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Forecasting medium-term natural gas demand for the European Union

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Abstract
The European Commission proposed to increase the greenhouse gas emission reduction target to at least 55% by 2030 compared to 1990 level. The aim of this article is to visualise the EU natural gas consumption trend until 2023 regarding to energy transformation. The Autoregressive Integrated Moving Average (ARIMA method) is used in this study. The analysis is based on historical volumes of natural gas consumed in 2016–2020 in 28 European Union countries. An effort can be made to state that the next coming months will have a slight increase in natural gas consumption, however, the growth will depend on the pace of the economies and the pace of the energy transition.
Keywords: European Union (EU), European Green Deal, forecasting, natural gas, coronavirus, transformation.

Opracowanie prognoz średnioterminowych zapotrzebowania na gaz ziemny dla obszaru Unii Europejskiej

Streszczenie
Komisja Europejska zaproponowała zwiększenie celowej redukcji emisji gazów cieplarnianych do co najmniej 55% do roku 2030 w porównaniu z poziomem z roku 1990. Celem niniejszego artykułu jest analiza trendu zużycia gazu ziemnego w UE do roku 2023 w kontekście transformacji energetycznej. W badaniu wykorzystano metodę ARIMA. Analizę przeprowadzono w oparciu o historyczne ilości zużytego gazu ziemnego w latach 2016–2020 dla 28 krajów Unii Europejskiej. Na podstawie wykonanych prognoz można stwierdzić, że najbliższe miesiące będą charakteryzowały się niewielkim wzrostem zużycia gazu ziemnego, jednak wzrost będzie zależał od tempa rozwoju gospodarek i tempa transformacji energetycznej.
Słowa kluczowe: Unia Europejska (UE), Europejski Zielony Ład, prognozowanie, gaz ziemny, koronawirus, transformacja.

The 2030 climate and energy policy framework provides EU-wide policy targets and objectives for 2021–2030. As part of the European Green Deal, in September 2020 the European Commission proposed to increase the greenhouse gas emissions reduction target to at least 55% by 2030 compared to 1990 levels, after analysing the actions required in all sectors, including increased energy efficiency and use of renewable energy. In this process, defined as an energy transition, natural gas can be a transition fuel. In an attempt to determine the direction of natural gas consumption in the EU for the upcoming months, it is necessary to make a short-term forecast.

Forecasting natural gas consumption in the context of the energy transition

"The Paris Agreement[1] and the EU's energy policy objectives clearly set out the urgent need to address climate change. It is clear that the EU has an important leadership role in this, both within Europe but also internationally" (*Urban Agenda for the UE* 2019). The low-carbon energy transition in the world is today taking place unevenly and too slowly to preserve the climate and biodiversity. It was found that 2019 and 2020 may show a greater use of renewables and gas in place of coal power (Eyl-Mazzega, Mathieu 2020). This trend is in line with goals of the strategy *Europe 2020,* and it determines the achievement of the other targets of the strategy (Kryk, Guzowska 2021). Consequently, a major aspect to examine the trend in natural gas consumption for end consumers in the European Union.

Methodology

The available literature suggests a variety of forecasting techniques. Characterisation of fuel consumption in the form of time series provides the possibility to use tools appropriate for handling of this kind of data. ARIMA models are one of such tools (Bartnicki, Nowak 2018). "The historical demand information was used to develop several autoregressive integrated moving average (ARIMA) models by using Box–Jenkins time series procedure" (Fattah et al. 2018). ARIMA "helps in predicting future values of the series based on the characteristics. Forecasting is important in fields like finance, industry" (Mondal et al. 2020: p.13) and energy.

