TRANSACTIONS OF THE INSTITUTE OF FLUID-FLOW MACHINERY

No. 137, 2017, 105–121

Klaudia Metelska[a], Rafał Biały[b], Tomasz Cieślik[a,c*] and Adam Szurlej[a]

Comparison of electricity generating from natural gas and from other sources in selected EU member states and in the USA — A review

[a] *AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, Mickiewicza 30, 30-059 Kraków, Poland*

[b] *AGH University of Science and Technology, Faculty of Energy and Fuels, Mickiewicza 30, 30-059 Kraków, Poland*

[c] *Institute of Nuclear Physics, Polish Academy of Sciences, Radzikowskiego 152, 31-342 Krakow, Poland*

Abstract

The analyses scale of natural gas use for power generation in selected countries have been analyzed. In the USA natural gas has strengthened its position as fuel in the electricity generation sector, while in the EU member states opposite tendencies were observed. One of the main reasons for these differences are significantly higher prices of natural gas in EU member states in comparison to prices in the USA. The article examines the relationship between gross domestic product and natural gas consumption. Moreover, the costs of electricity obtained from different sources were compared, with particular emphasis on technologies based on natural gas.

Keywords: Gas production; Gas price; Power generation; Production for electricity

1 Introduction

Natural gas is an important carrier of primary energy in the European Union. It covers 25% of primary energy supply and is mainly used for producing electric-

*Corresponding Author. Email adress: tomasz.cieslik@ifj.edu.pl

ity, heating, as an industrial raw material, and, on a marginal scale, as a fuel in transport [1].

With regard to Poland, the investment climate recently appears to be favourable for power generation based on gas. However, there are several barriers that effectively limit the development of gas-fired power generation. One of them is the high cost of producing electricity from natural gas. At present this cost is significantly higher when compared to brown coal, which currently plays a vital role as fuel for the Polish energy sector. Use of solid fuels in the case of Poland is attractive due to relatively large reserves in comparison to other European countries. With regard to natural gas, import is necessary to balance domestic demand (less than 30% is extracted from own deposits). Progress may be observed in the area of investment projects in gas energy, for example, combined cycle gas turbine (CCGT) units of 450 MWe and 240 MWe in Stalowa Wola, 463 MWe in Włocławek and Płock [2]. It is expected that by 2020 there will be a nearly threefold increase in electricity generated with natural gas-fired power sources. The development of gas energy can also be observed globally (in 2013 natural gas was second after coal as a resource for electricity generation, with a 22% share) [3]. In the future, gas energy development might be influenced by legal regulations intended to limit emission of pollutants. The eco-friendly qualities of gas units, their high flexibility, relatively short construction time and lower costs of investment per unit of power are arguments in favour of developing gas power. The main problem, however, is natural gas price, which in Europe is substantially higher than in the USA, for instance. Nevertheless, it can be noticed that in the first half of 2016 natural gas price differences between the USA and the EU shrank and the price ratio at present is approximately 1:2, as compared to the 1:3 ratio in 2013 [4].

2 The analysis of gas prices and gross domestic product in the USA and the EU

The relation between gross domestic product (GDP) growth and energy consumption has been analysed many times in scientific publications worldwide. Some examples include analyses of the situation in the USA, Poland, Greece, Spain, Italy, Turkey, Portugal and many other countries [5–7]. Having performed a review of literature which included 83 articles concerning the relationship between GDP and energy consumption, it was observed that 52% of all the articles supported the feedback hypothesis which states that there is a mutual relationship between GDP and energy consumption [8]. More than one quarter of the articles put forward the growth hypothesis which argues that causality runs from

energy consumption to growth of GDP. About 10% of the studies emphasized the conservation hypothesis which says that relationship runs from GDP growth to energy consumption and energy saving may have a detrimental effect on GDP growth. The remaining 10% of the studies pointed to the neutrality hypothesis whose main premise is the lack of correlation between GDP growth and growth in energy consumption. Therefore, it is worth comparing GDP of certain countries as an introduction to the analysis of the development of gas power in the sector of electricity production.

