**Research Article**

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# Comparison of chosen aspects of Energy Security Index for the natural gas sector in Poland and Ukraine

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**Abstract:** The energy security is a subject often picked by government representatives of current times, who take actions influencing geopolitical relationship of Europe and globe. It is an important aspect because of its economical, ecological and environmental nature. Tensions between countries of Eastern Europe, legislative changes made by European Union and rapidly increasing demand in the energy sector lead players to securing their resources and its supplies, along with infrastructure. Energy Security Index (WBE) proposed by A. Sokołowski (2010) and Kościuszko Institute is an effective tool for measurement, impartial assessment and classification of analyzed economies, checking their flexibility and possibilities in the international energy arena. The index is built as multidimensional comparison analysis, which gives the prospect of creating rankings. This article presents the essence of energy security in the context of an economic potentiality in the gas sector, with the chosen elements counting into WBE and its applications. The vast aggregate is created by calculations, using worked data, to summarize assessment of energy security status of examined country. The authors tried to compare chosen elements of WBE of neighboring Polish and Ukrainian economies. As an addition, based on data availability, information is enriched by appropriate commentary. Graphics shows the essence and summary of gas transportation infrastructure in both countries and gives the idea of possibilities of cooperation between them.

**Keywords:** energy security, energy security index, Poland, Ukraine, natural gas

## 1 Introduction

Energy security is often discussed by political representatives who shape the relations in the European and global geopolitical arena. This aspect is essential for economic, ecological and environmental reasons. The Energy Security Index, proposed by A. Sokołowski and the Kosciuszko Institute [2010], is an effective tool facilitating objective assessment and classification of analyzed economies in terms of their capabilities and flexibility in the international energy sector. This index constitutes a part of the so-called multidimensional comparative analysis, incorporated in the multidimensional data analysis, which allows to prepare a ranking.

This study presents the essence of economic security as well as the structure and applications of the Energy Security Index. The constituents of the described tool form a broad aggregate using the prepared data to provide an overall assessment of the energy security of a given country. The main purpose of his paper was to comparatively analyze individual components of the index for two national economies of Poland and Ukraine. Depending on the up-to-dateness and availability of data, appropriate comments are provided to supplement the information and indicate the possibilities of cooperation between the analyzed economies in the described field.

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The current geopolitical situation between the economies of Poland, being a member of the European Union (EU), and Ukraine involved in the conflict with Russia increases the significance of this study in the context of the possibility of cooperation between Poland and Ukraine in terms of connection and development of gas networks infrastructure, among others through the investments at the Hermanowice facility, including the design and construction of the pipeline in Ukraine and the construction of five line shut-off and relief valve stations.

## 2 The essence of energy security in the context of the elements of the Energy Security Index related to earth gas

The essence of free market and the possibilities of trading energy resources encourage the energy sector stakeholders to intensify competition. Energy requirement, and in particular the necessity of existence of power resources and the continuous growing demand for them, challenge the global economy to ensure stable access to these resources for the society, governmental organizations and enterprises. The loss of such access would be followed by a number of negative consequences, with direct impact on all users of electric and thermal energies.

The energy security of a country or an economy is widely and ambiguously defined in the subject literature. Despite the vitality of the issue, no consensus has been reached in terms of precise interpretation of the definition and no methodology applicable in every situation is available. It is impossible to create a universal model for all countries, since the values of possessed resources, economic growth, climatic conditions, demographic factors, geopolitical position, etc. are different in each one of them [Radovanović et al., 2017]. It can be accepted that a common part of many definitions is relating risk with the energy security [Månsson et al., 2014]; however, the problem is that the scale of the threats that needs to be considered is too broad [Franki and Viskovic, 2015], especially in terms of their varied intensity. The authors often attempt to describe this aspect beginning with national security [Jankowska, 2015] or state security [Świątkowska, 2012], and also with a straightforward definition of security itself [Ruszel, 2016], as a starting point for further analyses of the problem essence. Among the authors who attempted to analyze the problem of providing a compact definition of energy security over the last few years were Ang et al. [2015], issuing 104 publications concerning this particular issue. In addition, Månsson, Johansson and Nilsson referred to the studies conducted by Chester [2010] and Winzer [2012]. The definition and the range of energy security may be described as dynamic and evolving with the time, along with relevant circumstances, for instance, along with the technological advance, the awareness of climatic changes and sustainable development increases, which are reflected in proper economic transformations [Ang et al., 2015]. Defining energy security as an interdisciplinary issue unfortunately allows to justify certain instruments of the energy policy [Glynn et al., 2017]. Besides, many authors limit their definitions to the most important elements, not including a number of aspects, such as cultural, environmental or technological factors, which makes these definitions incomplete [Azzuni and Breyer, 2018]. Ruszel [2016] points out that energy security is a component of resources security of the economy and may also be perceived as a condition of economy or process. The proposed definition is based on the following six various aspects:

1. geopolitical;
2. economic;
3. legal;
4. ecological;
5. technical and
6. personal.

The history of development of the energy security concept dates back to the early 20th century, when it was related with the necessity to provide fuel for the army [Cherp and Jewell, 2014], and clarifies the further interest of specialists in economic sciences [Yergin, 1991, 2006; Goldthau, 2011; Hughes and Lipscy, 2013;

Hancock and Vlado, 2016]. Cherp and Jewell, following Baldwin's assumptions, formulated three basic questions asked when defining the energy security: against whom? what values? against what threats? It implies considering the perception of energy security depending on the point of reference against a specific subject. Jankowska [2015] claimed that "the perception of energy security depends on their role in relation to the aspects of resources and energy". This problem was also mentioned by Gryz et al. [2018], who emphasized that it was perceived differently in the countries possessing energy resources and those that need to import them. Additionally, Delgado [2011] defined a basic division of energy security in a market approach, i.e. in the character of security of supplies (quantity and price – importer) and demand sustainability security (revenue – exporter) and also divided energy risk into physical risk (partial or complete interference with physical flow of energy) and economic risk (significant change in energy prices). The author also introduced a more specific division of aggregates and relevant determining risks.