A time series, $\{X_t\}$ is a seasonal ARIMA (p, d, q)(P, D, Q)$_s$ process with period *s* if *d* and *D* are nonnegative integers and if the differenced series:

$$Y_t = (1 - B)^d (1 - B^s)^D X_t$$

Is a stationary autoregressive moving average (ARMA) process defined by the expression:

1 The *Paris Agreement* is the first-ever universal, legally binding global climate change agreement, adopted at the Paris climate conference (COP21) in December 2015. (see more: European Commission WWW).

$$\varphi(B)^{\Phi}(B^s)Y_t = \theta(B)\Theta(B^s)Z_t$$

where B is the backshift operator defined by

$$B^a W_t = W_{t-a}\varphi(z) = 1 - \varphi_1 z - \Lambda - \varphi_p z^p, \quad \Phi_{(z)} = 1 - \Phi_{1z} - \Lambda - \Phi_{pz}{}^p,$$
$$\theta(z) = 1 - \theta_1 z - \Lambda - \theta_q z^q, \quad \Theta(z) = 1 - \Theta_1 z - \Lambda - \Theta_1 z^Q,$$

p and P are the autoregressive order and seasonal autoregressive order, respectively, q and Q are the moving average order and seasonal moving average order, respectively, and Z_t is a white noise process identically and normally distributed with mean zero, variance σ^2, and $\mathrm{Cov}\ (Z_t,\ Z_{t-k})=0\ \ \forall\neq 0$, i.e., $\mathrm{WN}(0, \sigma^2)$ (Williams et al. 1998).

Using the mean absolute percentage error (MAPE) to check the forecasting accuracy of the model, it is proved that the produced outcomes are accurate (Ismail, El-Metaal 2020).

Input data

The main part of forecasting is the preparation of the input data on the basis. The data must be compiled in appropriate gradation and corrected for any errors. Often there are telemetry problems. Data get hung up, there are also fades in data transmission. Therefore, this stage should be approached meticulously, so the constructed model is based on reliable data. The next step after data collection is the initial analysis of the time series. The analysis mainly concerns detecting the nature of the phenomenon represented by the sequence of observations. Once a pattern is established, it can be applied to other data. Regardless of the accuracy of the theoretical justification of the model form, we can always predict future values of a time series by extrapolation. The next phase is the extraction of all possible elements of the time series, i.e. the development trend, periodic fluctuations and random fluctuations. There are two main groups of time series decomposition methods: 1) mechanical methods, which include ordinary and centred moving averages; 2) analytical methods, which include the least squares method. The final stages are to specify the model and verify its accuracy.

The data used in the study was taken from the *European Network of Transmission System Operators for Natural Gas* online platform (https://entsog.eu/). The time interval of data was from 2016 to September 2021. The ENTSOG is an association of Europe's transmission system operators (TSOs), that was created on 1 December 2009 by 31 TSOs from 21 European countries. The data concerned 90% of all operators and related to the supply of gaseous fuel to final industrial customers.

Application of the ARIMA model in forecasting natural gas consumption

The producer adjusts its production capacity on a daily basis, taking into account the availability of gas pipelines and transmission pipelines and customer demand. In this context, distribution companies are forced to programme in the early hours the total amount of gas to be consumed throughout the day. Taking into account in this study was analysed using time series models *Autoregressive Integrated Moving Average* (ARIMA), which is a popular method (Cardoso, Cruz 2016). The ARIMA method can also be used in forecasting natural gas consumption for households, which in countries based mainly on natural gas, is very significant. An interesting example of the application of this method for households is the forecasts developed for Turkish households (Akpinar, Yumusak 2013). An additional issue of this method is both in minimising energy costs and maintaining reliability, as has been demonstrated for the Egyptian power system (Ismail, El-Metaal 2020). A study conducted for the Danish transmission system also indicated that the ARIMA model benefits in terms of high accuracy in the development of forecasts (Karabiber, Xydis 2021). Based on the literature review, forecasting natural gas consumption for transmission system operators, distribution system operators, traders and other market players using the ARIMA model is widely used.