GDP per capita has been presented for selected EU member states and the USA (Fig. 1). Additionally, changes in GDP for these countries in years 2004 to 2014 were demonstrated. It can be stated that the last world economic crisis in most of these countries ended in 2010 [9]. Since that time the GDP of EU-28 has been on the rise. Total GDP for the 28 European Union member states (EU-28) in 2014 reached EUR 13.9 trillion. The USA's GDP, in comparison, was EUR 13.1 trillion. In 2014, the highest GDP per capita among the examined countries was noted in Denmark and Sweden, EUR 45 500 and EUR 44 300, respectively. Romania and Bulgaria tailed the list with EUR 7 500 and EUR 5 800 per capita, respectively. When compared to other countries in the analysis, USA has a very good result with EUR 41 100 per capita. This figure is higher from the EU-28 average (EUR 27 300 per capita) and the euro area average, also known as EA-19, (EUR 29 800 per capita). Poland, as a developing country, does not look impressive with one of the lowest GDPs per capita in the EU – EUR 10 700. In the case of Poland, Romania and Slovakia, i.e., countries with low GDP per capita, some positive insights may be drawn from the analysis of GDP changes in years 2004–2014. It may be observed that Poland recorded the third highest (after Romania and Slovakia) GDP growth of nearly 101.5%. Within the above time frame Greece had the weakest performance and stood out as the only country that recorded negative GDP growth (-7%). If we look at Eurostat data on accumulated GDP growth in the years 2008–2014 in EU member states, Poland stands out with a 23.8% growth in GDP. Assuming further GDP growth and relatively low electricity consumption per capita in Poland (Tab. 1), one can expect a growth in demand for electricity and therefore an increase in the use of natural gas for power generation.

The analysis of natural gas prices for households (Fig. 2) and industrial consumers based on available data [10] shows that the average price of natural gas for households in EU-28 countries was EUR 72 per MWh in 2014 and increased by 3% in comparison to 2012. In Eurozone countries the average gas price in the household sector was EUR 79 per MWh. Among the examined countries the

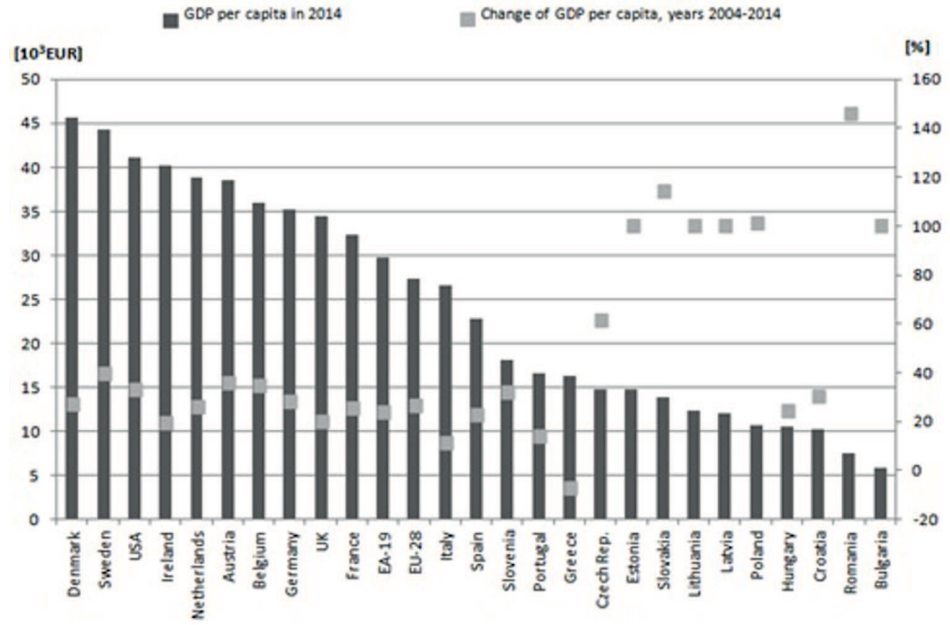

Figure 1: Summary of GDP per capita in selected EU-28 countries and the USA along with GDP changes in years 2004-2014 (compiled on the basis of [9]).

Table 1: Change in electricity consumption (MWh) per capita in years 1993–2013 in selected countries (compiled on the basis of [4]).

Year	Poland	Germany	United Kingdom	USA	Japan	France	China
1993	2.978	6.288	5.492	12.262	6.789	6.453	0.663
2013	3.938	7.019	5.407	12.988	7.836	7.374	3.762

highest natural gas prices within the analysed sector in 2014 were found in Sweden (EUR 114 per MWh), Portugal EUR 104 per MWh, Spain (EUR 96 per MWh), Italy (EUR 95 per MWh) and Denmark (EUR 88 per MWh). The lowest prices in the EU were found in Romania (EUR 32 per MWh), Hungary (EUR 35 per MWh), Bulgaria (EUR 47 per MWh), Croatia (EUR 48 per MWh) and Latvia (EUR 49 per MWh). In the years 2013–2014 the highest increase in natural gas prices for household consumers was reported in Portugal and the United Kingdom – 11.5% and 10%, respectively. The most substantial decrease in gas prices within this sector took place in Lithuania and Hungary – 16.5% and 18.5%, respectively.

