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THE USE OF UNCONVENTIONAL GAS RESOURCES AND THE DEVELOPMENT OF ENERGY MARKET

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Abstract: The author discuss the problem of unconventional natural gas extraction and its impact on the gas market. The article presents the history of natural gas extraction from unconventional sources, focusing on shale gas and the areas of its current and potential extraction. The text also briefly describes the main ecological and social hazards resulting from shale gas extraction. The author presents the distribution of potential and presently exploited sources of unconventional gas, as well as the impact of its extraction on the regional (North America) and global gas market. The text also briefly describes the shale gas extraction technology and the main hazards to the natural environment.

Key words: shale gas, unconventional fuel, global and regional gas market, USA, China

1 INTRODUCTION

Nowadays, fuels serve many purposes, they are used for heating and the whole industry depends on them. More and more energy is consumed due to the increasing global population and rapid economic development, growing production and consumption of goods and services. The world consumption of primary energy increased from 5532 Mtoe (million tons of oil equivalent) in 1971 to 11740 Mtoe in 2006 (212%) (Soliński and Gawlik, 2012, p.146). According to Bartosik (2009), in the second half of the 20th c. people used more energy than all the previous generations.

Energy can be classified as primary energy (it takes any form, does not undergo conversion or transformation, its carriers include fossil fuels, such as coal, oil gas, biomass, nuclear fuels) or secondary energy (it takes any form of converted primary energy or another secondary energy, its carriers include electricity, steam, compressed air). Primary energy carriers used to be called energy resources, while secondary energy carriers are means to transport energy (Hardy, 2010).

The World Energy Council (WEC) divides fuel stocks into resources (proved amount in place) and proved recoverable reserves (Soliński, 2008). Another classi-

fication of energy sources is quoted after Wrzosek (1977) by Wrona and Rek (1998, p. 244), who distinguish between two main groups:

1. renewable sources: inorganic (solar ad wind energy, inland waters and sea energy) and organic (biofuels: wood, rice and sugar cane waste; human and animal physical power; animal fuels – manure).
2. non-renewable: fossil minerals (solid: black and brown coal, peat; liquid: petroleum; gas: natural gas, methane, oil shale and sands) and fissile minerals (uranium, thorium).

As regards availability, commonness and traditional use, we speak of conventional and unconventional energy industry and sources. Conventional energy industry has a long tradition and currently plays the most important role in energy production. It is based on popular and easily accessible conventional sources of energy, including black and brown coal, petroleum, conventional natural gas and fissile materials. Unconventional energy industry is based on innovative, often prototypical solutions and so far has made a fraction of the overall energy production (Hardy, 2010). It makes use of unconventional resources, such as natural gas and petroleum obtained from shale, natural gas from coal or sandstone formations (tight gas), or gas hydrates.

Currently, about 86% of energy comes from non-renewable primary energy sources (Bartosik, 2009). Net resource depletion as a result of intensive exploitation is unavoidable, which is a serious problem (Bradshaw, 2010a). First signaled in the report entitled *The Limits to Growth*, prepared under the auspices of the Club of Rome in 1972. It revealed alarming forecasts regarding the possibility of natural resources and food depletion, as well as environmental pollution. Though repeatedly criticised and often inaccurate, the report initiated a world-wide discussion on global resources depletion.

It is believed that it is impossible to say exactly when individual resources will run out because their new varieties are constantly being discovered. On the other hand, their depletion in the future is thought to be certain. With the present average annual increase in energy consumption (2%), it is estimated that the existing available reserves of all fossil sources of primary energy will have been depleted in 70-120 years' time. It is also assumed that using new (e.g. unconventional) primary energy resources, such as methane hydrates, and exploiting the disappearing reserves reasonably will give us additional 260 years (Bartosik, 2009, p.8).

Global energy resources depletion makes finding new energy sources essential. In recent years they have been intensively searched for in the United States. The main target is to invent and implement an effective technology of natural gas extraction, mainly from shale formations. Many works devoted to this "shale revolution" have been published by geologists, geo-physicists, and people dealing with environmental protection and international politics. However, so far it has not raised much interest among geographers.

The main aim of the article is to present the most important sources of unconventional gas in the world, describe its extraction sites, as well as the economic effects of gas extraction on the market of energy resources, focusing on the gas mar-

ket. The article is based on a literature review, Internet publications, as well as on statistical sources regarding global energy resources extraction. It is divided into four parts. The first one is the introduction, the second one describes the energy resources market in the globalization era. Part three presents shale gas sources all over the world. Part four is conclusions summarizing research results presented in the article.

2 GLOBALIZATION VS. THE GLOBAL MARKET OF ENERGY RESOURCES

Globalization has been influencing the world's population for over 35 years. It should be understood as a global multidimensional process of a growing interdependence of economic, political, social, cultural, environmental and technological aspects of life. The main features of globalization include the development and liberalization of international trade, deregulation of national economies, development of information and communication technologies, culture universal, the decreasing role of state borders, and the growing mobility of people and goods (Giddens, 1990; Haggett, 2001; Holton et al., 2006 etc).

Globalization is closely connected to neoliberalism. Over the past 30 years, the relation between them has deepened. They both rapidly developed in the early 1980s, as a result of the neoliberal policy favoured in the USA (at the time of Ronald Reagan's presidency) and Great Britain (when Margaret Thatcher was the Prime Minister).

The energy sector is the pillar of the functionality and stability of today's economy and society, not only at the state level, but also globally. Energy supply determines all human activity, and withholding it means a catastrophe in all social and economic areas. Energy is becoming an increasingly important piece on the global geopolitical and economic chessboard.

Globalization has many faces, both positive and negative. Most authors stress its economic aspect, as it intensifies international competition and creates development opportunities. The same can be said about energy. The world crisis, which affected global economy the strongest after 2008, made the world leaders realize the potential effects of fossil fuels depletion and the need to find alternative energy sources. Selling petroleum, gas and coal abroad plays a significant role as a source of income for many world economies. On the other hand, fuels supply is indispensable in the countries which base their economy on the process industry. Both these situations are often used to exert political pressure internationally.

International Energy Agency (IEA) conducted a comprehensive study of 800 main world oil fields. It was concluded that traditional sources of petroleum may run out faster than it was originally assumed. IEA unofficially announced that global economy has already reached the "oil peak". After half of the petroleum reserves were used, its extraction started to decline, which will cause global economic problems. Similar forecasts regard the world extraction of natural gas (gas peak). In this

situation, the use of alternative energy resources, such as oil sands or shale gas, will become a major trend in energy economy. The pressure to use this type of resources will be growing, despite the fact that their extraction and conversion are very difficult and often more harmful to the environment than the use of conventional resources. The exploitation of shale gas is often connected with local communities resistance due to the fear of environment degradation (Kopačka, 2010; Kronenberg, 2014; Michalski and Ficek, 2016).

At the time of the global economic and financial crisis, the state's social role is being discussed in many countries. It is commonly agreed that globalization has caused a crisis of the welfare state, which was popular after World War II (e.g. in Western Europe). In the 1950s to 1970s, the idea of a caring state helping its citizens was considered to be one of the main achievements of the post-war socio-economic modernization. Currently, it seems necessary to drastically reduce expenses for this purpose because of the decreasing economic power of many developed countries, which are losing economically in the competition with the developing countries (China, India). Reducing social expenditure seems inevitable in order to deregulate the market and create a competitive national economy in the world (Keller, 2007). Again, the issue of new energy resources emerges here, because they increase the economic competitiveness of the countries which possess them and attract investors. Extracting these resources lowers energy production and import costs, creates jobs and makes export possible, generating additional profits.