The use of the ARIMA method in predicting energy consumption in a variety of energy networks

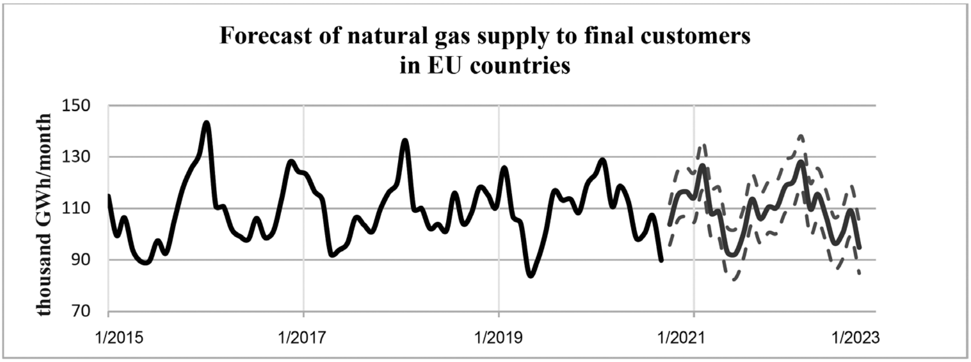
In addition to the possibilities of using the ARIMA method in the natural gas market, it also has potential for application in electricity market. The future work in photovoltaic will be based on a new optimised forecasting method for PV energy production (Fara et al. 2021). Due to its accuracy, ARIMA will also be used in future research, including in the area of renewable energy sources. One element of renewable energy is the possibility of using wind. Researchers are also applying the ARIMA method here, specifically in the prediction of wind speed. "Modelling and forecasting wind speed are noteworthy to predict the potential location for wind power generation. […] ARIMA model proposed provided good forecast accuracy measure of wind speed series in Peninsular Malaysia" (Hussin et al. 2021). Furthermore, hybrid ARIMA methods are used for research in electricity supply prediction in the critical area of IT security (Guo et al. 2021). "Accurately forecasting the electricity consumption is a crucial technology for the planning of the energy resource, which could lead to remarkable conservation of the building electricity consumption" (Fara et al. 2021).

Electricity is one of the critical role players to build an economy. Electricity consumption and generation can affect the overall policy of the country. In the research *Mid-term electricity load prediction using CNN and Bi-LSTM*, the authors found satisfactory results for the accuracy of the ARIMA method used (see: Gul et al. 2021).

Research results and data analysis

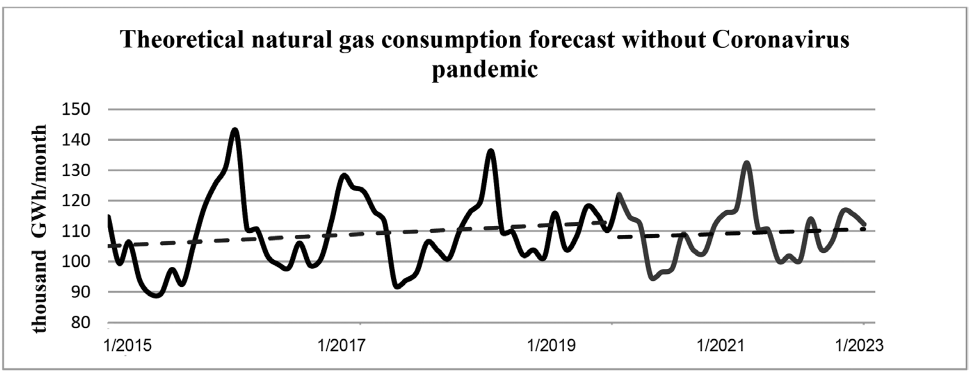
The forecast of natural gas consumption for the EU, performed according the ARIMA method, is presented on the *Figure 1*. On the basis of the forecast trajectory of natural gas consumption, it can be concluded that for the point forecast for the coming months gas supply will remain stable with an upward trend. In the forecasting process, intervals were taken into account in which the pandemic lasted, with the result that the introduced economic shock showed a certain disturbance in the course of natural gas consumption. Therefore, an additional analysis was made for the period in which the pandemic did not occur, i.e. from 2016 to 2020. In this case, the ARIMA technique gave results with an increasing trend with MAPE error for the test and learning part within 4–5 %, which was a good result (see: *Figure 2*).

Figure 1: Forecast of natural gas supply to final customers in EU countries (2022–2023)



Source: own studies based on Eurostat (2021).

Figure 2: Theoretical forecast of natural gas supply to final customers in EU countries (2022–2023), without Coronavirus pandemic.