Therefore, energy security can be basically defined as ensuring the constant level of prices and continuity of supplies of energy resources along with proper infrastructure allowing for processing and distribution and maintaining its quality, from the perspective of the national economy or a macroeconomic organization (EU, V4, OPEC, etc.)

The level of energy security must be measured using an aggregate index, including all essential elements determining this security. Energy Security Indexes have three functions: normalization, determining the significance of normalized values and aggregation of these values [Ang et al.,2015]. Ang [2006] divided the factors that determine such indexes into groups defined by thermodynamic factors, physical factors and money (economic) factors. Both various types of fuels and various methods of production of electric or thermal energy imply the use of sets of values constituting a uniform and objective modeling tool. Having determined the aggregated values for specific energy sectors, it is possible to generate appropriate comparative rankings of selected economies. The authors of this study focus on comparing the aggregate of the earth gas sector of two national economies: Poland and Ukraine. The basis for the study is the Energy Security Index proposed in 2010 by A. Sokołowski and the Kosciuszko Institute, selected components of which have been compared for both countries. The following alternative indexes, mentioned by Prakash et al. [2011], IEA [2007], Scheepers et al. [2007], Bollen [2008], Le Coq and Paltsey [2009] and Quemada et al. [2012], refer to a similar issue:

1. indexes based on the *Shannon Diversity Index* [Energypolicyblog, 2018];
2. geopolitical energy security measure [Blyth and Lefevre, 2004];
3. Energy Security Indexes: *ESIprice* + *ESIvolume* [IEA, 2007];
4. Supply/demand index for the long-term security of supplies [Scheepers et al., 2007];
5. *Willingness to pay* function, for security of supplies [Bollen, 2008];
6. Security of external energy supply [Le Coq and Paltsey, 2009] and
7. Socio-economic Energy Risk Index [Marín, 2009].

The listed economic tools include various combinations of aggregated measurable values of sector elements, such as energy sources, energy supplies, political stability, energy reserves, market flexibility, energy intensification, energy distribution, GDP, energy dependence and replaceability of energy sources. At the beginning of the 21st century, this issue was roughly analyzed and only the digitalization and increased data availability allowed to develop the measuring models and computerize their function in a broader scale during the following decade.

The Energy Security Index described by the authors of this study in terms of earth gas sector encompasses the following components [Szlagowski, 2010]:

1. National earth gas production – coverage of the yearly demand by the national gas production output

2. Import infrastructure

2.1. Import infrastructure capacity – this criterion is used to assess the possibility of using the infrastructure of a given country in earth gas import:

2.1.1. Pipelines – relation of pipeline capacity and the total import volume

2.1.2. Terminals – relation of terminal capacity and the total import volume

2.2. Infrastructure capacity divided into directions of supplies – infrastructure diversification potential assessment, described using the Herfindahl–Hirschman Index (HHI) – the HHI indicates the level of competition on a given market and facilitates the assessment of potential consequences of enterprises' concentration. The index is being used f.e. by antimonopolism organs, research agencies and variety of institutions, including US Justice Department. Its name comes after the surnames of creators of HHI, who did it in early years after World War II (WWII). It is described as expressed in percent sum of market shares square powers of each firm competing in a market. Literature also presents it in additive form or as valued in range of (0; 1)

3. Import structure

3.1. Import diversification

3.1.1. Transfer directions – yearly transfer capacity in billions of cubic meters

3.1.2. Producing countries – import diversification degree assessment in terms of supply directions and countries of origin

3.2. Contracts (yearly approach) – purchase/sale volume in billions of cubic meters

3.2.1. Diversification of supplies – supply directions and countries of origin

3.2.2. Term structure of import contracts portfolio

4. Capacity of gas storage facilities

4.1. Working capacity – assessment of total working capacity of underground gas storage (UGS) facilities

4.2. Maximum deliverability of UGS facilities – assessment of gas deliverability of storage facilities during peak demand periods

5. Earth gas market structure – assessment of competitiveness of various earth gas market segments

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5.1. Competitiveness on the importers' market

5.2. Competitiveness on the production market

5.3. Competitiveness on the wholesale market

5.4. Competitiveness on the retail market (end clients)

The data concerning some of the listed measures have been compiled and systematized in order to conduct a comparative analysis of selected components, which facilitated further considerations.

Energy security of EU, considered as the whole society of 28 countries, is seen as satisfactory. The so-called "energy mix" is highly diverse, which leads to uniform, even distribution of energy carriers such as fuels, electricity and heat [Dreyer and Stang, 2014, s. 81]. Despite this generally positive state of affairs, energy crises in 2006–2009 connected to Russian delivery breaks has shown weaknesses of some of the EU members, mainly in Central and Eastern Europe [Tylec, 2015]. Although there was enough supply of natural gas through internal sources, the solidarity rule was sometimes impossible to apply. Natural gas conflicts between Russia and Ukraine revealed the real problems anchored within the energy system of EU [Andoura, 2013], which was no real diversity in sources and strong dependence on Russian source fuel market. Moreover, it was underlined that there are no existing connections between systems that could

allow to transport natural gas from west of EU to the eastern countries, and even if these connections are there, they operate one way only. In addition, the essential issue that needs to be considered here is late, inappropriate reaction of EU toward Russian aggression on Ukraine (Crimea annexation).