Successful state management in the times of globalization requires:

- Balanced public finances (low deficit and public debt), financial surplus, stable financial markets. This is possible to achieve with additional financial means obtained from shale gas export.
- Business environment improvement, properly constructed tax systems, market flexibility (including labour market), low level of regulation and bureaucracy in the country, combating corruption, good governance and properly functioning public institutions.
- Education and research development, computerization, introducing knowledge-based economy, combining scientific research with practical application in economy. Income from shale gas extraction (e.g. from concession fees) may be used to subsidize such activity.
- Democratization of large international economic organizations, moderating the excessive influence of large and rich countries.
- Influential pro-social and powerful international economic organizations, e.g. the World Trade Organization (WTO), caring mostly about how to increase the world's wealth.
- Effective solutions as regards global and national energy management, which will reduce economic costs, create additional income that may be used for combating poverty, investing and developing demographic programs. Profits from shale gas extraction (e.g. from concession fees, taxes paid by the mining companies) can be used to subsidize such activities.

As it was mentioned earlier, the global danger of fossil fuels depletion is extremely serious. Alternative renewable energy sources (e.g. wind, sun), will be important in the future but currently they are not very significant on the global energy market. It is estimated that in the foreseeable future fossil resources may be completely used up and the Earth may face a civilization breakdown (Bartosik, 2009). The role of energy resources must be also considered in the context of energy security of individual countries and regions. The world distribution of fossil fuels is very uneven (Bradshaw, 2009). The largest deposits of natural gas are found in the United States, Russia, China and India. Petroleum is mostly found in Saudi Arabia, Iran, Iraq, Kuwait and others, and the largest deposits of unconventional natural gas belong to Russia, Iran, Qatar and Saudi Arabia. The majority of these countries are also the largest producers, and some of them the largest exporters of these resources in the world too (Soliński and Gawlik, 2012).

The 1970s and 1980s oil crisis showed that unrest on the world fuels market may lead to a deep economic crisis in individual countries and groups of countries. The first big energy crisis was connected with the oil embargo proclaimed by the OPEC countries on the countries supporting Israel in the Jom Kipur war, waged against Egypt and Syria in 1973. The other one was related to the revolution in Iran and the limited export of oil from this country. As a result of both, interest in new conventional and unconventional fuels considerably increased. Moreover, many countries, mainly European, decided to invest in renewable energy sources (biomass, solar energy, wind energy, hydropower). These, however, are unable to replace fossil fuels at the moment.

Some countries are trying to use their fuels deposits as an element of a political-economic pressure exerted on other countries, which was already observed during the Jom Kipur oil crisis. In 1973, the Arab countries of OPEC (Organization of the Petroleum Exporting Countries) imposed an embargo on oil trade with the countries supporting Israel in this war, mainly the USA. That decision resulted in petroleum prices rising on the world markets. The United States (the largest consumer in the world) could not satisfy its needs using internal sources and started to purchase petroleum on external markets, other than the OPEC countries. This in turn increased the demand for petroleum from outside the Middle East and its prices soared, from $3 (Money-Of-The-Day) in 1972 to about $11 in 1974, i.e. by about 360%. After the Iranian revolution and the reduction of petroleum export from that country, its price increased to about $34 (WORLD OIL PRICES, 2013).

Nowadays, fuels are also used as an element of economic and political pressure. Russia, for instance, has been trying to do this for the last several years, using the Gazprom state company (Michalczyk, 2011; Młynarski, 2012 etc). Examples of Russia's influence on the neighbouring countries, depending on the import of Russian fuels include the gas conflicts with Ukraine in 2006 and 2009. By limiting the supply from pipelines traversing other European countries, Russia affects them as well (Bradshaw, 2010b). Huge fuel reserves are also found in politically unstable countries or those under authoritarian rule (e.g. Venezuela, Iran, Libya, Nigeria, Al-

geria, or to some extent Saudi Arabia), where the decisions concerning extraction and export may be taken irrationally and destabilize the global market.

In today's world, there is a large group of countries economically based on fuels extraction and export (e.g. Saudi Arabia, Arab Emirates, Nigeria or Venezuela as well as Russia). They are mostly developing countries, which do not have other significant assets than energy resources. On the other hand, there are countries (e.g. Japan, South Korea, Great Britain or Italy) with very few or sometimes no resources at all, but having a well-developed economy. A particular case is China, which has sizable deposits, but also imports large quantities. For the latter group of countries, having natural resources (including fuels) is the basic condition for further development.

The United States and Russia are in different situations. The former has large deposits of different resources (petroleum, natural gas, black coal), but it also imports large quantities to satisfy the needs of its highly advanced process industry. Moreover, selling some resources (e.g. gas) abroad, outside the NAFTA countries (North American Free Trade Agreement) was earlier formally forbidden in the USA. However now (2017) the export of LNG gas is possible due to the change of US policy and introduction of "LNG Now Act of 2017". Thanks to this the LNG gas has already entered the Central European market. First LNG transport from USA reached Lech Kaczyński LNG terminal in Świnoujście (Poland) on 22nd of May 2017. Later polish gas supply firm PGNiG signed a medium-term five-year contract with US company Centrica LNG for LNG gas supplies from the United States. The contract will enter into force in 2018 and includes nine LNG transports from USA to Poland (GAZ LNG, 2017).

Russia has been struggling with the problems of the socio-economic and political transformation and the decline of the outdated industry since the fall of communism. However, it still remains an important country as regards industrial processing (metallurgy, chemical industry, electrical and mechanical engineering). On the other hand, it remains the world leader in fuels extraction and export. The resources and their export are treated in Russia as a strategic part of the country's economy. They are also an element of Russia's political game played with other countries, mostly European.

The uneven distribution of fuels, varying consumption and the use of resources as a political tool lead to a situation where many countries consuming large quantities of energy (mainly imported) are looking for new sources. Examples of such countries include the United States, Canada, Japan or European Union countries, e.g. Germany, Great Britain or Poland. Apart from searching for their own deposits, they also want to liberalize the fuels supply market. The principle of guaranteeing supplies from one reliable source (supply security) was replaced with a policy of securing the supplies by liberalizing the fuels market, in order to introduce stronger competition on the internal extraction market, as well as to import the resources from various areas. A large number of suppliers is to guarantee more security, because if the supply from one source is withheld, there are still many other suppliers left to fall back on (Szablewski, 2010). Nowadays (2017) for example there has been a sig-

nificant change in the Polish energy policy. The Lech Kaczyński LNG terminal in Świnoujście (Poland) is functioning and there are plans to develop it. Besides building of a gas pipe called Baltic Pipe from Poland through Denmark to Norway is planned. It is also planned to integrate countries of Central and Southern Europe lying between Adriatic, Baltic and Black Seas around so called Three Seas initiative. It is planned to built a common energy market there, which will be based among others on LNG supplies from the USA (REUTERS, 2017).