Source: own studies based on Eurostat (2021).

The tabulated data (see: *Table 1*) in monthly gradations for the years 2016–2021, presented that in the examined timeframes the smallest delivery volumes were in 2016. Between 2017 and 2019, gas deliveries fluctuated up to +6% compared to 2016. More importantly, 2019 was the year most benefited by the consumption of gaseous fuel. A significant year was 2020, which had the lowest natural gas consumption in the months from May to July during the period under review. However, in an annual calculation, 2020 was not the year of worst consumption. An argument can be made that the next coming months will have a slight increase in natural gas consumption, however the increase will depend on the pace of the economies and the energy transition.

Table 1: Forecast of natural gas supply to final customers in EU countries (2022–2023)

GWh/month	2016	2017	2018	2019	2020	2021	2022	2023
January	114 701	142 734	122 995	136 269	125 773	128 351	126 571	127 799
February	99 458	110 822	116 368	109 707	106 919	110 717	108 095	109 905
March	106 350	110 711	113 077	109 994	104 103	118 594	108 590	115 496
April	93 643	101 766	92 244	102 177	84 384	112 827	93 191	106 746
May	89 318	99 069	93 790	103 844	89 486	98 450	92 261	96 533
June	89 541	97 988	96 430	101 358	100 654	100 323	100 551	100 393
July	97 372	106 089	106 301	115 898	116 473	107 063	113 559	109 074
August	92 602	98 656	103 544	104 071	113 223	89 854	105 986	94 849
September	105 346	101 045	100 986	108 143	113 528	103 796	110 514	
October	117 449	113 473	109 845	118 055	108 358	115 052	110 430	
November	125 217	127 886	116 270	115 245	119 270	116 491	118 409	
December	130 687	124 433	119 829	110 380	123 161	114 337	120 428	
Total	1 261 684	1 334 672	1 291 679	1 335 141	1 305 332	1 315 855	1 308 585	

Source: own studies based on Eurostat (2021).

Table 2: Applicable criteria

AIC	AICc	BIC
737,98	738,73	742,73

Source: own studies based on Eurostat (2021).

In the *Table 2,* Akaike criterion[2] is used to filter out redundant parameters that do not significantly improve the fit of the model to the empirical data. The results obtained allow us to conclude that the model approximates reality in a positive inference, i.e. it is consistent with the empirical data. Another indicator of model fit was the Bayesian Schwartz Information Criterion[3]. The resulting BIC score is also satisfactory. It was concluded that the developed forecast is also satisfactory in terms of the mentioned indicators.

Table 3: Errors of prediction

ME	RMSE	MAE	MPE	MAPE	ACF
928	4762	3122	0,8	2,7	-0,004

Source: own studies based on Eurostat (2021).

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[2] A criterion proposed by Japanese statistician Hirotugu Akaike for choosing between statistical models with different numbers of predictors. It is one of the indicators of model adjustment.

[3] A criterion for model selection among a finite set of models.

The *Table 3* presents the available prediction errors. The MAPE error, or percentage error of prediction, is the most commonly used in business. The error shown is for the learning part of the time series, a similar result was also for the testing part of the time series under study (MAPE: 2,7–3,0 %). The results obtained were satisfactory.

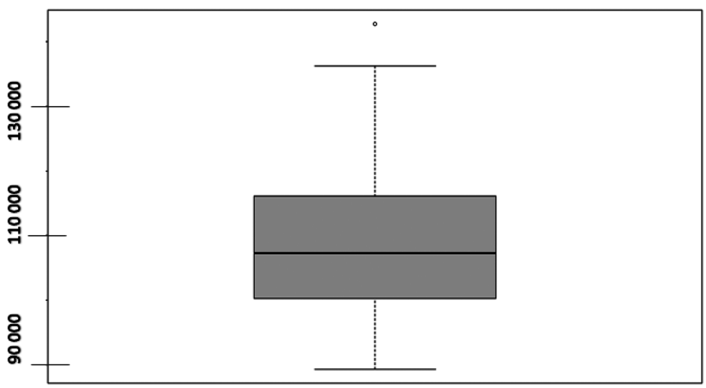
Table 4: Basic values of a box plot

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
1646	2675	16788	21415	38629	66600

Source: Eurostat 2021.