# 3 Comparative analysis of selected aspects of aggregate gas Energy Security Index

Considering geographical aspects, the area of Ukraine (603628 sq. km) is almost twice as large as the area of Poland (312679 sq. km). Ukraine is situated between the EU (Poland is the western neighbor) and the Russian Federation, with access to the Black Sea and the Sea of Azov. According to the statistical data, in 2017, the population of Ukraine was 42 million [Ukrastat, 2018], while Poland was inhabited by 38 million people [Demografia, 2018]. The population density determined on the basis of the obtained data is 123 persons per sq. km in Poland and 75 persons per sq. km in Ukraine.

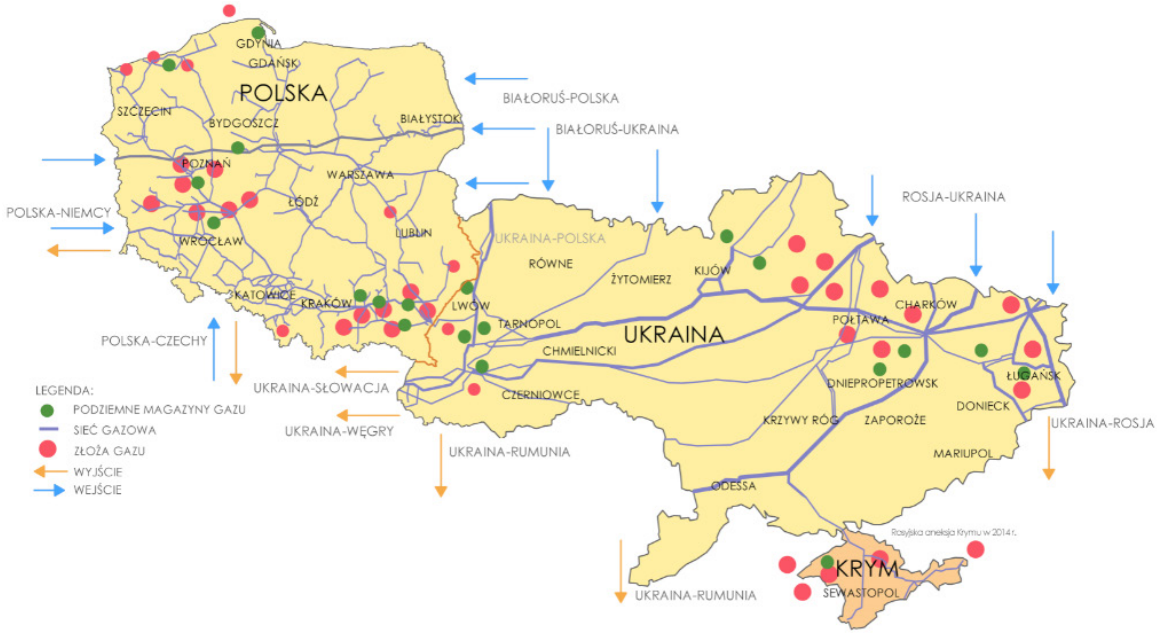


**Fig. 1.** Poland and Ukraine with transfer infrastructure, underground gas storage (UGS) facilities and earth gas reservoirs. Source: own elaboration based on www.naftogaz-europe.com and http://www.pgnig.pl/ (accessed on 30 April 2018)

Ukraine has a great potential in natural resources and capacity of UGS facilities; however, due to geopolitical conditions, a difference between certain determinants of national energy security is noticeable. Figure 1 presents a map of Poland and Ukraine with marked earth gas reservoirs, UGS facilities and the blue fuel transmission network.

# 4 National production and usage of earth gas in Poland and Ukraine

In 2015, Poland extracted 4.33 billion cubic meters of gas; in the following year, it was 4.18 billion cubic meters [Polish Ministry of Energy, 2016, 2017]. In 2017, according to the outputs estimated by the Polskie Górnictwo Naftowe i Gazownictwo S.A. (PGNiG), earth gas production reached 4.5 billion cubic meters. According to the data provided by this institution, Poland had documented gas reservoirs with the capacity of 98 billion cubic meters [Polish Ministry of Energy, 2017; PGNiG, 2010]. Currently PGNiG has 21 licenses to search and identify crude oil and earth gas reservoirs and also 25 common licenses (search, identification and extraction).

Gas production in Ukraine in 2015 reached 19.2 billion cubic meters, while in the following year, it was 20.1 billion cubic meters. Gas extraction output in 2017 increased by 0.45 billion cubic meters (2%) compared to that in 2016. Table 1 presents gas production volumes in 2015 and 2016. The Ukrainian reserves of earth gas amount to 1094 billion cubic meters, while the capacity of reservoirs is 4292 billion cubic meters. Gas reserves in the Black Sea and the Sea of Azov area reach 48 billion cubic meters, while the gas reservoirs have the capacity of 1751 billion cubic meters. Natural reserves of the country, if used properly, should ensure independence from foreign suppliers, increasing the energy security of the state.

Ukraine intends to increase earth gas production to the volume of 27–29 billion cubic meters. Over the past two years, the Ukrainian economy managed to increase gas production, thanks to optimized field development, increased production drilling and significant hydrocarbon production enhancement operations including hydraulic fractures and coil tubing. Meanwhile, delays in extending and granting licenses by the State Geology and Mineral Resources Service of Ukraine, the blocking of licensing processes by regional councils and the overregulated land allocation procedure have all hampered higher growth of gas output. All marketable gas produced by "Ukrgasdobycha" in 2017 was purchased by Naftogaz at a price of UAH 4849 per thousand cubic meters and sold at UAH 4942 per thousand cubic meters to cover household demand. Prices, conditions and supply procedures are set out in the regulations of the Cabinet of Ministers of Ukraine [Naftogaz, 2018a].