3 SHALE GAS – EXTRACTION, DISTRIBUTION AND IMPACT ON THE GAS MARKET

Extraction and distribution of shale gas

The growing demand for energy will require finding its new, unconventional sources. This is also true about natural gas (*blue fuel*), which is a mineral resource containing mainly methane and found in the earth's crust in the form of non-associated and associated gas deposits. Natural gas may be also divided into that found in conventional and unconventional rock formations. It was being formed for millions of years, seeped through rock layers, rising to the surface until it was trapped in porous rock sealed with impermeable rock. Such rock traps are reservoirs from which conventional gas is extracted by drilling (Zarębska and Baran, 2010). After extraction, natural gas can be transported via pipelines. It can also be liquefied (LNG) and transported by ships. Currently, over 20% of the global gas export is done this way, with Japan as a major importer.

Gas was used as fuel for lighting cities already in the 19th c., but the true development of gas extraction and use in industry took place in the second half of the 20th c., especially after the 1970s oil crisis. At present, gas is used in agriculture, heating, energy, chemical, food and metallurgic industry. Considering the advantages of this fuel, i.e. its availability, low emission combustion and low extraction costs, its global consumption is bound to increase (Niedziółka, 2010).

The growing demand for gas in the 20th c. increased its prices in many areas of the world (in North America, in the last decade of the 20th c., the prices were different due to the "shale revolution"). For instance, the average price for one million BTU (British Thermal Unit) of natural gas imported by Germany increased from $4.25 in 1985 to $11.03 in 2012 (BP Statistical Review, 2013, p. 27). The growing demand and high prices made many countries search for new, alternative resources. From the economic point of view, unconventional gas is more difficult and less economical to exploit, because it is found in rocks of very low permeability. Shale gas is confined in the pores of shale rock sealed off by other impermeable rocks. However, there are also deposits of other types of unconventional gas – tight gas, found in the small fissures of sandstone or carbonate rocks, or coal-bed methane. A huge, though still unexploited source of gas are gas hydrates (methane clarates), i.e. a crystalline combination of methane, found e.g. in ocean depths (Zarębska and Baran, 2010).

Currently, the most significant economically are shale and tight gas. The first gas extracted in 1812 in the United States came from the Appalachian deposits of shale gas. Shale gas extraction, however, was soon abandoned due to the ineffectiveness of the technologies of that time. It was not until horizontal drilling was invented and combined with the technology of producing a network of cracks in the drilled rock that shale and tight gas deposits could be exploited. This technology, known as hydraulic fracturing (Zarębska and Baran, 2010), was first used in 1947, in the USA, for petroleum extraction. It was not until the last decades of the 20th c., however, that the method was refined in such a way that it could be successfully used in industrial gas extraction. The majority of world drillings have been done over the last few years. It is estimated that by 2012 this technology had been used about a million times (Mazurczak et al., 2013, p. 2498).

Shale and tight gas extraction begins with vertical boring into the rock, next the direction of boring changes to horizontal. This makes it possible to penetrate impermeable horizontal rock layers, e.g. shale. Next, the drilled hole is washed with 15% hydrochloric acid and a mixture of water and chemicals is pumped under great pressure into it in order to produce micro-cracks in the back section of the bore hole. Next, the cracks are filled with sand or another ceramic material, which is to prevent the fissures made in the gas-rich rock from closing. After that, the gas from the shale formation passes to the drilled hole and may be extracted to the surface. Hydraulic fracturing is used to extract 15-40% of gas contained in shale formations, and the effectiveness of this method is gradually growing (Mazurczak, Sówka and Zwoździak, 2013).

We must not ignore the influence of the above technology on the natural environment, which is strongly stressed by many researchers and shale gas extraction opponents, such as ecological organizations, inhabitants of some areas where the gas has been found, the governments of some countries (e.g. France, Bulgaria), or some representatives of EU institutions. According to Howarth et al. (2011), Macuda and Marchel (2011) and Mazurczak et al. (2013, p. 2503), hydraulic fracturing produces pollution, the sources of which include:

– heavy vehicles and drilling machinery (noise, SO_2, NO_x, CO particles),
– gas conversion and transport (noise, SO_2, NO_x, CO particles),
– the evaporation and penetration into the ground of the liquids used during fracturing and stored in open reservoirs after the drilling,
– leaks of technical liquids,
– uncontrollable methane emission (the main component of natural gas and a greenhouse gas at the same time) to the atmosphere as a result of leaking (see also: Miller et al., 2013; Brandt et al., 2014).

We must also consider the adverse effects of using this technology, such as landscape devastation, the destruction of the underground technical infrastructure, or underground water contamination with the liquid used in hydraulic fracturing. There are a number of publications in the world literature which confirm the serious hazards to the natural environment, as well as health, due to shale gas extraction. A particularly great risk comes from the contamination of surface and underground

water with hydraulic fracturing liquid (Fontenot et al., 2013; Lutz, 2013; Warner et al., 2013). Different authors also quote examples of the growing radioactive contamination of the water used for hydraulic fracturing with radium isotopes coming from the rock (Nelson et al., 2014). They discuss the issue of the negative influence of the pollutants (via air, water and soil) on the health of the people living in the area of shale gas extraction (Finkel and Hays, 2013; Kovats et al., 2014). Furthermore, they point to the intensification of anthropogenic earthquakes due to hydraulic fracturing (Ellsworth, 2013). The damage potential of gas extraction is also implanted in people's awareness through films, such as the American documentary entitled *Gasland* produced in 2010, which in a very suggestive way shows the negative environmental and social effects of shale gas extraction in the United States.

On the other hand, there are also many scientific publications, whose authors consider the information about the extremely negative influence of this technology on the environment to be overstated (Burnham et al., 2012). Moreover, they postulate not only to measure the overall increase of pollutants in shale gas extraction areas, but also more often compare them with the level of contamination recorded in similar areas of conventional gas extraction. Naturally, the pollution caused by this technology is often greater than in the case of conventional gas, but by introducing suitable legal regulations (as regards, e.g., the composition of the hydraulic liquid or the rules of storing and utilizing waste), it is possible to minimize the negative effects. Howarth et al. (2011, p. 688) point to the fact that at certain stages of natural gas extraction, methane emission to the atmosphere may be reduced by up to 90%, provided modern technologies are used. Similarly, the information that groundwater may be contaminated is sometimes considered to be inaccurate (see: Ridley, 2011). Another criticism concerns the large consumption of water in shale gas extraction, while research shows (Nicot and Scanlon, 2012, p. 3585) that net water use for shale gas is within the same general range as that for other energy sources. The hazards of using large quantities of chemically aggressive fracturing liquid can be drastically reduced by reapplying it (Maloney and Yoxtheimer, 2012). It appears that due to the complexity and novelty of the problems related to shale gas extraction, it is necessary to conduct further comprehensive research in order to conclusively define its influence on the natural environment (including the comparison of the influence of shale gas extraction to the effect of traditional procedures of natural gas extraction).

On the other hand, unconventional gas extraction creates a realistic chance (e.g. in Poland) to decrease the use of coal, which may lead to a considerable reduction of CO_2 (one of the important greenhouse gases) emission. This is one of the priorities of the environmental and energy policy of the European Union set for the nearest decades (Wijermars et al., 2011). CO_2 emission from gas combustion is by 30% smaller than in the case of petroleum, and up to 60% smaller than in the case of black coal (Szyjko, 2011, p. 58; see also Jenner and Lamadrid, 2013).

Shale gas is currently extracted on a large, commercial scale in the USA, where the state introduced an intensive research program, evaluating the amount of shale gas and developing extracting technologies already in the 1970s (Curtis, 2002). Moreover, in 1980, the United States Congress introduced a program of incentives

in the form of tax exemption for investors, called Nonconventional Fuels Tax Credit (Siemek et al., 2011). Industrial scale gas extraction started in 2003, when the exploitation of the Barnett Shale deposit in the geological basin of Fort Worth, Texas began. While large-scale commercial production of shale gas has not yet been achieved in Canada, many companies are now searching for and developing shale gas resources in Alberta, British Columbia, Quebec, and New Brunswick (CAPP, 2013).