Natural gas prices in Poland in 2014 were close to the EU average, i.e., EUR 50 per/MWh with a 2% decrease as compared to 2013. Due to the 'shale gas revolution' natural gas price in the USA was lower than in the EU and fluctuated around EUR 28/MWh (despite the 6% price growth in comparison to 2013) [11].

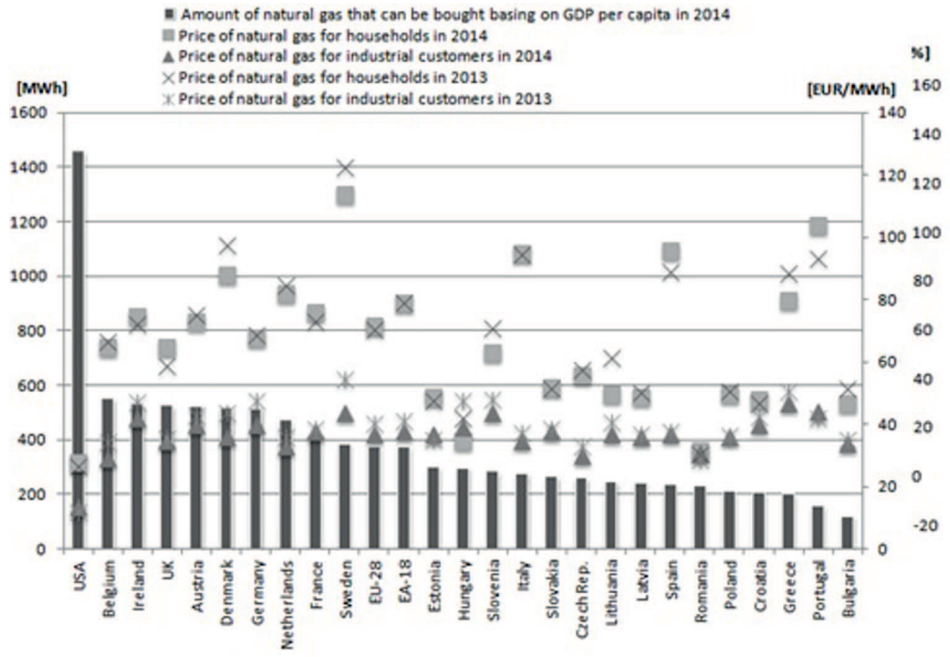

Figure 2: Comparison of natural gas prices for industrial consumers and households in the USA and selected EU member states years 2013–2014 and determination of purchasing capacity of households on the basis of GDP per capita in 2014 (the average price of natural gas in the U.S. was calculated using the mean exchange rate from 2014: 1 EUR = 1.33 USD, 1 EUR = 0.81 £(compiled on the basis of [10–13]).

Additionally the volume of natural gas (in MWh) that household consumers could buy depending on GDP per capita in 2014 were shown in Fig. 2. Due to low price and high GDP per capita the most favourable conditions were present in the USA, where GDP per capita allowed buying gas to provide more than 1552 MWh per year. As far as EU member states, shown in Fig. 2, are concerned, the most favourable ratio of GDP per capita to gas price in 2014 was observed in Belgium and Ireland, enabling purchase of 554 MWh and 536 MWh per year, respectively. In countries with the highest GDP, i.e., Denmark and Sweden, natural gas price was the main reason for the disproportion between 518 MWh and

388 MWh. In the poorest countries, i.e., Romania and Bulgaria, GDP per capita allowed for gas purchases in the amount of 234 MWh and 123 MWh, respectively. With respect to the above summary, an average Polish citizen could afford to buy only 214 MWh in 2014 (over 7 times less than the average US citizen).

In the Fig. 3 GDP per capita and prices of natural gas in the selected EU countries and USA in 2014 are compared. Considering GDP per capita, potential of purchasing natural gas that were worse than in Poland were in Croatia, Greece, Portugal and Bulgaria. In Croatia and Bulgaria it was due to lower GDP per capita that is 10 200 EUR and 5 800 EUR and the price of natural gas 47 and 48 EUR/MWh, respectively. In case of Portugal and Greece where GDP per capita were over 16 000 EUR the deciding factor was relatively high price of natural gas 104 and 80 EUR respectively. Also in the rich Scandinavian EU countries, this is Denmark and Sweden, because of high natural gas prices 88 and 114 EUR/MWh, the potential of purchasing natural gas was lower than expected. The most optimal conditions of purchasing natural gas in Europe (in the analyzed period) were in Belgium and Ireland where the prices of natural gas were 65 and 75 EUR/MWh and the GDP per capita were 36 000 and 40 200 EUR, respectively.

