna - Bohorodchany) connects with the "Soyuz" and Urenhoy - Pomary - Uzhgorod gas pipelines. The second-largest UGS in the region is Borohodchansk. The total storage capacity is 2 300 million m³. The Bohorodchan underground storage facility is connected to the "Soyuz", Urenhoy - Pomary - Uzhgorod, Ananyev - Chernivtsi - Borodchany gas pipeline systems and the Bilche - Volyzko - Dolyna gas pipeline. Dashawske, Oparske, and Uherske underground storage facilities are connected to the Ivatsevichi - Dolyna, Kyiv - Western Ukraine gas pipeline systems and to each other. Also, they are connected to the highly productive gas pipeline Bilche-Volyzko-Dolyna (1420 mm diameter, 84 km long), which, taking gas from the Bilche-Volyzko-Uherske UGS and the three gas storage facilities mentioned above, is essentially a gas pipeline-collector. The total capacity of the Dashawske gas storage facility is 2 150 million m³, Oparske - 1920 million m³, and Uherske - 1900 million m³. Due to the technological features of the storage facilities, the complex creates favourable conditions for manoeuvring volumes of gas pumping and its selection over a wide range. In order to understand better the potential of gas storage, it is worth considering the characteristics of each UGS in the Western Region separately for the last gas year (Pryrodnij gas u pidzemnych showyshcach Ukrainy: dynamika zapasiw protjahom chervnja 2014 - lypnja 2018, 2018). As noted earlier, the largest gas storage facility in Ukraine in general and in the Western region, in particular, is Bilche-Volyzko-Uherske. The total capacity of the gas storage facility, as noted earlier, is 17 050 million m³. Figure 3 shows actual PSG use, total capacity, and potential usage.

In the previous gas year, the Bilche- Volyzko -Uherske gas storage wa used by 51% of the total capacity at the beginning of the extraction period. If we leave 10% of the UGS volume for gas balancing purposes, 6 575 million m³ of gas volume could be allocated for storage by third parties only within this gas storage facility. The second-largest gas storage facility in the West region of Bohorodchanske, with a total capacity of 2300 million m³, was used slightly more during the past gas year: the volume of pumped gas is 65% of the total UGS capacity (Fig. 4).

If we leave 10% of the "free" volume, Bohorodchanske UGS could store additional 566 million m³ in the current gas year. The third-largest gas storage – Dashawske has the highest usage percentage. The total UGS capacity is 2 150 million m³ (Fig. 5).

Without taking into account 10% of the gas storage volume, additional 207 million m³ of gas could be used by third parties in the current gas year. One of the least used in the current gas year was the fourth largest gas storage facility – Oparske (Fig. 6).

The total capacity of the gas storage facility is 1920 million m³. As of the 18th of November, 2017 the volume of gas stored in the UGS made 611 million m³. That means the gas storage was filled by 32% of its total capacity. The gas pumping period for the UGS also started relatively late: if the increase in gas in the Bilche-Volyzko-Uherske, Bohorodchanske, Uherske gas