The overall natural gas extraction in the USA has been growing gradually since the 1980s, which results recently mainly from the increasing unconventional gas extraction. The percentage of unconventional gas share in whole gas production in USA (mainly shale gas, tight gas and coal-bed methane CBM) is constantly growing. In 1990, it was about 14% (Zarębska and Baran, 2010, p. 177), in 1996 23% (Poprawa, 2010, p. 221) and in 2009 55% (Młynarski, 2012, p.7). The extraction of shale gas alone in the USA is also rising. In 2008 it was over 10% of the overall amount of extracted gas and in 2010 it was already 23% (about 137 billion m^3 (Siemek et al., 2011, p. 119). According to Mazurczak et al. (2013, p. 2497), shale gas made 30% of all the gas extracted in 2012 in the United States. It is predicted that by 2035 shale gas will have made 49% of the gas extracted in this country (Mazurczak et al., 2013, p. 1497). It must be stressed, however, that in recent years it has been repeatedly suggested that shale gas resources in the United States have been overestimated. If this information is confirmed, we may expect a lower rate of gas extraction in the United States in the next few decades.

Economic impacts of shale gas extraction

At present, there are over 20 geological basins with proved shale gas resources, the most important of which are Barnett Shale (Fort Worth basin), Marcellus and Ohio Shales (Appalachians basin), Antrim Shale (Michigan basin), New Albany Shale (Illinois basin), and Haynesville and Fayetteville, Woodford, and Gammon Shales (Wyoming) (Poprawa, 2010, p. 221) (Fig.1).

Such extensive gas extraction from this source had numerous impacts on American economy. The first one was the increase in gas production in this country in recent years. As a result, in 2009 the USA became the world leader in gas extraction, outrunning Russia, which had been in the lead until 2008 (Zarębska and Baran, 2010; Młynarski, 2012). According to the BP report, in 2012, gas production in the United States was again the largest in the world, reaching 619.2 Mtoe, while the Russian production reached 533 Mtoe (20.14% and 17.6% of the global production, respectively). To compare, in 2006 it was 479.3 Mtoe in the United States and 535.6 Mtoe in Russia (BP Statistical Review, 2013, p. 24).

The growing gas production caused a decrease in its prices in the USA and Canada (Siemek et al., 2011). According to the BP report, the price of natural gas in the USA fell from $4.23 per million BTU in 2000 to $2.76 in 2012 (Henry Hub prices), i.e. by about 65%. In 2012, the price of gas in the USA was nearly four times lower than in Germany and six times lower than in Japan (BP Statistical Review, 2013, p. 27). The decrease in gas prices causes greater competitiveness of the

American economy on the global market. As a result, the cost of the functioning of industrial plants and households using gas is lower. This leads, e.g. to some plans for new production investments in the United States, announced by some foreign companies (which will be described later). It may also stop/prevent the outflow of plants representing some industries (e.g. chemical or metallurgic) out of the country.

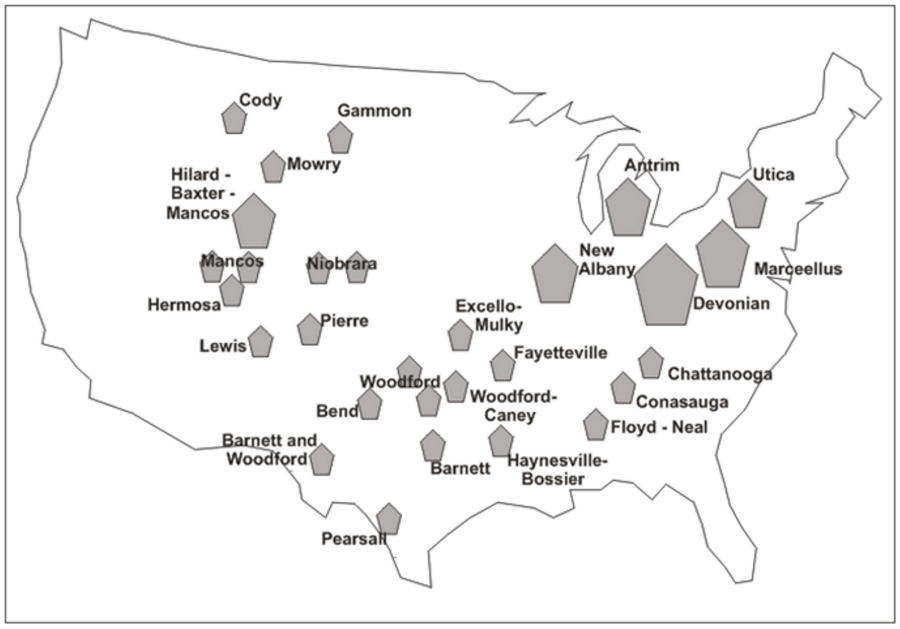

Figure 1 Distribution of gas shale deposits in the United States. Source: Own elaboration on the basis of David et al., 2010, p. 5679

Another effect of the increasing natural gas extraction is the United States becoming nearly totally independent of natural gas import, which decreased from 130.7 billion m^3 in 2007 to 104.63 billion m^3 in 2010, with the total consumption growing from 654.04 billion m^3 to 683.37 billion m^3 (Siemek et al., 2011, p. 119). In 2010, the United States was not self-sufficient yet as regards natural gas, but it was possible to minimize the LNG gas import transported by sea. Therefore, LNG terminals are not fully used today, and the imported gas is transported via pipelines, mainly from Canada (Młynarski, 2012, p.7). In the future, the USA may stop depending on import completely and even become a significant LNG gas exporter. Moreover, American researchers are considering working on liquid fuels synthesis from shale gas (Kryzia and Gawlik, 2012, p. 7). Referring to the latest IEA forecast, Walewska (2013) expects that soon the United States will have become the largest producer of energy carriers in the world, which will be the result of the large gas and petroleum extraction from unconventional sources (e.g. shale formations). North America will benefit economically from that and a large part of gas will be exported

as LNG. This in turn may cause a drop in gas prices on the world market. This drop in gas prices may affect the international situation of its global exporters, such as Russia, which will then be forced to lower the prices of natural gas exported, for instance, to Europe.

Another important effect of the growing gas extraction is the rising number of new jobs and additional profits for the state budget, coming from taxes and other payments made by extraction companies. For instance, in Pennsylvania, where the Marcellus Shale is found (Appalachian basin), 29 000 new jobs were created in 2008, and $2.3 billion were earned. State budget and local communes' incomes from the taxes paid by extraction companies reach about $238 million annually (David et al., 2010, p. 5680).

Recently the media have been reporting about the plans for substantial industrial investments to be made in the United States by American and foreign companies, attracted by the low price of natural gas. It has been confirmed in the reports by one of the largest press agencies in the world – Bloomberg (BLOOMBERG, 2016), which claims that the Austrian steel concern Voestalpine AG is planning to build a factory in the USA, worth $661 million. The choice of location is based mainly on the low prices of gas. Plans to build a modern steelworks have been announced by a large Australian company, Bluescope Steel Ltd. Similarly, many chemical firms, for which gas is the basic raw material, are planning to build factories in the United States.