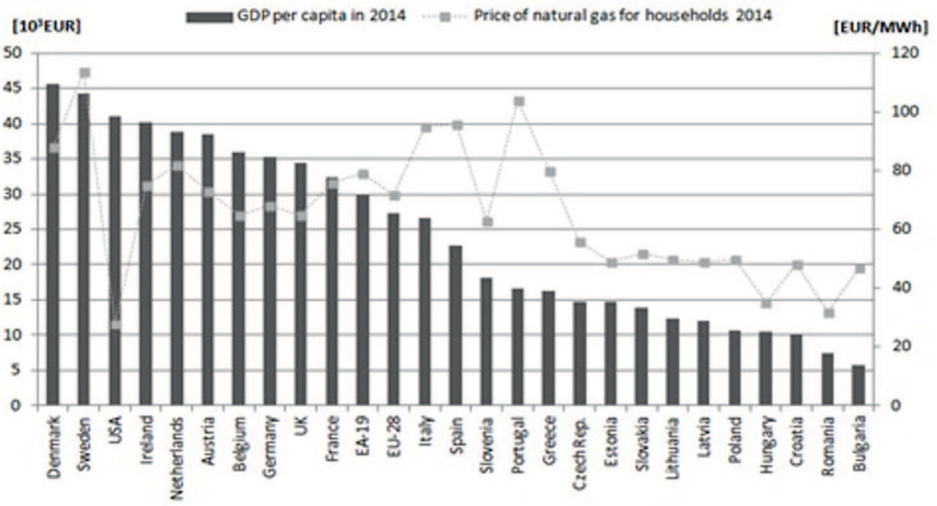

Figure 3: Comparison of GDP per capita and natural gas prices for households in the USA and selected EU member states in 2014 (the average price of natural gas in the U.S. was calculated using the mean exchange rate from 2014: 1 EUR = 1.33 USD, 1 EUR = 0.81 £) compiled on the basis of [9–11,13].

As far as industrial consumers are concerned, the highest prices of gas were found in Portugal and Greece: EUR 47 per MWh [10], the lowest in Belgium and the Czech Republic: EUR 29 per MWh and EUR 30 per MWh, respectively. Our analysis of natural gas price increases in the sector of industrial consumers in the years 2013–2014 (with respect to countries included in the analysis) has indicated that the biggest increase in price was recorded for Portugal – 13%. The price of gas in the analysed sector for Poland in 2014 was EUR 36 per MWh, similar to the EU average of EUR 37 per kWh in EU-28. By way of comparison the average price of natural gas in the industrial sector in the USA at the time was merely EUR 14 per MWh. This significant difference in price also encourages European companies, from the chemical industry for example, to invest in production facilities in the U.S. [12,13]. When analysing barriers to the development of natural gas power generation in the EU, one should underline the importance of supply security and building an integrated electricity market established upon free market competition and implementation of environmental policy (decarbonisation of industry).

The current technical capabilities regarding supplies of natural gas to the European market are sufficient to secure demand for natural gas in the EU. Since European terminals have been used only to a low capacity (under 20%) in the last few years, there is a huge potential for increasing imports of natural gas in the event of an increase in demand. When analysing security of natural gas supplies to the EU we should bear in mind the tension between Ukraine and Russia. When the conflict began in 2013, supply of natural gas from Russia to Ukraine was restricted. Luckily for Ukraine gas began to be transferred using reverse flows and cross-border interconnections from EU member states. The annual capacity of these interconnections is approximately 6 billion cubic metres (bcm) from Hungary, 1.5 bcm from Poland and 9.7 bcm from the territory of Slovakia. Poland, thanks to its location and commissioning of an liquided natural gas (LNG) terminal offering a capacity of 5 bcm per year, and later possibly 7.5 bcm per year, may become an important gas hub for countries in north-east Europe [14]. In order to use this opportunity interconnections with Ukraine would have to be developed and new interconnection with Baltic states would need to be built. This would have the added value of connecting to the Danish transmission grid for direct importing of natural gas from the Norwegian continental shelf. Importantly, PGNiG (Polish Petroleum and Gas Mining) holds shares in Norwegian concessions and has been withdrawing natural gas and oil from the Norwegian continental shelf for a few years.

Another important factor that has an impact on the development of a power sector based on natural gas is the liberalisation of the gas market and the creation of a single energy market in the EU. This process started more than ten years ago and has been continued under legislative pressures of the European Commission. Building a single energy market in the EU could lead to reductions in energy prices. However, we must bear in mind that price reductions cannot be the main argument for a decision on liberalisation and integration of the energy market, but rather its consequence [15]. Success of electricity market liberalisation depends on creating a market characterised by openness, regulation of market quality, participation of private companies and adequately high GDP [16]. This is why the EU single energy market should be based on fair and clear rules of competition for all participants.