**Table 1.** Gas production in Poland and Ukraine from 2015 to 2016 (billions of cubic meters)

| | Poland | Ukraine |
|---|---|---|
| 2015 | 4.33 | 19.2 |
| 2016 | 4.18 | 20.1 |

**Source:** own elaboration based on http://www.naftogaz.com (accessed on 21 April 2018).

Consumption of earth gas in Ukraine in 2017 reached 31.9 billion cubic meters, while in the previous year (2016), it was 33.2 billion cubic meters. Comparing the gas consumption volumes, it can be concluded that this country is capable of covering approximately 48% of the demand [Naftogaz, 2018b]. Figure 2 presents gas consumption in Poland and Ukraine in the period from 2011 to 2016. Ukraine could cover 60% of earth gas demand by the national gas production.

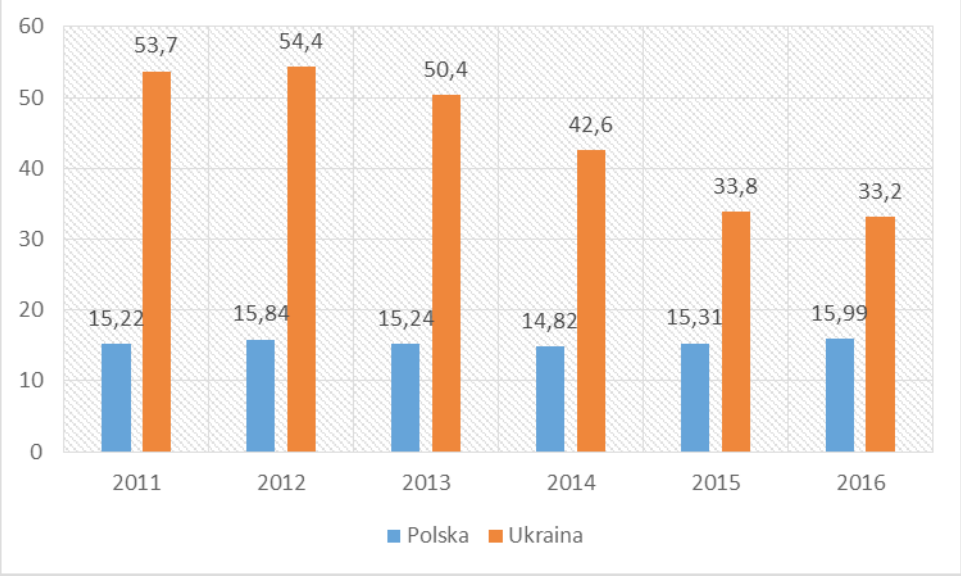


**Fig. 2.** Gas usage in Poland and Ukraine from 2011 to 2016 (billions of cubic meters). Source: own elaboration based on https://www.osw.waw.pl/pl/publikacje/analizy/2016-02-03/ukraina-udana-dywersyfikacja-dostaw-gazu (accessed on 24 April 2018).

Since 2013, a decreasing trend in gas consumption has been observed in Ukraine. The reason of a significant drop in 2014 may be connected with the actual loss of the most industrialized part of the Donbas and the collapse in the Ukrainian economy (GDP of Ukraine decreased by approximately 10% in 2015). Furthermore, in spring of 2014, the government in Kiev implemented the first of the three planned stages of gas price increase for individual clients, which aimed at marketization and reducing the debt of the national corporation Naftogaz, Ukraine (7% of GDP in 2014). A gas market act was also enforced. One of its goals was the depoliticization of Naftogaz and transforming it into a transparently managed profitable corporation [Iwański, 2016].

In Poland, gas production in 2016 reached 4.46 billion cubic meters, while gas consumption reached 15.99 billion cubic meters [Polish Ministry of Energy, 2017]. The level of consumption is rather stable, with a slight increasing trend. Considering the volume of extraction, Poland is capable of covering 28% of its earth gas demand individually, while the rest is covered by imported gas.

# 5 Earth gas import infrastructure in Poland and Ukraine

In 2017, gas was supplied to Ukraine only from the European market. In comparison with 2016, gas import increased by 27% – from 11.1 billion cubic meters to 14.1 billion cubic meters. A significant result was the increase in the import volume and contribution of private entrepreneurs and gas recipients. In 2017, these clients imported 1.8 of the quantity received in 2016, which was 5.4 billion cubic meters. Such activities allow to increase the flexibility of market operations performed by business entities and improve their capabilities. Table 2 presents the information concerning the parameters of earth gas transfer infrastructure in Ukraine and Poland. The input gas transfer efficiency in Ukraine is 287.7 billion cubic meters, while the output value is 178.5 billion cubic meters [Укртрансгаз, 2018]. It should be noted that due to geographical situation, Ukraine is a transit country, with estimated capabilities in yearly earth gas transfer to the EU reaching approximately 140 billion cubic meters [European Commission, 2010]. According to the data provided by the Gaz System, the transfer efficiency in Poland is 17.6 billion cubic meters [Gaz System, 2018a, b].