Another effect of the "shale revolution" in the United States was the growing interest in shale gas extraction in other regions (see among others: Aguilera and Radetzki, 2015). Shale gas is commonly found in countries on all continents (Tab. 1), and its use may considerably extend the time of exploiting primary energy sources on Earth. According to The World Energy Council (WEC), shale gas reserves may be five times larger than those of conventional gas (Szablewski, 2010, p. 136). Therefore, many countries all over the world are interested in increasing their own gas production (Tab. 1) and are searching for potentially usable unconventional gas (mainly shale gas) resources.

Shale gas is currently being sought in Mexico, Argentina, Libya, Turkey, India, Australia, China and Russia, as well as in many European countries, such as Germany, Sweden, Hungary, or Poland (Poprawa, 2010, pp. 221-222). Ukraine is also increasingly interested in shale gas, as its energy market depends on import. The results of the shale revolution are observed globally, not only in North America. The structure of natural gas extraction has changed all over the world. It is the USA and not Russia that is the world leader, which was unthinkable a few years ago. Also China – a large importer of gas – has high hopes regarding shale gas extraction (see: Chang et al., 2012). According to LUPKIPOLSKIE (2013), "China spends $17 billion annually on the import of gas, half of which is liquefied (LNG). Currently, China does not extract shale gas on the industrial scale, but by 2020 they intend to obtain 80 billion m^3 of gas a year from this source, which is 23% of the forecasted demand for natural gas." We must remember that shale gas production in China may have geo-political effects, as it undermines Russia's plans to export gas to China.

Table 1 Resources of technically extracted shale gas in billions m^3

Country	Resources
China	36 104
The United States	24 409
Argentina	21 917
Mexico	19 284
South Africa	13 734
Australia	11 213
Canada	10 987
Libya	8 212
Algeria	6 541
Brazil	6 400
Poland	5 295
France	5 097
Norway	2 350
Chile	1 812
India	1 784
Paraguay	1 756
Pakistan	1 444
Bolivia	1 359
Ukraine	1 189
Sweden	1 161

Source: Kryzia and Gawlik 2012, p. 8.

Europe also has many regions which are potentially rich in shale gas, but it still largely depends on the import of gas from Russia (about 30% of the gas imported to the EU comes from Russia). The current EU policy is to create a homogenous fuels market and diversify their sources. Hence, gaining larger access to domestic natural gas deposits seems to be highly desirable (Matyasik and Słoczyński, 2010; Michalczyk, 2011; Riley, 2011). On the one hand, shale gas is mentioned in many EU documents (e.g. Energy Road Map 2050) as a means to decrease the European Union countries' dependence on natural gas import. Individual EU bodies, such as The European Parliament or the European Commission, are becoming increasingly involved in searching for European unconventional gas deposits, by supporting research projects, studies, collecting reports or organizing meetings with experts (ZASOBY GAZU I ROPY, 2012).

Moreover, the growing gas extraction may lower coal consumption in electric power production in EU member countries (e.g. Poland), which would comply with the Union's long-term policy of reducing CO_2 emission (we must not forget of course about the controversies regarding the impact of the shale gas extraction pro-

cess on the environment) (Szyjko, 2011). In 2013, shale gas extraction tests were initiated in the drilling area of Lębork in Poland (pomorskie voivodeship). A preliminary examination was completed, a bore hole was drilled using the hydraulic fracturing technology, and gas was obtained. The drilling was performed by Lane Energy Poland, controlled by the American Conoco-Philips company. During the test extracting, 8000 m^3 of gas per day were extracted there (Piszczatowska and Furman, 2013). As shown by Uliasz-Misiak et al. (2014) the development of shale gas extraction in Poland has its pros and cons. It is among others dependant on environmental and law regulations. Nowadays (2017) it may be said that the initial optimism from the 2013/2014 regarding the exploitation of Polish shale gas has decreased mostly due to the lack of law regulations. Such regulations should have been introduced immediately after the increase of interest in shale gas extraction in Poland (i.e. in between 2013-2015). However such regulations were not introduced in these years. Therefore lots of investors (mainly from the USA) stopped their investments in Poland. However after 2016 (when the government has changed in Poland) again more attention is being put on shale gas extraction, what could caused a realization of Polish shale gas revolution in the future.

Furthermore, according to Gazeta Wyborcza (a major Polish daily newspaper), in 2012 Germany signed a contract with a Canadian company, which is to sell up to five million tons (c. 7 billion m^3) of liquefied shale gas extracted in North America a year to the German EON concern. The gas was to be delivered to several terminals in Western Europe and further transported via pipelines to Germany (WYBORCZA, 2013).

On the other hand, we may observe opposite tendencies. For instance, some EU countries (France, Bulgaria and the Czech Republic) have introduced limits on shale gas extraction due to the not yet fully recognized effect of hydraulic fracturing on the environment.

The Treaty on the Functioning of the European Union allows member states to exploit all forms of natural gas. However, in recent years there have been many speculations regarding the possibility to limit this right by changing or introducing a new interpretation of the law. This may result from the fears concerning the influence of gas extraction technology on the natural environment. However, it must be remembered that recent years have brought enormous investments in conventional gas extraction, such as the Nord Stream (formerly known as the North European Gas Pipeline), connecting Russia with Germany and Western Europe. There is a real danger then that regulations of this type will be introduced due to the potentially low profitability of such investments if shale gas extraction increases (ZASOBY GAZU I ROPY, 2012).

At present, the largest supplier of gas on the EU market is the Russian Gazprom. One Russia's politics objective is to control the European energy market, which is apparent in the company's policy. Gazprom dominates on the European market mostly by buying out gas companies in other countries, taking over gas infrastructure (e.g. gas-pipelines, gas-ports), or the controlling interest in companies which import and distribute gas. As a result, Gazprom is gaining a monopolist posi-

tion on individual countries' markets. This type of policy can be observed in Germany, where Gazprom is the largest gas supplier thanks to the Nord Stream, built at an enormous cost (Michalczyk, 2011, p. 103). Similar moves are described in the reports by a prestigious Polish Centre of Eastern Studies (Łoskot-Strachota, 2009; Paszyc, 2011). According to onet.pl, a large Polish Internet portal, recently "The Russian gas concern, Gazprom, will own 100% of the German Wingas company. The shares will be taken over from the German BASF company in return for the petroleum and gas deposits in Siberia. This agreement means that Gazprom will become the owner of the OPAL pipeline (Ostsee-Pipeline-Anbindungs-Leitung), which connects Nord Stream with the German power transmission grid" (GIELDA, 2013). The situation is similar in Poland, where (before 2016) Russian gas satisfied ca. 70% of consumption needs (in order to become independent of the only source of gas supplies, Russia, in 2006 Poland decided to build a large LNG terminal in Świnoujście, at the cost of 600 mil. Euros). It is considered to be a strategic investment in Poland, as regards energy economy. It seems then that the development of the shale gas sector will be of great concern to Gazprom management and may cause lobbyist activity in order to hamper shale gas extraction in Europe.

As it was pointed out earlier in the article, the increasing extraction of unconventional gas has lowered its prices in the United States and Canada. In the nearest future, further increase in unconventional gas extraction and export may lead to a decrease in the prices of gas on the global market. It is suggested in the report by a renowned analytical-consultancy firm Delloite, entitled „Exporting the American Renaissance. Global impacts of LNG exports from the United States". It shows that LNG export will lower the global prices of gas. Delloite experts claim that in the future, the global price of gas will be correlated with its price in the United States (currently much lower than in other countries) and will not depend on the high prices of petroleum, which it has been strongly correlated with so far (LUPKIPOLSKIE, 2013). The decreasing LNG import to the United States has already forced the exporters (e.g. Qatar) to look for new sales possibilities in Asia and Europe, as well as to offer competitive prices (Siemek et al., 2011; Szablewski, 2010).

