An Overwiew of Economic Impacts of U.S. Shale Gas Revolution

Janda, Karel and Kondratenko, Ivan

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Karel Janda[*] and Ivan Kondratenko[**]

Abstract

This paper aims to analyze the possible shale gas development in context of energy security as based on the experience of shale revolution in the USA. It focuses on updating research on shale gas, explaining its specifics, discussing the US model of shale gas development and possible impacts on the EU energy market. It provides a literature review, an overview of the worldwide shale gas development and discusses the most relevant related environmental issues connected with shale gas.

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Keywords	shale gas, European Union, energy security, shale revolution, energy market, US

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[*] Karel Janda, Department of Banking and Insurance, University of Economics, Prague, W. Churchilla 4, 13067 Praha 3 and Institute of Economic Studies, Charles University, Opletalova 26,11000 Praha 1, <Karel-Janda@seznam.cz>

[**] Ivan Kondratenko, Institute of Economic Studies, Charles University, Opletalova 26,11000 Praha 1, <ivan.kondr@seznam.cz>

1 Introduction

The recent changes in energy that occurred over the last 10 years were preceded by the extensive research in the field of searching for effective methods of shale minerals manufacturing. Due to the ecological characteristics of these species (i.e. distinguished by particularly low porosity and penetrability) the traditional method of obtaining hydrocarbons was either impossible or economically ineffective. However, the growth of prices for hydrocarbons that skyrocketed in the 2000s, increased the interest in these minerals and provided hope for funding further research. A combination of advanced methods of well-known basic methods (water ruptures of plays, which was already invented in the US in the 1970s and implemented for the first time by George Mitchell in Texas) led to decisions which (at least in the US) proved to be commercially effective.

As for now, for at least a decade the whole world observes a raging process of further development of this experience. At the same time, every half year the direction of this development changes and application of new technologies is introduced. The surplus of dry gas has led to rapid fall of gas prices in the US. The higher usage for wet gas with high level of (quite expensive) ethane, propane, butane, and gas concentrate became a subject of special interest. Few years ago, the excess of production of these fractions (specifically ethane) compared with insufficient capacity of oil-gas industries also led to decrease in their prices. With these conditions the possibility of effective usage of new technologies for hard-extraction oil resources manufacturing became possible. Shortly, the significant part of oil manufacturing was redirected into this field. As a result of higher effectiveness of basic components of technological process, the extraction of shale gas stabilized even as the volume of total extraction went down. At the same time, re-orientation of released capacity conduced to impressive fast growth of oil extraction (involving the gas concentrate) in the US.

As a result, the transformation of the US energy market led to many consequences. The US is turning from the biggest world consumer and importer of energy sources into an independent "Great Power" in the energy market with the ability to influence the world's prices of energy. In 2014, American coal in Europe is competing with Russian gas, car-owners in South America and Europe are already tanking American gasoline; Great Britain expects to import large amount of LNG from the US (and also to extract own shale gas); Japan is already preparing for excepting American LNG and is developing new technologies of methane hydrations from Pacific Ocean. Meanwhile, we observe higher consumption of coal in Japan, as the gas surplus is expected.

Generally, the "shale revolution" became an accentuated demonstration of more general feature in the new epoch of energy industry. The world started to focus on the development of technologically more robust ways of mining energy resources. This turn seems to be very important for the traditional energy exporters, e.g. for energy sector of the Russian Federation, and particularly for the oil sector of Arctic shelf and oil fields inside the continent, which can be extracted by traditional and conventional methods. These two directions can impulse the development of this sector, however not in short-term (as we observed it in the US), but more strategically and probably in the long-run horizon, considering all possible consequences. At the same time, the simple shift of well-designed technological decisions is insufficient; the new decisions and adaptation of previous ones to more complicated conditions are required.