The total volume of earth gas imported to Poland in 2015 reached 11.45 billion cubic meters, 72.5% (8.3 billion cubic meters) of which was gas from the East (Yamal–Europe pipeline), 26.5% was imported from Germany (3.02 billion cubic meters), 0.13% (14.37 billion cubic meters) from the Czech Republic and 119.63 million cubic meters from Qatar (1.04% of the total imported volume) [Polish Ministry of Energy, 2016]. In 2016, gas import increased to 13.88 billion cubic meters. The volume imported from the Eastern countries increased to 10.3 billion cubic meters, which was 74.26% of the total volume of imported earth gas. The intra-community acquisition from Germany dropped in relation to the previous year to the volume of 2.5 billion cubic meters, constituting 18.20% of the total import. Similarly, smaller volume was imported from the Czech Republic, only 0.04% (4.94 billion cubic meters). The liquefied natural gas (LNG) terminal was used for importing earth gas from Qatar (increase to 963.57 million cubic meters, constituting 6.94%) and Norway (78.39 million cubic meters, which was 0.56% of the total import volume) [Polish Ministry of Energy, 2017].

**Table 2.** Gas transfer infrastructure in Ukraine and Poland

| Parameters | Measurement unit | Ukraine | Poland |
|---|---|---|---|
| Total length of pipelines | Thousands of km | 38.55 | 11.06 |
| Gas transfer efficiency: | Billions $m^3$/year | | 17.6 |
| Input | | 287.7 | |
| In line | | 178.5 | |
| Gas pumping units | pcs | 702 | 14 |
| Underground gas storage (UGS) facilities | pcs | 12 | 9 |
| Total working capacity of UGS facilities | Billions $m^3$ | 31 | 3 |

Source: http://utg.ua/utg/gts/description.html http://www.gaz-system.pl/strefa-klienta/system-przesylowy/przesyl-w-liczbach/(accessed on 21 April 2018).

In 2017, gas was imported to Ukraine by 67 companies (in 2016 – 34 companies). In 2017, Naftogaz imported 8.7 billion cubic meters of gas from the European market, which was 6% more than in the previous year. The number of European suppliers that sold earth gas to Naftogaz in 2017 was 13 (in 2016, it was 15 companies). None of them supplied more than 30% of the volume of imported gas. The changes in the Ukrainian gas market are possible on the grounds of the "Gas Market Act" (that came into force on 1 October 2015) and due to other measures taken with the aim to form an open and transparent earth gas market in Ukraine.

Considering long-term gas import, Ukraine's aim to diversify the sources of supply is noticeable. Figure 3 presents the volumes of gas imported from the EU and the Russian Federation from 2013 to 2017. At the end of November 2015, Ukraine ceased direct gas purchase from Gazprom. From that time, the fuel has been purchased from Poland, Slovakia and Hungary on a reverse supply basis. In Poland, Hermanowice gas pipeline that transfers gas eastwards is very important.

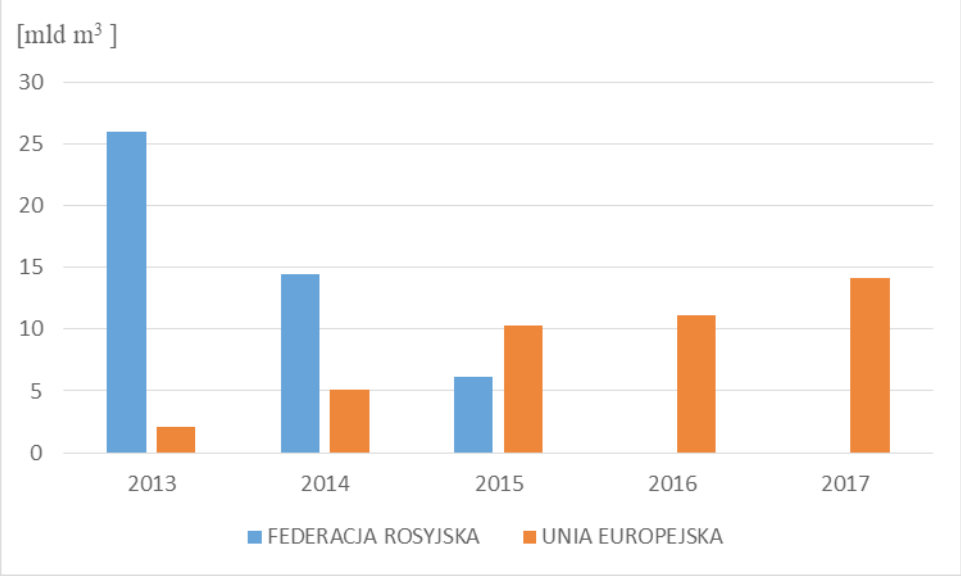


**Fig. 3.** Gas imported by Ukraine from 2013 to 2017 (billions of cubic meters). Source: own elaboration based on http://biznesalert.pl/ukraina-zmniejsza-import-gazu-zle-wiesci-dla-korytarza-norweskiego/(accessed on 24 April 2018).

The drop in the volume of gas imported from the Russian Federation may result from the Kiev's actions aiming at diversification of supply sources and limiting the dependence from the single supplier. Additionally, the prices of gas delivered by Gazprom, previously imported in volumes reaching 50–60 billion cubic meters yearly, have been constantly increasing, and Russia has not agreed to renegotiate the gas contract concluded in 2009, which was unfavorable for Ukraine. In this connection, the volumes of gas imported from the East have been decreasing. The growth in the import of gas from the EU countries was facilitated by the increase in the yearly capacity of the reverse connection with Slovakia (from 9.5 billion cubic meters to 14.5 billion cubic meters). It was the effect of cooperation with Bratislava and Brussels, along with the surplus of gas in the European markets.