Interesting data was provided by Niedziółka (2010, p.181), who claims that in 2009 and 2010 the mean prices of gas plummeted all over the world, which coincided with the United States becoming the world leader in gas production due to the increasing production of shale gas and other unconventional resources. However, this drop in prices should be treated carefully and related not only to the "shale revolution", but also to the global economic crisis, which peaked in 2008. At that time, it caused a short-term lowering of the prices of resources due to a smaller demand. It must be stressed, however, that in the following years (2010-2012), the gas prices on global markets increased again (except the USA and Canada) (BP Statistical Review, 2013, p. 27).

We can talk about the global petroleum market, but something like the global natural gas market does not exist. This results from the regionalization of its production and problems with transport. Moreover, when it comes to gas, long-term contracts are signed, which are difficult to negotiate. These difficulties make natural gas

prices less flexible and they do not change as easily as the prices of petroleum (Tarnowski, 2011). Despite these misgivings, gas production forecasts are rather optimistic and suggest that due to the increasing extraction of unconventional gas the global gas market will become more a consumers' than producers' market. This in turn may bring a global decrease in the prices of this fuel and enhance the global economic revival, as well as reduce the possibility of political pressure exerted by the countries exporting gas.

4 CONCLUSIONS

The article presents the problem of extracting unconventional energy resources, using the example of shale gas. The analysis shows that the global consumption of energy will be gradually increasing, leading to the slow depletion of traditional energy resources. As a result, unconventional sources will be in great demand. The governments of some countries, such as the United States, noticed this process and took action to increase unconventional natural gas extraction, mainly from shale formations. This caused a rapid increase in the natural gas production in this country, a fall in its prices and an economic revival in industry. It must be stressed that the so called "shale revolution" is and will be strongly influencing the natural gas market. It has led to a change of the leader in gas production, raised enormous interest in the extraction of this fuel in many other countries (China, European and South American countries), which are currently conducting studies of the location and the possibility to use the unconventional natural gas deposits. If the studies are continued and the issue of gas extraction in regions other than North America is further examined, the world gas market will undergo a strong transformation, which will include further changes in the structure of global gas production and a fall in the price of this fuel. Besides, the energy security of individual countries may increase, the time of using conventional fuels by the human civilization will be extended. If the production of gas increases, it may eventually replace the use of coal in some countries. This in turn may cause a lower emission of CO_2 – one of the most common greenhouse gases. Moreover, in some countries, the possibility of using energy resources as a political tool will become limited.

On the other hand, we must not forget about the negative aspects of natural gas extraction from shale formations. The most important element, stressed in the article, is the hazard to the natural environment. There are studies confirming larger emission of pollutants than in the case of conventional natural gas extraction. Therefore, it is very important to improve the hydraulic fracturing technology, as well as to control extraction companies. Another danger seems to be the activity of various lobbyist groups, which may try to reduce shale gas extraction, e.g. in Europe.

References

AGUILERA, R. F., RADETZKI, M. 2015. Rewolucja łupkowa: Światowe rynki gazu i ropy naftowej w warunkach transformacji1. *Gospodarka Surowcami Mineralnymi*, 31(1), 5-26.

BARTOSIK, M. 2009. *Globalne zasoby energii pierwotnej a kryzys energetyczny* (Global primary energy resources and the energy crisis) – a paper presented at the scientific panel held in Warsaw by the Polish Academy of Science, entitled "Energy Studies Strategy in Poland". (1-14) [online] [accessed 2017-12-05]. Available at: <http://ziemianarozdrozu.pl/dl/Prof_Marek_Bartosik-SYTUACJA-ENERGETYCZNA-SWIATA-i-POLSKI.pdf>

BLOOMBERG, 2016. *Bloomberg press agency website* [online] [accessed 2016-08-26]. Available at: <http://www.bloomberg.com/>

BP statistical review, 2013. *BP statistical review of world energy june 2013* [online] [accessed 2017-12-05]. Available at: <http://energypolicy.columbia.edu/sites/default/files/home-slider/statistical_review_of_world_energy_2013.pdf>

BRADSHAW, M. J. 2009. The Geopolitics of Global Energy Security. *Geography Compass*, 3(5), 1920-1937.

BRADSHAW, M. J. 2010a. Global energy dilemmas: a geographical perspective. *The Geographical Journal*, 176(4), 275-290.

BRADSHAW, M. J. 2010b. In Search of a New Energy Paradigm: Energy Supply, Security of Supply and Demand and Climate Change Mitigation. *Mitteilungen der Österreichischen Geographischen Gesellschaft*, 152 Jg., 9-26.

BRANDT, A. R., HEATH, G. A., KORT, E. A., O'SULLIVAN, F., PÉTRON, G., JORDAAN, S. M., TANS, P., WILCOX, J., GOPSTEIN, A. M., ARENT, D., WOFSY, S., BROWN, N. J., BRADLEY, R., STUCKY, G. D., EARDLEY, D., HARRISS, R. 2014. Methane leaks from North American natural gas systems. *Science*, 343(6172), 733-735.

BURNHAM, A., HAN, J., CLARK, C. E., WANG, M., DUNN, J. D., PALOU-RIVERA, I. 2012. Life-Cycle Greenhouse Gas Emissions of Shale Gas, Natural Gas, Coal, and Petroleum. *Environmental Science & Technology*, 46, 2, 619-627.

CAPP, 2013. Canadian Association of Petroleum Producers [online] [accessed 2013-10-20]. Available at: <http://www.capp.ca/canadaIndustry/naturalGas/ShaleGas/Pages/default. aspx>

CHANG, Y., LIU, X., CHRISTIE, P. 2012. Emerging Shale Gas Revolution in China. *Environmental Science & Technology*, 46, 22, 12281-12282.

CURTIS, J. B. 2002. Fractured shale – gas systems. *American Association of Petroleum Geologists Bulletin*, 86(11), 1921-1938.

ELLSWORTH, W. L. 2013. Injection-induced earthquakes. *Science*, 341(6142), 142 p.

FINKEL, M. L., HAYS, J. (2013). The implications of unconventional drilling for natural gas: a global public health concern. *Public Health*, 127(10), 889-893.

FONTENOT, B. E., HUNT, L. R., HILDENBRAND, Z. L., CARLTON JR, D. D., OKA, H., WALTON, J. L., HOPKINS, D., OSORIO, A., BJORNDAL, B., HU, O. H., SCHUG, K. A. 2013. An evaluation of water quality in private drinking water wells near natural gas extraction sites in the Barnett Shale Formation. *Environmental science & technology*, 47(17), 10032-10040.

GAZ LNG, 2017. Website of a Polish public radio [online] [accessed 2017-12-05]. Available at: <https://www.polskieradio.pl/130/6257/Artykul/1931164,Gaz-LNG-z-USA-poplynie-do-Polski-Nowa-jakosc-rewolucja>

GIELDA, 2013. Large Polish Internet portal [online] [accessed 2013-08-26]. Available at: <http://gielda.onet.pl/gazprom-stanie-sie-100-proc-wlascicielem-niemiecki,,5304457, news-detal>

GIDDENS, A. 1990. *The Consequences of Modernity*. Policy Press, Cambridge.