Therefore, nothing is clear in the world's future energy image. Graphics of business forecasting are usually divided into two parts; left one, where the history is, with high fluctuation, and the right one, where the prognosis is – mostly straight line with steep slope. Rapid changes are not likely to be predicted, fluctuation are never expected. Matters of last decade will probably put an end to this tradition very soon. It is a well-known fact that the last boom of shale gas drilling and badly-approachable oil in the US was not predicted even 10 years ago. At the time when George Mitchell, the "father" of shale gas revolution, sold his company Mitchell Energy and Development to Energy Devon for 3,5 billion dollars (Devon Energy, 2002), US Energy Department still did not see a new tendency behind this big success and evaluated the perspectives of shale gas drilling as a small scale endeavor.

It is well-known fact that recently billions of dollars were invested into LNG import terminals and factories for re-gasification of LNG in the US. Investors of these projects were building the perspective of clear energy future. However, all of them lost. In our days, the investment processes in two main (competing) ways are developing – firstly, the development of LNG export, and secondly, the gas chemistry industry, each of them for billions of dollars. Competitiveness of both these ways was built on long-term expectancies for low gas prices. However, their development began to evolve in other direction. Because of high growth of new sector in energy economy investors are no more likely to take a risk for investments to this field, based on previous non-success of big players.

So far, there is no clear evidence about the capacity of economically effective resources of hardly-extractable oil in the US, and researchers have not established the future of this oil and shale gas. No one knows whether the fall of extracted amount should come around 2020 or long after that. One more problem is related to the environment – the regulation of realization of hydro-rupture of plays. Majority of environmental issues in the US are in the State of New York, where are large supplies of shale gas at well Marcellus (Ivanov, 2014), but they are not realized because of shale gas drilling moratorium from 2008. Over the years experts try to analyze all aspects, but they still have not found a unified solution. As a result, there will be probably realized regulations for shale oil and shale gas drilling, which will make these methods economically ineffective.

It is already clear this tendency is getting progression – more states are actuating the stricter rules of hydro-rupture process, and the US federal government is following initiative and is issuing own regulations, which makes the whole situation even more complicated. Both US civil society and government are trying to estimate the future in energy in the US. Two sides of the coin are considered – either the US will become energetically completely independent country and it will contribute to US economy positively, or we become a “green” country, which tries to preserve the environment. As we will see later, the European Union prefers the second option. In comparison with the EU, the Barack Obama’s administration has not confirmed which direction the US energetics should go, how to unify these two different approaches to shale oil and gas, and has not offered its own solution, which would be most suitable for all political, economic, social, and environmental fields.

And not only US companies are waiting for this solution – many countries around the world are in the same position.

This indeterminacy is partially linked to development of technologies in other industry sectors and other regions. For as long as the renewable energy resources will not be totally economically effective (or their subsidiary by government or society will not be lower), the oil and gas will still be in high demand. Moreover, geopolitics experienced shocks in recent years. The "Arab Spring", Iraq, Syria, Iran, and Ukraine – no one knows in which part of the world one can expect the political transformation next. If the changes are so rapid and unprecedented, what should one expect at geopolitical map of the world in a few years? The forecast of this evolution of recent situation is very complicated. For the European Union everything happening in the world's energy market is very important – both economically and politically. And concrete image of our future depends on many factors, which involve our ability to follow world's tendencies and to react to them adequately.

Generally, hale gas is a product of groundbreaking technology which helps to realize American dream, which seemed to be unapproachable not a long time ago – to get out of energy dependence. Natural gas from unconventional resources (i.e. from black mineral shale) is being already mined in capacity, which allowed to US intensely reduced import of liquefied natural gas (LNG), and in near future the U.S. gas will be fully exportable. Already all attention is paid to decreasing of oil import in US. Energy independence of North America becomes real horizon.