Further efforts to achieve targets connected with reducing greenhouse gas emissions will be important for increasing the share of natural gas in electricity production in Europe. The agreed targets clearly indicate that by 2050 emissions of these gases are to be reduced by 80% (in comparison to 1990 levels), reducing CO_2 emissions from the power sector by 85% [17]. These ambitious plans require an international agreement and signatory countries determined to implement the measures they have undertaken. The climate changes that have taken place to date will force a shift in the perception of potential investments related to construction of new power stations or upgrading existing ones [18]. It seems that these changes will especially affect economies producing large amounts of energy from coal.

3 Overview of natural gas consumption for power generation in the USA and the EU

3.1 The United States of America

The United States have 9.571 bcm of natural gas reserves. In 2014 there was demand for 756 bcm, while production stood at 707 bcm [19]. According to BP data, the demand slightly exceeded production in the USA in 2015: 778 to 767.3, respectively. A similar difference had been observed in the previous year.

Currently, we may observe an increased demand for natural gas from the U.S. electricity generation sector. An increase in electricity generation from natural gas between 2001 and 2015 up to over 1000 TWh a year was observed. At the same time there was a drop in electricity generated from coal from 1 800 TWh to less than 1000 TWh [20]. This change may be explained by the fact that the USA

have been extracting shale gas on an industrial scale since 2005. In 2005, 28% of natural gas was produced from shale rock. This value is expected to reach 49% in 2035 [21]. Taking opportunity of the relatively favourable geological conditions, including shallowly located deposits of shale rock used for obtaining shale gas, the USA increased its production. Forecasts indicate that the United States will join the ranks of net exporters of natural gas within the next few years. By 2035 year shale gas withdrawals are to reach 35% of total gas production in the U.S. market. In the period from 2008 to 2015 the United States increased production of gas by 196.5 bcm and reduced the amount of imported gas (Fig. 4).

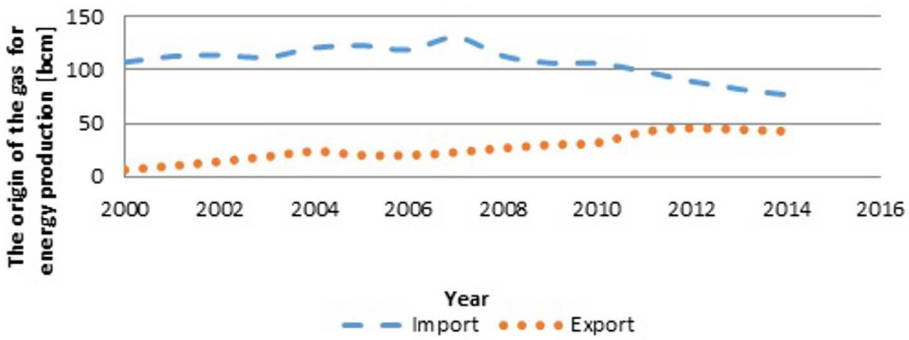

Figure 4: Change in the structure of the gas market in the USA (compiled on the basis of [20]).

Currently, gas is being imported to the USA by pipelines from Canada and Mexico and through LNG terminals from Algeria, Norway and Trinidad [20]. In 2019 there will be 7 terminals for natural gas liquefaction in the USA, with a total capacity of 45 MTA, amounting to 10% of world LNG production [22]. An increase in the amount of electricity produced from gas was observed from January 2015 to January 2016. Almost 30% of total energy generation comes from gas power plants and gas combined heat and power plants. At present, most energy in the USA is produced from natural gas. According to projections a new record in terms of electricity produced from gas will be set in 2016 with 3.8 million MWh of daily production [23].

3.1.1 Use of natural gas for production of electricity in the USA

There had been a significant increase in gas-generated electricity, from 681 TWh in 2002 to 1272 TWh in 2014 [20], which amounts to 28% of the domestic production of electricity (Fig. 5). Within ten years there had been an increase in the number of gas power stations from 1670 in 2004 to 1770 in 2014. There are more gas

power stations on the east coast and in 15 states they are the primary source of electricity [20,24].