In the compiled box plot, one outlier was observed (see: *Figure 3, Table 4*). This is the delivery of gaseous fuel in January 2017. This month was a record month for natural gas off-take by end users. The position of the box plot indicated the range of the data. The graph is within the range: 90–140 000 GWh/m. It can be considered that the graph has an asymmetrical distribution, the so-called right-hand side, i.e. the distance Max from Mean is significantly greater). The highest concentration of gaseous fuel supply was between 110 000 and 115 000 GWh/m.

Figure 3 : Theoretical forecast of natural gas supply to final customers in EU countries (2022–2023), without Coronavirus pandemic.

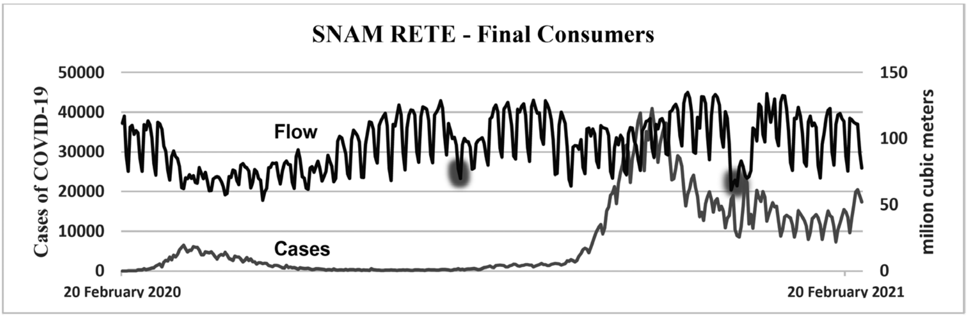


Source: own studies based on Eurostat (2021).

External factors affecting natural gas consumption

The consumption of natural gas by industrial consumers and households is influenced by many indirect and direct external factors. Those worth mentioning are the availability of infrastructure, the current price of gaseous fuel, atmospheric factors, and the trend in natural gas consumption by industry (EIA 2021). The cyclical nature of consumption depends primarily on the prevailing season. The number of heating degree days is an interesting indicator. It is a useful tool for predicting the demand for any fuel for space heating. It should be determined annually for the area served by heat and gas suppliers and compared with energy consumption. Knowledge of the energy (gas) consumption per heating degree day allows for objective examination of trends in energy (Dopke 2006) consumption changes. In the last two years, the coronavirus pandemic (e.g, in Italy, see: *Figure 4*) and weather anomalies (e.g. in Spain, see: *Figure 5*) have been noteworthy.

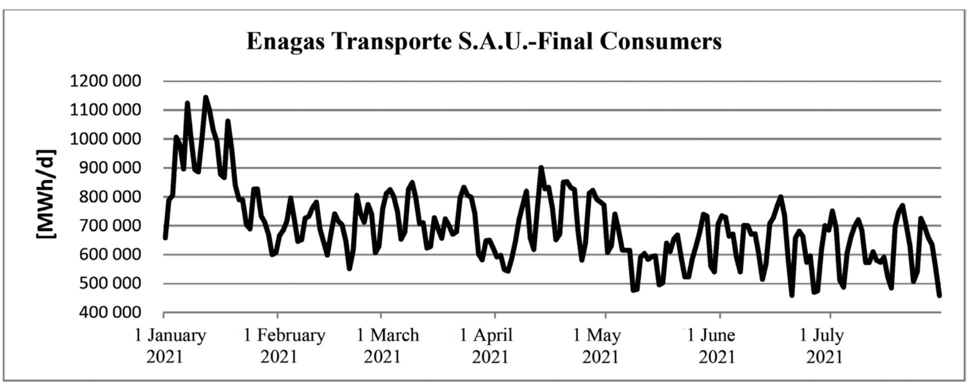
Figure 4 : Snam Rete – Final Consumers, Italy.



Source: own studies based on ENTSOG (2021b).