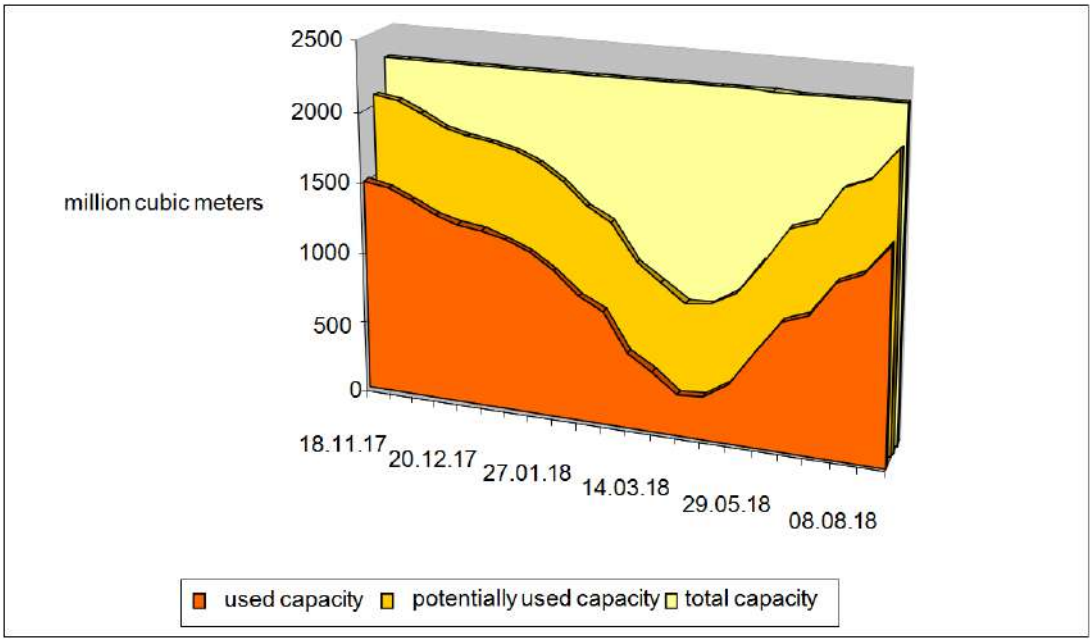

Fig. 4. Capacity of the Bogorodchanske gas storage facility

storage facilities was already observed in April, then the gas pumping in the Oparske and Dashawske gas storage facilities began only in July. Oparske UGS, which is one of the smallest in the region, due to the fact that it is not being used to its full extent, has a large enough potential for gas storage by third parties. Only this gas storage could store up to 1117 million m³ for third parties in the current gas year.

The smallest UGS of the region is Uherske with a total capacity of 1900 million m³. The percentage of utilization of this gas storage is also very small: at the beginning of the selected season, the gas level in the UGS was at the level of 637 million m³. This is about 34% of the total UGS capacity (Fig. 7).

If we leave 10% of the volume for balancing, this gas storage facility could theoretically store about 1710 million m³ of gas within one gas year.

The extent of gas storage is also determined by its location. Gas storage facilities - Bilche-Volyzko-Uherske, Oparske, and Uherske are within the intersection of the main gas pipeline networks. During the gas year, there is much more opportunity to diversify occupation of gas storage facilities from different sources. In spite of this fact, Bilche-Volyzko-Uherske, which is the country's most powerful gas storage facility, balances the region's gas transmission system, leaving two smaller gas storage facilities with less capacity. During the gas year, the Dashawske and