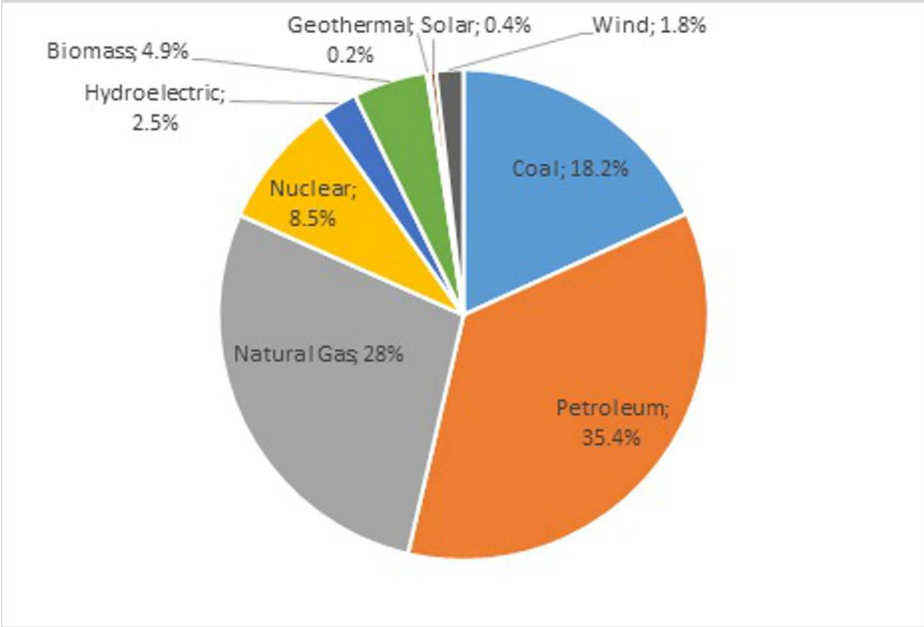

Figure 5: Electricity generation in the USA by source in 2014 (compiled on the basis of [20]).

The cost of 1 MWh of energy produced from natural gas is approximately 54 EUR. The price depends mostly on the technology used for production of energy and the location of the power plant. The cost of electricity obtained from gas is lower than the cost of electricity generated by: wind farms, solar panels, coal-fired power plants, geothermal energy, nuclear power plants and hydropower (Tab. 2)[25].

3.2 The European Union and Poland

Europe as a continent is not rich in natural gas. EU member states in total have proven reserves of 1 302 bcm of natural gas, which is less than the reserves of Libia, for example. The EU member states with the largest reserves are the Netherlands (675 bcm) and the UK (206 bcm). In 2015 demand for natural gas in the EU was 402 bcm, while production stood at 120 bcm (the lowest in history), close to Norway's volume of production. It is worth adding that in the years 2004–2015 production of natural gas in the EU decreased nearly by half [24]. The

Table 2: Electricity prices depending on source (compiled on the basis of [25])*.

Source/price	Wind farms	Solar panel	Coal power plants	Gas power plants	Geothernal	Hydroelectric power plants	Nuclear power plants
Min. price [Euro/MWh]	62	107	58	49	89	20	20
Max. price [Euro/MWh]	143	215	67	58	179	53	107

*Currency courses on the basis of: http://www.nbp.pl/home.aspx?f=/kursy/kursya.html

proportion of natural gas obtained from own production to total demand for gas is similar in the EU and Poland, at around 30%. As for Poland, own production is maintained at the level of around 4 bcm/year [27]. Currently, a gradual decline in the use of natural gas for electricity generation and fuel in municipal services may be observed. Marked changes can be seen, especially for the period 2010–2014 (Figs. 6 and 7) [20,27–28].

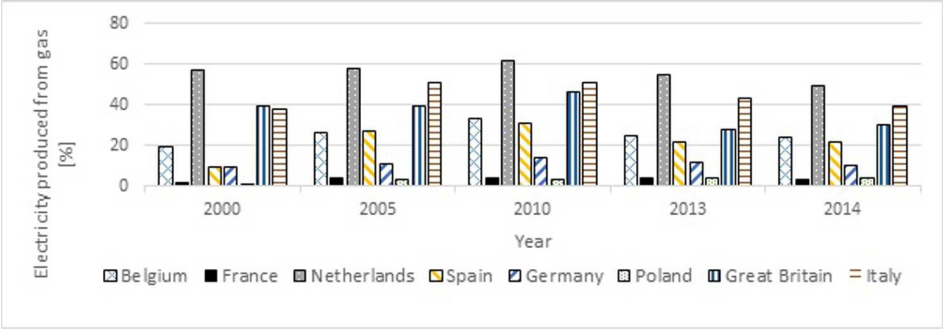

Figure 6: Electricity produced from gas in selected member states of the EU. (compiled on the basis of [27,28,36]).