The prolonged lockdown measures introduced "depress industrial and power generation demand for natural gas" (Amara, Belaifa 2020: p. 12). The fullassessment of the impact of coronavirus on the main gas sectors will be possible in the following months. "Italy's energy demand fell last year at the fastest rate since World War Two as a sharp drop in road and air traffic during the pandemic undercut oil consumption" (Reuters 2021a). The coronavirus pandemic has become an additional new factor affecting gas fuel consumption. Unfortunately, it is a negative factor that has introduced an economic shock and disruption to natural gas consumption.

Figure 5 : Enagas Transporte S.A.U. – Final Consumers, Spain.



Source: own studies based on ENTSOG (2021a).

"The modern climate of the Mediterranean region is influenced by high-pressure systems in summer and westerly storm tracks in winter, giving rise to a highly seasonal climate with dry summers, relatively wet winters, and strong seasonal temperature contrasts. Nevertheless, the climate of the region is not homogeneous and the pattern of climate changes across the region is complex" (Lionello 2012; qtd. in Wei et al. 2021). "Heavy snow and icy winds blasted Spain as temperatures plumetted to -34.1C, the lowest ever recorded on the Iberian peninsula, the State Meterololgical Agency said on Wednesday" (6 January 2021, see: Reuters 2021b). "This was two degrees lower than in 1956, when temperatures of -32°C were recorded in Estany-Gento, in Lleida, in northeastern Spain" (Reuters 2021b). "Spain is experiencing its first heatwave of the year, one that will affect the Balearic Islands and almost the entire peninsula apart from Cantabria, with daytime temperatures reaching 45 degrees Celsius in Andalusia's Guadalquivir valley and night's with minimums of 26°C to 28°C in several parts of the country" (Medina, Tasca 2021). Recent weather anomalies indicate that with record low outside air temperatures, there are record daily withdrawals of natural gas. Knowledge of this provides information to European transmission system operators, indicating the need for appropriately developed transmission, distribution and storage infrastructure to ensure security of supply.

Review of the state of the storage facilities

Fundamental to a successful transmission system is cooperation with storage system operators. Such elements include underground natural gas storage facilities and LNG terminals. Underground gas storage facilities play an important role in the maintenance of energy balance. Underground gas storage allows for more efficient operation in the Europe (Skrzyński 2020). In addition, alternative for underground gas storage is terminal LNG. "The analysis of the significance of LNG in satisfying the demand for gas demonstrates that it has changed rapidly all over the world in recent years" (Matelska et al. 2016).

Table 5: Supply of LNG to transmission system operators.

TWh/m	2016	2017	2018	2019	2020	2021
January	21,75	29,34	28,41	48,36	64,74	33,78
February	24,51	24,16	23,37	40,97	56,64	37,08
March	26,08	27,13	26,45	55,01	65,30	56,91
April	19,51	29,08	29,19	58,79	60,27	59,39
May	18,81	29,06	37,15	59,85	61,72	56,95
June	23,41	32,86	27,95	61,62	52,09	46,65
July	26,07	35,13	28,21	62,73	60,27	39,01
August	16,96	35,01	27,12	56,19	45,44	32,89
September	20,50	33,17	25,64	51,81	46,92	
October	21,63	25,60	44,43	52,87	40,60	
November	24,79	33,41	44,58	62,55	45,54	
December	27,36	31,14	42,57	60,59	38,06	
Total:	271,38	365,10	385,08	671,34	637,58	

Source: own studies based on ENTSOG (2021c).

In the period between 2016 and 2020 (see: *Table 5*), a trend of increasing preference for LNG was noticed. 2019 turned out to be a record year for LNG deliveries, accounting for as much as 2.5 times more than 2016. The highest monthly deliveries were in March 2020, because the unraveling coronavirus pandemic in Europe. In contrast, the first half of 2021 noticed a decline in LNG deliveries due to an emerging deficit of the fuel.