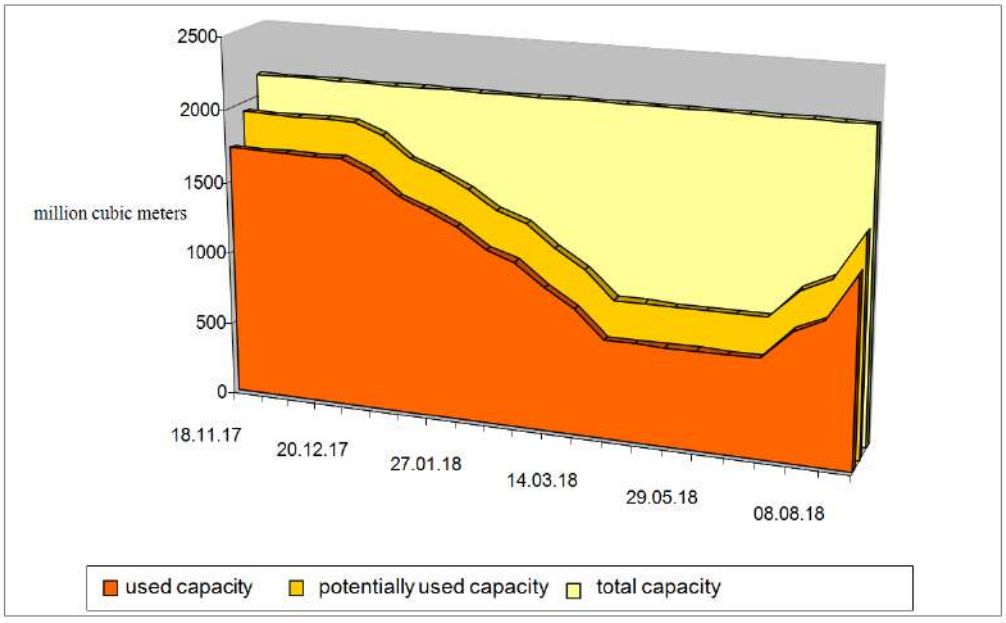

Fig. 5. Dashawsky gas storage capacity

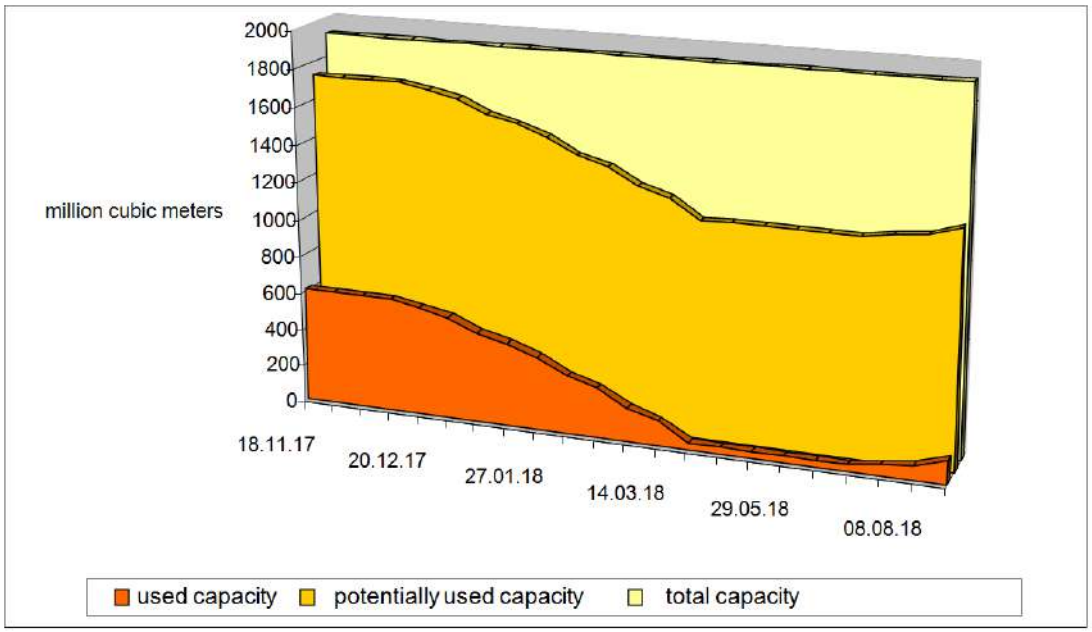

Fig.6. Capacity of Oparske UGS

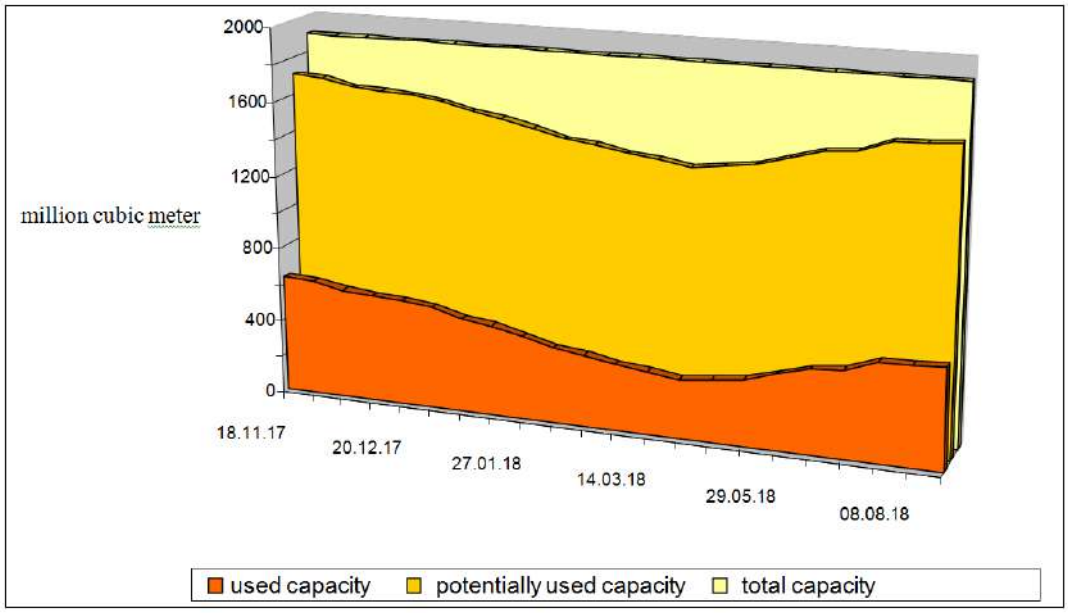

Fig.7. Uherske gas storage capacity

Bohorodchanske gas storage facilities are occupied sufficiently as they have some autonomy.