HAGGETT, P. 2001. Globalizaton. In: *Geography a Global Synthesis*. G. Canale & C. S.p. A, Harlow, 584-613.

HARDY, T. 2010. *Maszynoznawstwo energetyczne (Energy mechanics – lecture script)*. Technical University of Wrocław, Wrocław. [online] [accessed 2013-08-10]. Available at: <http://www.spalanie.pwr.wroc.pl/dydaktyka/Maszyny/maszyny.htm>

HOLTON, R. 2006. Globalizace. In: Harrington, A. et al. (eds.), *Moderní sociální teorie*. Portál, Praha, 385-410.

HOWARTH, R. W., SANTARO, R., INGRAFFEA, A. 2011. Methane and the greenhouse – gas footprint of natural gas from shale formations. *Climatic Change*, 106, 679-690.

JENNER, S., LAMADRID, A. J. 2013. Shale gas vs. coal: policy implications from environmental impact comparisons of shale gas, conventional gas, and coal on air, water, and land in the United States. *Energy Policy*, 53, 442-453.

KELLER, J. 2007. *Teorie modernizace*. Slon, Praha.

KOVATS, S., DEPLEDGE, M., HAINES, A., FLEMING, L. E., WILKINSON, P., SHONKOFF, S. B., SCOVRONICK, N. 2014. The health implications of fracking. *Lancet*, 383(9919), 757-758.

KRYZIA, D., GAWLIK, L. 2012. Perspektywy gazu z łupków w Polsce (Shale gas perspectives in Poland). *Zeszyty Naukowe Instytutu Gospodarki Surowcami Mineralnymi i Energii Polskiej Akademii Nauk*, 82, 5-20.

LUTZ, B. D., LEWIS, A. N., DOYLE, M. W. 2013. Generation, transport, and disposal of wastewater associated with Marcellus Shale gas development. *Water Resources Research*, 49(2), 647-656.

ŁOSKOT-STRACHOTA, A. 2009. *Ekspansja Gazpromu w UE – kooperacja czy dominacja Gazprom expansion in the EU – cooperation or domination?)*. Ośrodek Studiów Wschodnich, Warszawa. [online] [accessed 2013-08-20]. Available at: <http://www.osw.waw.pl/sites/default/files/GP_EU_10_09.pdf>

LUPKIPOLSKIE, 2013. Website presenting information on shale gas extraction and research into this source of energy in Poland and in the world [online] [accessed 2013-08-26]. Available at: <http://www.lupkipolskie.pl/>

MACUDA. J., MARCHEL, P. 2011. Oddziaływanie prac wiertniczych na środowisko przy poszukiwaniu gazu łupkowego w Polsce (The impact of drilling works on the environment when searching for shale gas in Poland). *Wiertnictwo Nafta Gaz*, 28(1-2), 263-271.

MALONEY, K., YOXTHEIMER, D. A. 2012. Production and Disposal of Waste Materials from Gas and Oil Extraction from the Marcellus Shale Play in Pennsylvania. *Environmental Practice*, 14(4), 278-287.

MATYASIK, I., SŁOCZYŃSKI T. 2010. Niekonwencjonalne złoża gazu – shale gas (Unconventional gas deposits – shale gas). *Nafta – Gaz*, 3(LXVI), 167-177.

MAZURCZAK, M., SÓWKA, I., ZWOŹDZIAK, J. 2013. Wybrane aspekty środowiskowe i technologiczne związane z rozpoznaniem i wydobyciem gazu ziemnego z łupków (Selected environmental and technological aspects of locating and extracting shale gas). *Rocznik Ochrony Środowiska*, 15, 2496-2509.

MICHALCZYK, L. 2011. Polska a Gazprom w długofalowej koncepcji polskiego bezpieczeństwa energetycznego (Poland vs. Gazprom in the long-term conception of Polish energy security). *Polityka Energetyczna*, 14(1), 91-105.

MICHALSKI, R., FICEK, A. (2016). Environmental pollution by chemical substances used in the shale gas extraction—a review. *Desalination and water treatment*, 57(3), 1336-1343.

MILLER, S. M., WOFSY, S. C., MICHALAK, A. M., KORT, E. A., ANDREWS, A. E., BIRAUD, S. C., DLUGOKENCKY, J. E., ELUSYKIEWICY, J., JANSSENS-MAENHOUT, G., MILLER, B. R., MILLER, J. B., MONTYKA, S. A., NEHRKORN, T., SWEENEY, C. 2013. Anthropogenic emissions of methane in the United States. *Proceedings of the National Academy of Sciences*, 110(50), 20018-20022.

MŁYNARSKI, T. 2012. Geopolityczne implikacje rozwoju shale gas w Europie (Geopolitical implications of shale gas development in Europe). *Polityka Energetyczna*, 15 (1), 5-20.

NELSON, A. W., MAY, D., KNIGHT, A. W., EITRHEIM, E. S., MEHRHOFF, M., SHANNON, R., LITMAN, R., SCHULTZ, M. K. 2014. Matrix Complications in the Determina-

tion of Radium Levels in Hydraulic Fracturing Flowback Water from Marcellus Shale. *Environmental Science & Technology Letters*, 1(3), 204-208.
NICOT, J. P., SCANLON, B. R. 2012. Water Use for Shale-Gas Production in Texas, U. S.. *Environmental Science & Technology*, 46(6), 3580-3586.
NIEDZIÓŁKA, D. 2010. Znaczenie gazu łupkowego (The significance of shale gas). *Zeszyty Naukowe Instytutu Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauk*, 78, 175-185.
PASZYC, E. 2011. *Sektor gazowy: ekspansja Gazpromu na regionalnym rynku (Gas sector: Gazprom expansion on the regional market)*. Ośrodek Studiów Wschodnich, Warszawa. [online] [accessed 2013-08-18]. Available at: <http://www.osw.waw.pl/sites/default/files/Aktywnosc_ sektor_gazowy.pdf>
PISZCZATOWSKA, J., FURMAN, T. 2013. Popłyną gaz z łupków (Shale gas has flown). *Rzeczpospolita*, 28. August 2013, 200 (9624), 1.
POPRAWA, P. 2010. System węglowodorowy z Gazem ziemnym w łupkach – północnoamerykańskie doświadczenia i europejskie perspektywy (Hydrocarbon system with shale gas – North American experience and European perspectives). *Przegląd Geologiczny*, 58(3), 216-225.
REUTERS, 2017. Website of Reuters media agency [online] [accessed 2017-12-05]. Available at: <https://www.reuters.com/article/us-usa-trump-lng/trump-to-promote-u-s-natgas-exports-in-russias-backyard-idUSKBN19O2AH>
RIDLEY, M. 2011. *The Shale Gas Shock, The Global Warming Policy Foundation Report*. London. [online] [accessed 2013-12-01]. Available at: <https://www.dl.icdst.org/pdfs/files/2509c9a667d2ebf9fbc49d17035d58b2.pdf>
RILEY, A. 2011. Europejskie złoża gazu niekonwencjonalnego jako alternatywa wobec gazowej zależności od Rosji (European deposits of unconventional gas as an alternative to the gas dependence on Russia). In: Albrycht, I. (ed.), *Gaz niekonwencjonalny – szansa dla Polski i Europy? Analiza i rekomendacje*. Instytut Kościuszki, Kraków, 89-100.
SIEMEK, J., KALISKI, M., JANUSZ, P., SIKORA, S., SZURLEJ, A. 2011. Wpływ shale gas na rynek gazu ziemnego w Polsce (The impact of shale gas on the natural gas market in Poland). *Rynek Energii*, 5, 118-124.
SOLIŃSKI, J., GAWLIK, L. 2012. Rys historyczny i stan obecny światowego i polskiego sektora energii (Historical outline and the current situation of the global and Polish energy sector). *Energetyka*, 3-4 (693, 694/65), 142-149.
SOLIŃSKI, J. 2008. Światowe rezerwy surowców energetycznych (World reserves of energy resources). *Energetyka*, 2 (644/61), 99-104.
SZABLEWSKI, A. T. 2010. Zmiany paradygmatu polityki energetycznej – aspekty liberalizacji i bezpieczeństwa dostaw (Changes of the energy policy paradigm – liberalization and supply security). *Studia Ekonomiczne-Economic Studies*, 2(LXV), 125-140.
SZYJKO, C. T. 2011. Społeczno – gospodarcze bariery potencjalnej produkcji gazu łupkowego w Polsce (Socio-economic barriers to potential shale gas production in Poland). *Annales Universitatis Mariae Curie – Sklodowska*, Sectio K, XVIII(2), 53-74.
TARNOWSKI, M. 2011. *Spadkowy trend cen gazu na świecie* (The declining gas prices trend in the world). Instytut Kościuszki, Kraków. [online] [accessed 2013-08-15]. Available at: <http://www.cire.pl/pliki/2/trendy_cen_gazu.pdf>
ULIASZ-MISIAK, B., PRZYBYCIN, A., WINID, B. 2014. Shale and tight gas in Poland-legal and environmental issues. *Energy Policy*, 65, 68-77.
WALEWSKA, D. 2013. Duże zmiany na mapie świata (Substantial changes on the map of the world). *Rzeczpospolita*, 13. November 2013, 264(9688): B4.
WARNER, N. R., CHRISTIE, C. A., JACKSON, R. B., VENGOSH, A. 2013. Impacts of shale gas wastewater disposal on water quality in Western Pennsylvania. *Environmental science & technology*, 47(20), 11849-11857.