Table 6: Injection of natural gas into underground gas storage

TWh/m	2016	2017	2018	2019	2020	2021
January	3,51	2,71	3,40	3,67	1,90	2,74
February	2,66	3,96	1,99	3,62	3,86	6,13
March	4,03	14,91	6,95	25,07	8,83	11,82
April	34,16	43,45	66,84	58,52	60,70	26,31
May	83,99	88,32	104,55	76,88	75,73	65,00
June	86,50	98,18	93,92	93,28	65,05	81,94
July	105,13	109,35	92,70	67,97	54,90	81,34
August	79,87	114,20	99,03	71,46	58,68	89,92
September	56,97	76,47	64,72	43,86	44,67	
October	21,95	46,31	49,12	24,74	17,34	
November	1,91	4,16	14,26	14,06	11,34	
December	2,68	3,68	8,84	11,03	6,80	
Total:	483,37	605,71	606,33	494,16	409,82	

Source: own studies based on ENTSOG (2021d).

In 2017 and 2018 (see: *Table 6*), the largest amount of natural gas was injected from European transmission systems into underground natural gas storage facilities. The process of injecting underground natural gas storage is dependent on the cycle of the seasons, so therefore in the first and last quarter of the year injections are essentially non-existent. The analysis concluded that 2020 was the least abundant year for injections into underground natural gas storage facilities.

Table 7: The withdrawal of natural gas from underground gas storage.

TWh/m	2016	2017	2018	2019	2020	2021
January	125,9	192,1	130,8	122,4	105,5	188,1
February	80,9	105,8	167,1	73,7	72,2	114,1
March	76,5	31,2	97,5	35,9	59,4	63,8
April	10,1	5,3	5,9	16,7	14,5	31,4
May	1,6	4,6	3,4	6,2	8,7	15,4
June	2,2	9,6	3,4	4,1	4,1	4,5
July	2,2	6,4	6,1	5,2	15,9	9,0
August	5,5	6,3	4,4	3,4	5,4	6,9
September	3,7	13,2	2,7	3,5	5,3	
October	16,4	7,0	6,3	6,4	15,4	
November	82,4	77,4	51,7	23,3	59,4	
December	142,3	138,2	79,5	47,9	114,2	
Total	549,8	597,2	558,8	348,7	479,9	

Source: own studies based on ENTSOG (2021d).

The most significant withdrawals (see: *Table 7*) of natural gas on the annual basis were in 2017. The injection of gaseous fuel into the European transmission systems usually takes place in the first and last quarters of the year, which is associated with autumn and winter conditions. The year 2019 recorded the smallest volume withdrawals from underground natural gas storage. It was found that in the first quarter of 2021 there was significant increase in interest in natural gas coming from storage infrastructure compared to the last two years.

Conclusion

Recent months have seen a strong recovery of economies as attempted recovery from the onset of the coronavirus pandemic, potentially translating into attempts to increase energy consumption. In addition, the revival in energy consumption, including natural gas, is due to weather conditions. The long heating season and cold winter mainly contributed to this trend. In European countries there are trends of slight growth and maintenance of stability in natural gas consumption. The data indicated that current storage stocks are at low levels, which may influence high natural gas prices. Overall, natural gas fits in as a transition fuel in the ongoing energy transition. Data indicated that LNG is becoming increasingly popular. An important conclusion is that transmission operators storing natural gas should have a well-developed infrastructure in order to be able to supply end consumers.

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Tomasz Chrulski – doktorant Szkoły Doktorskiej w Akademii Górniczo-Hutniczej w Krakowie (specjalność - inżynieria środowiska, górnictwo i energetyka). W 2012 roku ukończył studia magisterskie na Wydziale Wiertnictwa, Nafty i Gazu (AGH w Krakowie). Ukończył także studia podyplomowe z zakresu inżynierii gazowniczej na Politechnice Warszawskiej, transportu gazu i energetyki gazowej na AGH w Krakowie, metody statystycznej analizy danych na AGH w Krakowie. Obecnie jest także słuchaczem studiów podyplomowych z zakresu *Data Scientist – Big Data i systemy zaawansowanej analizy danych* na Akademii WSB. Od 2016 roku współpracuje z OGP GAZ-SYSTEM S.A. Obszar badawczy związany jest z prognozowaniem zużycia gazu ziemnego oraz analizą danych.

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