## 6 UGS facilities in Poland and Ukraine

The Ukrainian gas transport system (GTS) is one of the largest gas transfer systems in the world. It has two major functions: supply of earth gas to domestic recipients and transit of earth gas through the area of Ukraine to the Western and Central Europe [Myxin, 2014]. The largest UGS facilities in the western part of Ukraine are of key importance due to their connection with the major transit gas pipelines. They balance the earth gas supplies from the Russian Federation to the EU countries, having a special role during the winter period. The great potential of the Ukrainian UGS facilities cannot be fully used for the purposes of the internal market [Ruszel, 2015].

According to the data of 24 September 2017, Ukraine received daily gas supplies from Slovakia in the volume of 26.05 million cubic meters, from Hungary – 16.34 million cubic meters and from Poland – 2.62 million cubic meters [Шрамко, 2017]. After the annexation of Crimea by the Russian Federation, Ukraine has 12 UGS facilities with the total capacity of 31 billion cubic meters. Figure 1 presents UGS facilities, location of resources and pipelines in Poland and Ukraine. The four largest gas storage facilities have the following deliverability: Bilche-Volotysko-Uherske 90 million cubic meters/day, Bohorodchanske 46 million cubic meters/day, Dashavske 25 million cubic meters/day and Oparskie 20 million cubic meters/day [Europen Commission, 2010]. What must be emphasized is the great advantage of the Ukrainian gas transfer network. It results from the geographical location of the reserves. Table 3 presents the basic parameters of the Ukrainian UGS facilities.

**Table 3.** Underground gas storage (UGS) facilities in Ukraine

| UGS | Working capacity [millions m³] | Total capacity [millions m³] | Buffer capacity [millions m³] |
|---|---|---|---|
| Uhersky | 1900 | 3850 | 1950 |
| Bilche-Volytsko-Uhersky | 17050 | 33450 | 16400 |
| Oparske | 3100 | 5800 | 2700 |
| Dashavsky | 2150 | 5265 | 3115 |
| Bohorodchanske | 2300 | 3420 | 1120 |
| Olishivske | 315 | 660 | 345 |
| Krasnopartisanske | 1200 | 2700 | 1500 |
| Solohivsky | 1200 | 2000 | 800 |
| Kehychivsky | 700 | 1315 | 615 |
| Proletarske | 2650 | 4800 | 2150 |
| Glebovskoe | 167.15 | 1507.15 | 1340 |
| Krasnopopyskaya | 420 | 800 | 380 |
| Verhunske | 400 | 920 | 520 |

Source: own elaboration based on: О.Т. *Чернова, Аналіз розвитку мережі підземних сховищ газу України,* Розробка родовищ: Зб. наук. пр. 2014. Т. 8. С. 261–276.

Currently, Poland has seven underground storage facilities of high-methane earth gas, including two in salt caverns (Mogilno and Kosakowo) and two nitrogen-rich gas storages (Bonikowo and Daszewo). Table 4 presents the characteristics of underground storage facilities of high-methane earth gas in Poland.

**Table 4.** Underground gas storage (UGS) facilities in Poland

| Storage facility | Working capacity [millions m³] | Maximum injection capacity [millions m³/day] | Maximum deliverability [millions m³/day] |
|---|---|---|---|
| Mogilno | 589.85 | 9.6 | 18 |
| Kosakowo | 145.5 | 2.4 | 26.8 |
| Husów | 500 | 4.15 | 5.76 |
| Strachocina | 360 | 2.64 | 3.36 |
| Swarzów | 90 | 1 | 1 |
| Brzeźnica | 100 | 1.44 | 1.44 |
| Wierzchowice | 1200 | 6 | 9.6 |

Source: own elaboration based on https://ipi.gasstoragepoland.pl (accessed on 30 April 2018).

Ukraine, due to its situation and the geopolitical factors, has earth gas storage facilities with the largest capacity. Comparing both countries, Ukrainian UGS facilities are 11 times as large as those in Poland. Considering the changing political conditions and the aim to change the supplier of earth gas, Ukraine

should use the available infrastructure to cover the domestic needs or to store gas for other countries. This could be beneficial for Poland. Receiving larger volumes of LNG at the terminal in Świnoujście or after the launch of *Nord Stream 2*, part of the gas volume could be stored near the Polish eastern border at Drozdowice.

# 7 Conclusions

Significant economic intensification and population density along with low natural resources of earth gas determine essential differences between both analyzed economies. In this article, authors discussed chosen elements of Energy Security Index created by Kościuszko Institute and A. Sokołowski. Poland does not have as large energy potential as Ukraine in terms of commercial and distribution capabilities. Despite this, its situation is better due to the investments made in order to diversify the sources of gas supply. Still, further development is strongly needed. Since 2015, Poland has been using its LNG terminal located at the Baltic coast in Świnoujście. The planned construction of *Nord Stream 2* pipeline will ensure the access to earth gas from Norway but increasing third-party countries (Germany) to increase their influence on the market. A growth in the transfer capabilities between both countries would largely contribute to the energy security of both economies, being the business partners of the Russian Federation. With over ten times larger capacity of UGS facilities and many possibilities to respond in a flexible way to geopolitical circumstances, Ukraine may secure its needs and earn from hiring the available storage facilities to other countries. Proper use of the available infrastructure and implementation of proper management of such facilities, based on the Polish solutions in these matters, could allow Ukraine to change the current situation related to ensuring reliable earth gas supplies on fair conditions. Relying on the cooperation with Poland, using the existing connections and extending them (Hermanowice), Ukraine may acquire access to LNG or the Norwegian blue fuel supplies. Taking into account documented natural gas sources on Ukraine, it comes naturally that the government should definitely consider investment directed to its extraction. A road to differentiate supply sources forces taking well-planned choices and decisions and gradually accomplish the targets. In view of geographic issues, it might be beneficial to consider cooperation of Poland and Ukraine but still it is essential to base on reliable data, which will give a wider view on actual situation and could state as a motivation to change.