WORLD OIL PRICES, 2013. Website presenting world oil prices [online] [accessed 2013-08-15]. Available at: <http://www.bp.com/en/global/corporate/about-bp/statistical-review-of-world-energy-2013/review-by-energy-type/oil/oil-prices.html>
WRONA, J., REK, J. (eds.) 1998. *Podstawy geografii ekonomicznej (Basics of economic geography)*. Polskie Wydawnictwo Ekonomiczne, Warszawa.
WRZOSEK, A. 1977. *Geografia energetyki świata (The Geography of world's energy industry)*. WSiP, Warszawa.
WYBORCZA, 2013. Website of a Polish influential daily paper [online] [accessed 2013-08-26]. Available at: <http://wyborcza.biz/biznes/1,100896,14032332, Niemcy_beda_importowac_gaz_z_Kanady_Lupkowa_konkurencja.html#ixzz2d6BHyUj0>
ZARĘBSKA, K., BARAN, P. 2010. Gaz łupkowy – niekonwencjonalne Źródło energii (Shale gas – an unconventional source of energy). In: *5th Young Scientists Krakow Conference materials*, Krakow, 175-180.
ZASOBY GAZU I ROPY, 2012. *Zasoby gazu i ropy ze złóż niekonwencjonalnych – zarys stanu prac poszukiwawczo – wydobywczych i możliwe implikacje międzynarodowe* (Gas and petroleum reserves from unconventional deposits – an outline of search and extraction works, possible international implications) [online] [accessed 2013-08-10]. Available at: <http://www.msz.gov.pl/resource/feec2fc6-b64d-4a16-8104-020f23765052:JCR>

Využitie nekonvenčných zdrojov plynu a rozvoj energetického trhu

Súhrn

Predložený príspevok je venovaný problému získavania nekonvenčných zdrojov energie na príklade bridlicového plynu. Analýzy ukazujú, že celosvetová spotreba energie sa bude postupne zvyšovať, čo povedie k postupnému vyčerpaniu tradičných konvenčných zdrojov energie. V dôsledku toho budú nekonvenčné zdroje veľmi žiadané a vyhľadávané. Vlády niektorých krajín, ako napríklad USA, tento proces samozrejme zaregistrovali a podnikli kroky na zvýšenie ťažby palív z nekonvenčných surovín, konkrétne ťažby zemného plynu z bridlicových formácií.

To spôsobilo rýchle zvýšenie produkcie zemného plynu v tejto krajine, pokles cien štandardných konvenčných palív a do určitej miery aj ekonomické oživenie v priemysle. Treba zdôrazniť, že takzvaná "bridlicová revolúcia" je tu a bude silne ovplyvňovať trh so zemným plynom. Táto "revolúcia" viedla k zmene vedúceho postavenia štandardnej ťažby v oblasti produkcie plynu, pričom vyvolala obrovský záujem o ťažbu tohto paliva v mnohých ďalších krajinách (najmä v Číne a v krajinách Európy a Južnej Ameriky), ktoré v súčasnosti investujú do rozsiahlych štúdií o lokalitách tohto zdroja suroviny a možností využitia týchto nekonvenčných ložísk.

Pokiaľ bude pokračovať výskum doterajším tempom a bude sa ďalej skúmať otázka ťažby bridlicového plynu i v iných regiónoch ako je Severná Amerika, bude svetový trh s plynom podrobený silnej turbulencii a pravdepodobne aj výraznej transformácii. Súčasťou tejto transformácie budú pravdepodobne aj ďalšie zmeny, napr. zmeny v štruktúre globálnej produkcie plynu, obchodovaním s ním a očakávaný je aj pokles ceny tohto palivo. Okrem toho sa môže rozvojom ťažby bridlicového plynu zvýšiť energetická bezpečnosť jednotlivých krajín, pričom je reálne očakávať aj predĺženie času využívania konvenčných palív ľudskou civilizáciou. Ak sa zvýši produkcia bridlicového plynu, môže táto skutočnosť viesť v niektorých krajinách nakoniec k nahrádzaniu používania uhlia. Táto zmena by jednoznačne priniesla nižší objem emisií CO_2 do ovzdušia, čo by významne znížilo produkciu tohto jedného z najbežnejších skleníkových plynov. Okrem toho sa v niektorých krajinách obmedzí aj možnosť využívania energetických surovín ako nástroja politického boja.

Na druhej strane nesmieme zabúdať na negatívne aspekty ťažby zemného plynu z bridlicových formácií. Najdôležitejším fenoménom, zdôrazneným aj v článku, je najmä nebezpečenstvo samotnej technológie ťažby pre životné prostredie. Existujú štúdie potvrdzujúce vyššiu emisiu znečisťujúcich látok ako je to v prípade bežnej ťažby zemného plynu. Preto je veľmi dôležité zlepšiť technológiu hydraulického lámania, ako aj dôslednejšie kontrolovať ťažobné spoločnosti pri dodržiavaní stanovených noriem ťažby. Ďalším nebezpečenstvom v kontexte využívania tohto zdroja paliva, sa zdá byť samotná činnosť rôznych lobistických skupín, ktoré sa môžu pokúsiť legislatívou znížiť ťažbu bridlicového plynu, čo je napr. v Európe veľmi aktuálne.