Therefore those who are familiar with the term "shale gas" usually ask two questions: is not this topic just an overvalued inflated bubble?; and how drilling of shale gas will affect supply of gas on world market? The answer to the second question is simpler than to the first one. Already in 2010, US started to export small amount of shale gas in form of LNG to Europe for probation. U.S. sold this gas in Europe for price lower than price of Norwegian and Russian gas which led to small (but significant decrease) of stock prices of major producers of gas in these two countries. After this event the demand for long-term contracts with gas exporters of Norway and Russia decreased and new customers began to deal the conditions of contracts more in detail. Period of unrealistic threat for main energy suppliers in Europe passed away. The world's market of energy is changing; all big players in oil and gas market have to adapt to new conditions settled by US to lower the loose, and to find the solution how to react to this challenge. Apart from that if it is bubble or not, if it is only the short-term fluctuation or long-term tendency, the development of own technologies how to mine and sell gas (natural or shale) in cheaper way seems to be necessary. The current situation can be also regarded as incentive for renovation of all used technologies to remain competitive.

2 Literature review: economic impacts of shale gas drilling

The purpose of this section is to provide a summarized overview of the most relevant literature to shale gas revolution in the US and its possible application on the EU market. The US shale revolution happened very quickly in terms of transformation of energy market and significantly changed the way of understanding the world market. After the shale miracle had taken place in the US, economists immediately began to observe economic changes and impacts on the US economy, to make predictions for the possible development and to discuss possible devolution of the US technology to the EU conditions. However, since the topic is highly recent, not many relevant studies regarding shale gas are available, specifically for the EU environment. The summaries and comparison of s relevant papers dedicated to the topic is provided below. Since the topic is highly contemporary, the space for contribution is large and researches with focus on many sub-topics corresponding to theme are likely to contribute in the near future.

2.1 The United States

Despite the majority of papers are dedicated to shale gas production in the US, only the most relevant were chosen to be discussed. Shellenberger et al. (2012) tracks the timeline of development of energy industry in the US, targeting the role of government in the process of shale revolution. They notify that despite the shale gas production has already been growing since 1980s, the hydraulic fracturing methods were not used almost till the end of 1990s. After the US government had approved usage of this technology for commercial reasons in 2002, the shale gas revolution began. From the study of Shellenberger et al. (2012) one can take that the government support (either through legislation or financial measures) may be crucial for a shale revolution to take place, regardless of a country.

Ivanov (2014) provides one of the most detailed analyses of the US shale gas market, with the emphasis on its economic efficiency. The up-to-date comparison of statistics of several US market leader companies is performed. Ivanov (2014) points out that shale gas drilling is not very economically effective by itself, compared to the natural gas drilling using conventional methods, however shale gas oil makes it profitable. Based on the data covering 3–5 years of different mining companies Ivanov (2014) proves that shale oil drilling is highly profitable and economically reasonable, and shale gas is drilled mostly due to its presence together with shale oil.

The initial euphoria for shale gas drilling have subsided and the number of shale gas wells decreases every year; instead the number of shale oil wells increases and the shale gas is being mined as a supplement.

More interesting point of view is provided by Gény (2010), who looks on all the changes which occurred in the US since 2000, both policy and market changes, and finds five catalysts, which stand behind the US success.

2.2 Application of the US methods abroad

According to Stevens (2010) the technology used in the US cannot be applied in the rest of the world because the American companies have a lot of experience with oil and gas mining, the US energy industry was ranked among the largest in the world and companies did have enough financial instruments for further investments. At the same time the increasing demand for oil and negative trade balance were incentives for research. Ivanov (2014) agrees and discusses the changes oncoming in the US energy sector that influences the global market. He does not dispute the fact that shale gas revolution significantly lowers the world price of oil and gas (however he stresses the long-term influence), but at the same time he doubts that "American miracle" can happen in any other country. Stevens (2010) also looks more into the future and discusses the consequences of potential cheap gas dominance on the world market as a result of spreading gas drilling using unconventional methods. He warns against "*serious gas shortages in the medium term*", based on the assumption that according to his data there are five times more proved reserves of shale gas than conventional gas but its exhaustion can happen much faster.

Companies willing to invest into energy market worldwide are facing the decision they have to make – conventional or unconventional. Two problems arise from investor uncertainty at gas value chain, according to Stevens (2010). Firstly, due to shale revolution during the last decade the market price fluctuated more than before. Additionaally, the investment into gas research and drilling is likely to be lower than it would be if the shale revolution in the US were not to happen. Second problem is caused by evolving climate changes. Stevens (2010) warns that if shale gas is to show the profitability in long term, the willingness of investors to focus on relatively expensive technology for production of energy with lower carbon emissions will decrease.