The authors see it essential to continue working on the given subject and create multi-elementary ranking of EU countries based on at least three different, independently measured Energy Security Indexes – including one described in this study. Creation of such a tool could be useful in addressing energy security issues and prioritizing actions toward places where they are mostly needed.

# References

Andoura, S. (2013), Energy Solidarity in Europe: From Independence to Interdependence, Notre Europe – Jacques Delors Institute, Studies & Reports, Paris.

Ang, B.W., Choong, W.L., Ng, T.S. (2015), Energy security: Definitions, dimensions and indexes, *Renewable and Sustainable Energy Reviews*, Vol. 42, pp. 1077–1093.

Ang, B.W. (2006), Monitoring changes in economy-wide energy efficiency: From energy–GDP ratio to composite efficiency index, *Energy Policy*, Vol. 34, No. 5, pp. 574–582.

Azzuni, A., Breyer, Ch. (2018), Definitions and dimensions of energy security: a literature review, *WIREs Energy Environment*, Vol. 7.

Blyth, W., Lefevre, N., (2004). Energy Security and Climate Change Policy Interactions. IEA, Paris.

Szlagowski, P. (2010), *Bezpieczeństwo Energetyczne Polski: raport otwarcia, red.*, Instytut Kościuszki, Kraków.

Gryz, J., Podraza, A., Ruszel, M. (2018), *Bezpieczeństwo energetyczne. Red.*, Wydawnictwo Naukowe PWN.

Bollen, J. (2008), *Energy security, air pollution, and climate change: an integrated cost-benefit approach*, Milieu- en Natuur-planbureau (MNP), Bilthoven.

Cherp, A., Jewell, J. (2014), The concept of energy security: Beyond the four As, *Energy Policy*, Vol. 75, pp. 415–421.

Chester, L. (2010), Conceptualising energy security and making explicit its polysemic nature, *Energy Policy*, Vol. 38, No. 2.

Чернова, О.Т. (2014), Аналіз розвитку мережі підземних сховищ газу України, Розробка родовищ: Зб. наук. пр. Т. 8. С. 261–276.

Demografia. (2018), The state and structure of the population, retrieved from http://demografia.stat.gov.pl/bazademografia/Tables.aspx [22nd April 2018]

Delgado, B.M. (2011), Energy security indices in Europe, *Economic Challenges for Energy Workshop*, Madryt, pp. 3.

Dreyer, I., Stang, G. (2014), Energy moves and power shifts: EU foreign policy and global energy security, European Union Institute for Security Studies, Paris.

Energy Character Secretariat. (2010), The role of underground gas storage for security of supply and gas markets, Occasional Paper, Energy Character Secretariat 2010. Brussels, September 2010, pp. 104.

Europen Commission. (2010), The role of underground gas storage for security of supply and gas markets, Occasional Paper, Energy Charter Secretariat, Brussels, September 2010, pp. 105.

European Energy Security Strategy. (2014), Communication from the Commission to the European Parliament and the Council, SWD(2014)330 final, COM(2014) 330 final, Brussels 28.5.2014.

Gaz System. (2018a), *Fizyczny rewers na gazociągu jamalskim,* retrieved from http://www.gaz-system.pl/centrum-prasowe/aktualnosci/informacja/artykul/201595/ [3rd June 2015].

Franki, V., Viskovic, A. (2015), Energy security, policy and technology in South East Europe: Presenting and applying an energy security index to Croatia, *Energy*, Vol. 90, pp. 494–507.

Gaz System. (2018b), Przesył w liczbach, retrieved from http://www.gaz-system.pl/strefa-klienta/system-przesylowy/przesyl-w-liczbach/ [30th March 2018].

Glynn, J., Chiodi, A., O'Gallachóir, B. (2017), Energy security assessment methods: Quantifying the security co-benefits of decarbonising the Irish Energy System, *Energy Strategy Reviews*, Vol. 15, pp. 72–88.

Goldthau, A. (2011), A Public Policy Perspective on Global Energy Security, *International Studies Perspectives*, International Studies Association.

Hancock, K.J., Vlado, V. (2016), International political economy: A field born of the OPEC crisis returns to its energy roots, *Energy Research & Social Science*, Vol. 1, pp. 206–216.

Energypolicyblog. (2018), How to measure security of supply? retrieved from https://www.energypolicyblog.com/2007/09/09/how-to-measure-security-of-supply/ [20th April 2018].

Hughes, L., Lipscy, P.Y. (2013), The politics of energy, *Annual Review of Political Science*, Vol. 16, pp. 449–469.

Ibarra, R.D. *LNG market development*, spring seminar of the Finnish Gas Association.

International Energy Agency (IEA). (2007), Energy Security and Climate Policy, Paris.

Iwański, T. (2016), Ukraina: udana dywersyfikacja dostaw gazu, OSW, 03.02.2016, retrieved from https://www.osw.waw.pl/pl/publikacje/analizy/2016-02-03/ukraina-udana-dywersyfikacja-dostaw-gazu [24th April 2018].

Jankowska, I.M. (2015), Bezpieczeństwo energetyczne w polityce bezpieczeństwa państwa, PWSZ IPiA Studia Lubuskie Tom XI, Sulechów.

Jewell, J. (2011), *The IEA Model of Short-term Energy Security (MOSES). Primary Energy Sources and Secondary Fuels,* International Energy Agency, Paris.

Le Coq, Ch., Paltsey, E. (2009), Measuring the security of external energy supply in the European Union, *Energy Policy*, Vol. 37, No. 11, pp. 4474–4481.