A fall in gas consumption for power generation and municipal services may be explained above all by increased use of renewable energy sources (RES) and the gas-coal price relation, which is influenced by changes in the US market and increased supplies of coal to the European market. Import of coal from the United States reduces coal price, which in turn increases the competitive advantage of coal over natural gas on the European market. In countries, where natural gas does not contribute to a large share of electricity production the ongoing changes

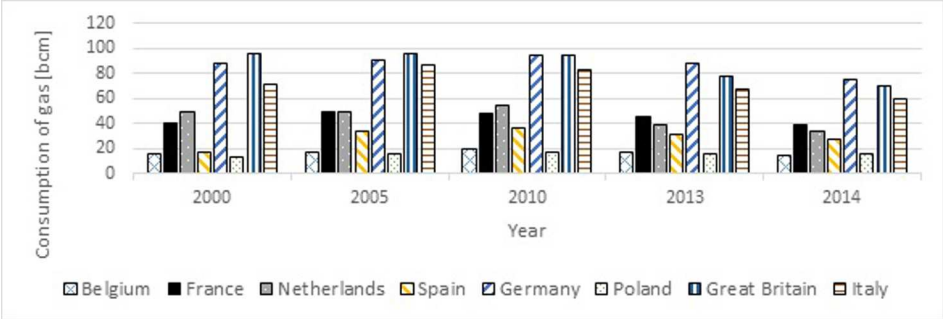

Figure 7: Total consumption of natural gas in selected EU member states (compiled on the basis of [26]).

should be explained by reduction in domestic production, RES development and low prices of CO_2 allowances [27].

3.2.1 Import of natural gas

Currently natural gas is imported to Europe from Norway, Russia, Africa and the Middle East. The European Union has LNG terminals in the UK, Poland, Spain, France, Greece, Belgium, Portugal, Italy, Lithuania and the Netherlands. The total capacity of terminals after upgrades is estimated to reach 147 MTA (million metric tons)in 2016. It should be noted that countries such as Estonia, Finland and Latvia were supplied by Russia in 100%, whereas this figure was 59% to 89% for Bulgaria, Austria, Hungary, Slovakia, Slovenia and Poland. Poland reduced its dependence on Russia from 61% in 2009 to 56% in 2013 [22,29,31,33].

3.2.2 Use of natural gas for the production of electricity in the EU and Poland

Poland produces 5.1–6.3 TWh of electricity from natural gas, which comprises about 3–4% of total electricity generation. Low consumption of natural gas in the Polish energy sector is conditioned first and foremost by a lack of proper and stable support of the state. An example of this may be the so-called yellow certificates, which were restored in 2014. At the moment there are new investments in Poland aimed at increasing the share of gas in electricity generation using the CCGT units in Stalowa Wola (450 MW_e), Włocławek (473 MW_e) and Gorzów (138 MW_e). We may expect that consumption of natural gas for power generation will double in the next few years [27].

Between 2010 and 2014 the amount of electricity produced from natural gas in the EU declined from 710 TWh in 2010 to 430 TWh in 2014 [32]. Countries using natural gas for generation of energy may be divided into three groups [32]:

I producing 1 to 10 TWh of energy (Fig. 8),

II producing 10 to 50 TWh of energy (Fig. 9),

III producing 50 TWh of energy and above (Fig. 10).

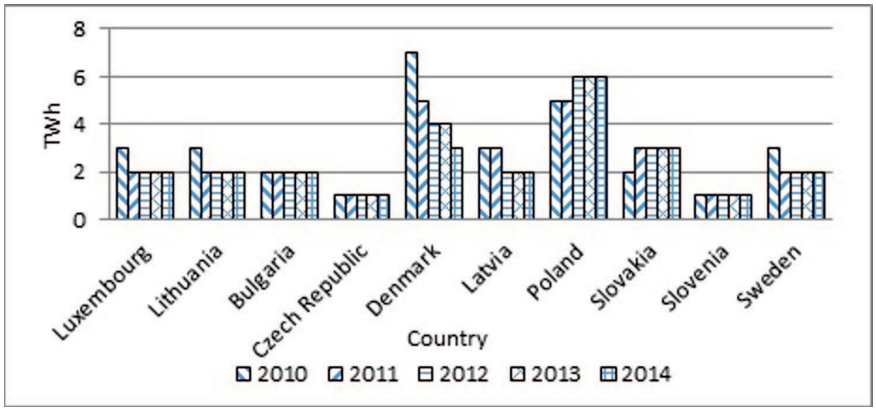

Figure 8: Electricity produced from gas in group I countries (compiled on the basis of [32]).