The value of underground gas storage is quite significant for the entire gas transportation system of the country. In terms of key features, Ukrainian gas storage facilities take the first place in the world after American and Russian. Underground storage facilities guarantee the reliability of natural resource transportation for both internal and external needs (Yaroshevych, 2018). The underground gas storage network can be considered as a liquid asset of the country, which is a component of its energy stability. The UGSs of Ukraine have great potential that can be used for internal and external directions of the development of the whole gas transportation system of the country and Middle East Europe.

Conclusions. The use of underground gas storage facilities allows reducing peak loads in a single gas supply system, to provide flexibility and security of gas supply. Underground gas storage facilities in Ukraine are intended primarily to regulate seasonal irregularities in gas consumption; additional gas supply to consumers with extreme temperature reductions, both in separate days and during abnormally cold winters; creation of long-term gas reserves in case of unforeseen emergency situations, such as long-term interruption of gas supplies due to major accidents, natural disasters, etc .; gas backup in the event of

short-term emergencies in the gas supply system. Studying the problems of the Eastern European Gas Hub and justifying the need for its formation is an important area of socio-geographical, in particular, economic and geographical research.

References

Derzawna nacionalna kompanija Ukrenerho, 2017. Formuwannja ta wykorystannja stratehicnych zapasiw palywno-enerhetycnych resursiw u zarubiznych krainach [National company Urkenerho, Formation and use of strategic fuel stocks and energy resources in foreign countries, official website] Retrieved from https://ua.energy/wp-content/uploads/2018/01/1.-Formuvannya-strategichnyh-zapasiv.pdf (in Ukrainian);

Gas infrastructure Europe, 2019. Retrieved from https://agsi.gie.eu/#/ ;

Heather P., 2012. Continental European Gas Hubs: Are They Fit for Purpose?, The Oxford university of energy studies Retrieved from https://www.oxfordenergy.org/publications/continental-european-gas-hubs-are-they-fit-for-purpose/?v=9b7d173b068d

Ministerstwo enerhetyky ta wuhilnoi promyslowosti (2017) Nowa enerhetychna stratehija Ukrainy do 2035 roku: bezpeka, enerhoefektywnist, konkurentospromoznist [New energy strategy till year 2035: security, efficiency, competitiveness, State of Energy and Coal Industry] Retrieved from http://mpe.kmu.gov.ua/minugol/control/uk/doccatalog/list?currDir=50358 (in Ukrainian)

Skat trade, 2018. Pryrodnij gas u pidzemnych showyshcach Ukrainy: dynamika zapasiw protjahom chervnja 2014 – lypnja 2018 [Natural gas in undeground storages of Ukraine: dynamic of inventoris during June 2014- July 2018, Skat trade, official website] Retrieved from https://skat-trade.com/analityka/pryrodnyj-gaz-u-pidzemnyh-shovyshchah-ukrainy-dynamika-zapasiv-protyagom-chervnya-2014-lypnya-2018/ (in Ukrainian).

Yaroshevych, M., 2018. Schidno-Euwropejskyj gasowyj hab w systemi gasowych habiw Europy [Eastern European Gas Hub in European gas hubs system`s] social`no-ekonomichnoyi geografiyi Charkivskoho nazionalnoho universytetu imeni V.N.Karazina [Human geograhy journal of V.N. Karazin Kharkiv National University.], (24), 83-89 (in English, abstr. in Ukrainian).

Yaroshevych, M., 2019. Transportno geografichne polozennja jak faktor formuwannja Schidno-Euwropejskoho hasowoho habu [Transport and geographical location as a factor of Easter European gas hubs formation] Visnyk Kyivskogo nacionalnogo universytetu imeni Tarasa Shevchenka, Geografiya [Bulletin of Taras Shevchenko National University of Kyiv, Geography], 1 (73), 68-72 (in Ukranian).