Marín-Quemade, J.M., (2009), Energy Security for the Eu in the 21st Century, Routledge.

Månsson, A., Johansson B., Nilsson L. J. (2014), Assessing energy security: An overview of commonly used methodologies, *Energy*, Vol. 73, pp. 1–14.

Naftogaz, У. (2018a), 2017 році обсяг видобутку природного газу в Україні збільшився на 450 млн куб. М, 31.01.2018a., retrieved from http://www.naftogaz.com/www/3/nakweb.nsf/0/8737DCC4D7A68FBDC22582260058B448?OpenDocument&year=2018&month=01&nt=%D0%9D%D0%BE%D0%B2%D0%B8%D0%BD%D0%B8 [21st April 2018].

Naftogaz, У. (2018b), 2017році використання природного газу в Україні скоротилось на 1,3 млрд куб. М, 31.01.2018b, retrieved from http://www.naftogaz.com/www/3/nakweb.nsf/0/D5680C5507AB775CC2258226005C61EF?OpenDocument&year=2018&month=01&nt=%D0%9D%D0%BE%D0%B2%D0%B8%D0%BD%D0%B8& [22nd April 2018].

PGNiG. (2010), Polskie Górnictwo Naftowe i Gazownictwo SA Strategia rozwoju PGNiG SA do 2015 roku. V Kongres Naftowców i Gazowników, Bobrka, 12-14 maja.

Polish Ministry of Energy. (2016), Sprawozdanie z wyników monitorowania bezpieczeństwa dostaw paliw gazowych za okres od dnia 1 stycznia 2015 r. do dnia 31 grudnia 2015 r., Warszawa.

Polish Ministry of Energy. (2017), Sprawozdanie z wyników monitorowania bezpieczeństwa dostaw paliw gazowych za okres od dnia 1 stycznia 2016 r. do dnia 31 grudnia 2016 r., Warszawa.

Prakash, L., Joutz, F.L., Cohen, G. (2011), Measuring Energy Security: Trends in the Diversification of Oil and Natural Gas Supplies, International Monetary Fund, Washington, D.C.

Quemada, J.M.M., Garcia-Verdugo, J., Routledge, G.E. (2012), Energy Security for the EU in the 21st Century: Markets, Geopolitics and Corridors, Universidad Nacional de Educación a Distancia, Madryt.

Radovanović, M., Filipović, S., Pavlović, D. (2017), Energy security measurement – A sustainable approach, *Renewable and Sustainable Energy Reviews*, Vol. 68, pp. 1020–1032.

Rozporządzenie Parlamentu Europejskiego i Rady (UE) nr 994/2010 z dnia 20 października 2010 r. w sprawie środków zapewniających bezpieczeństwo dostaw gazu ziemnego i uchylenia dyrektywy Rady 2004/67/WE, Dz. Urz. L 295/I, 12.II.2010.

Ruszel, M. (2014), Pozycja Niemiec na wspólnym rynku gazu Unii Europejskiej, Europejski wymiar bezpieczeństwa energetycznego a ochrona środowiska, Fundacja na Rzecz Czystej Energii, Poznań, pp. 683–698.

Ruszel M. (2015), Znaczenie Ukraińskich gazociągów tranzytowych w kontekście bezpieczeństwa energetycznego Europy, Bezpieczeństwo energetyczne, in: P. Kwiatkiewicz, R. Szczerbowski, (Eds), *Rynki surowców i energii. Energetyka w czasach politycznej niestabilności,* Poznań, pp. 585–586.

Ruszel M. (2016), Paradygmat bezpieczeństwa energetycznego, Zarys teorii bezpieczeństwa państwa, red. J. Gryz, Akademia Obrony Narodowej, Warszawa.

Scheepers, M., Seebregts, A., de Jong, J., Maters, H. (2007), Updates on the Crisis Capability Index and the Supply/Demand Index Quantification for EU-27, Energy Security and Climate Policy, Energy research Centre of the Netherlands.

Шрамко Ю., Україна заповнила газом свої ПСГ на 52%, 26 September 2017, retrieved from http://www.unn.com.ua/uk/news/1689728-ukraina-zapovnyla-hazom-svoi-psh-na-52 [22 April 2018].

Świątkowska J. (2012), Bezpieczeństwo energetyczne jako fundament współczesnego bezpieczeństwa narodowego Polski, Annales Universitatis Paedagogicae Cracoviensis. Studia Politologica 8, Kraków.

Gaz System. (2015), *TGE i Gaz-System chcą stworzyć w Polsce ‚hub gazowy' dla regionu*, retrieved from http://www.pb.pl/4160538,80087,tge-i-gaz-system-chca-stworzyc-w-polsce-hub-gazowy-dla-regionu [18th June 2015].

Мухін В.В. (2014), Газотранспортна система України: надійність та безпека, Економіка і прогнозування. № 2. - С, pp. 49–61.

Tylec T. (2015), Bezpieczeństwo dostaw energii w unii europejskiej – wyzwania i ograniczenia, Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach nr 228, pp 96–98.

Укртрансгаз. (2018), Характеристика газотранспортної системи України, retrieved from http://utg.ua/utg/gts/description.html [30th April 2018].

Ukrastat. (2018). Statistical information, Population, retrieved from http://www.ukrstat.gov.ua/ [22nd April 2018]

Winzer C. (2012), Conceptualizing energy security, *Energy Policy*, Vol. 46, pp. 36–48.

Yergin D.(2006), Ensuring energy security, *Foreign Affairs*, Vol 85, No. 2, pp. 69–82.

Yergin D., The Prize: The Epic Quest for Oil, Money, and Power, New York: Simon & Schuster.