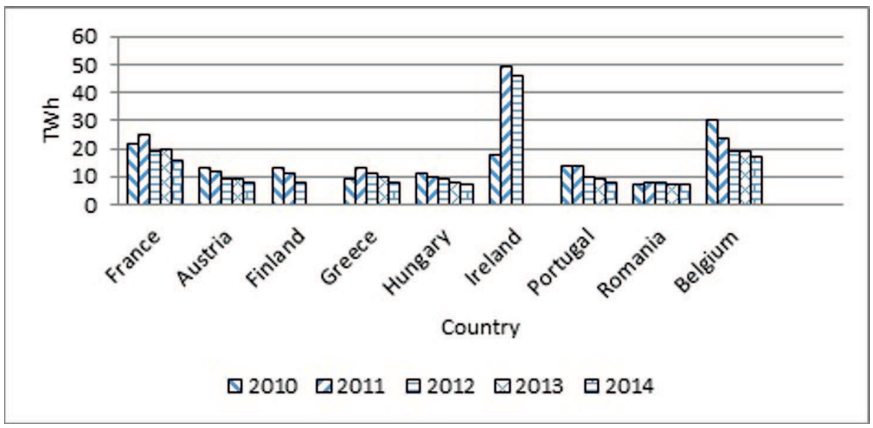

Figure 9: Electricity produced from gas in group II countries (compiled on the basis of [32]).

In group I countries, fluctuations of natural gas use were small. In the case of Denmark, gas consumption for the production of electricity decreased more than

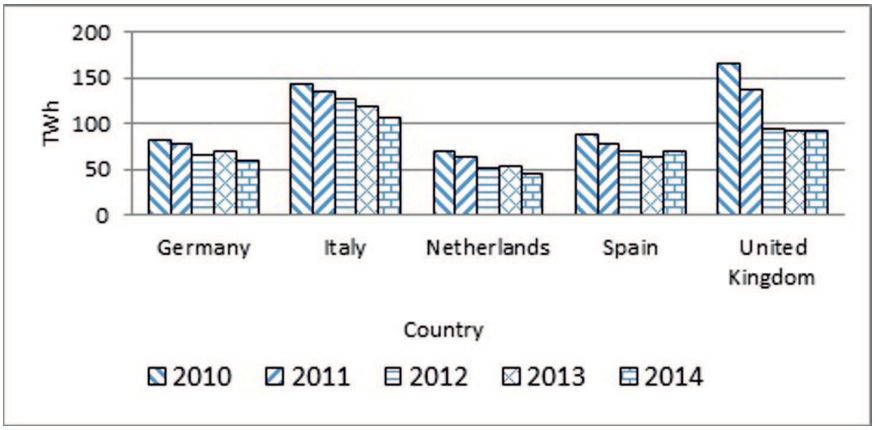

Figure 10: Electricity produced from gas in group III countries (compiled on the basis of [32]).

50%. In group II, Finland and Ireland ceased to produce electricity from natural gas. Group III is characterised by most marked changes, where the differences between the year 2010 and 2014 amount to 73 TWh in the UK.

3.2.3 Prices of electricity in the EU and Poland

The cost of 1 MWh of electricity produced from natural gas is approximately EUR 100. The price depends primarily on technological solutions used in electric power generation and taxes in a given country (Tab. 3) [34,35].

Table 3: Price of electricity in the European Union (EU) and Poland (PL) according to source (compiled on the basis of [35])

Source/price	Wind farms		Solar panel		Coal power plants		Gas power plants		Geothermal		Hydroelectric power plants		Nuclear power plants	
	UW	PL	UE	PL	UE	PL	UE	PL	UE	PL	UE	PL	UE	PL
Min. price [Euro/MWh]	50	60	100	130	30	40	50	80	30	–	30	50	80	–
Max. price [Euro/MWh]	110	180	125	150	50	50	80	100	90	–	160	250	110	–

4 Conclusions

The article shows what is the importance of natural gas in the European Union as a carrier of primary energy. EU policy is based on three pillars: competitiveness, sustainability and raw material safety.The diverse level of prices of natural gas is the basic factor that the scale of application depends on. Prices of natural gas in the European Union are higher than in the USA, however 2016 has seen a decrease in the difference in relation to the previous years. As far as Poland is concerned, an increase in the power generation by units operating on natural gas is expected before 2020. In 2017 alone, combined cycle units in Gorzów and Włocławek were commissioned. The domestic market of natural gas, as compared to other EU markets, has developed dynamically in the recent years. Natural gas is also expected to become more important in the future, as evidenced by scenarios where a 55% synergy of gas and renewable energy sources is demonstrated [37,38]. In the European Union, there has been a significant decline in the use of gas for energy purposes, from 730 TWh to 430 TWh between 2010 and 2014. This decrease was influenced by an increase in renewable energy sources use and a decrease in coal prices. In the United States, gas prices have remained at a low level for many years, thanks to the so-called shale revolution, which translated into an increase in gas production. Low prices encourage the development of gas energy in the USA, which is a leading country in the production of electricity from natural gas.

Acknowledgement The paper is an effect of the statutory project no. 11.11.190.555.

Received in November 2016

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