Ivanov (2014) also dedicates part of his book to the US-Russia relations and analyzes the US shale gas revolution in light of the interests of the Russian Federation. In relation to events, which can lead to restructuralization of world energy market, he makes suggestion for Russian government and leader companies to start with development of their own shale gas drilling technologies as soon as possible and do not lose contact with global leaders when the change occurs.

2.3 Environmental issues

Broomfield (2012) provides the critical report on environmental issues coming from hydraulic fracture methods, published as the document of the European Commission, and understood as official position of the EU. This study was written for supporting those European countries, whose governments were not convinced by the techniques used for shale gas drilling in the US, particularly pointing out the environmental respect. In his paper, Broomfield (2012) props oneself upon the several US studies analyzing environmental impacts of shale production, and legislation regulating hydraulic fracturing, such as documents from the US Environmental Protection Agency (EPA) or the Natural Gas STAR program. Broomfield (2012) showed that constructive standards had to be made before the mining was able to start. Another study published by EU officials, specifically the European Commission, is report written by Pearson (2012), who also considers the consequences of shale gas drilling in the EU, with stress on environmental issues. The study admits the possibility of local shale gas production, however does not see the shale revolution as probable to happen in the EU on a large scale.

According to Broomfield (2012), high attention to technology using hydraulic fracture should be paid by the European Council. He pointed out that many member states may be interested in possibility of shale gas research, however several of them already introduced legislation, which prohibits hydraulic fracturing methods due to water pollution anxiety. At the end of his paper, Broomfield (2012) agrees with restructuralization of energy security in the EU, but at the same time asks for formal regulations of present methods and suggests to develop own environmental-friendly technology. Jacoby, O'Sullivan and Paltsev (2011) show that technology used in the US model makes positive impacts on economy, energy stability, and also environment. They particularly analyze air pollution and conclude that increasing shale energy can lead to up to 50% reduction of emissions. However, Jacoby, O'Sullivan and Paltsev (2011) noted that safety and storage techniques should be modified.

To conclude, papers summarizing the US energy market are more optimistic. According to majority of authors, the potential of the US shale gas resources is high and economically profitable. On the other hand, the papers dedicated to the European market and prediction of shale production on the territories of the EU are rather pessimistic. Due to various environmental issues, regulations and lack of investments to this industry, the universal transition to shale gas is highly improbable. However, authors do not exclude local production which can change energy market on a regional level.

3 Evaluation of shale gas drilling development

EIA estimates world unconventional gas[2] reserves at 331 trillion cubic meters[3], but estimations for the real amount which can be drilled, are uncertain. According to EIA estimations from 2013 (EIA Annual Energy Outlook, 2013) there is about 208 trillion cubic meters of shale gas and EIA predicts that 7% of all natural gas production will have origin in shale plays by 2030.

The biggest (and in commercial sense we can say “only”) producer of shale gas is the US, in cooperation with Canada, through the common system of pipelines. Shale gas plans are discussed in all parts of the world, mostly in China, Argentina and the EU. Shale gas already forms 47% of the total consumption of gas in the US (EIA Annual Energy Outlook, 2015) and due to shale success in 2009 the US overtook Russia in the list of the biggest natural gas suppliers. It affected the US price of natural gas, which will be shown later. As we can see in Figure 1, the natural gas price in world terms is highly unstable, but tendency of decreasing price is observable. In the EU the acceptance of the technology and its utility is subject of discussion by government representatives individually across member states and therefore the approaches to the shale gas drilling vary greatly. Public opposes the technology mainly due to environmental issues.

[2] Unconventional gas is: shale gas, methane from coal plays and gas in other mineral forms
[3] The estimated world reserves of conventional gas are 421 trillion cubic meters (EIA, 2014).

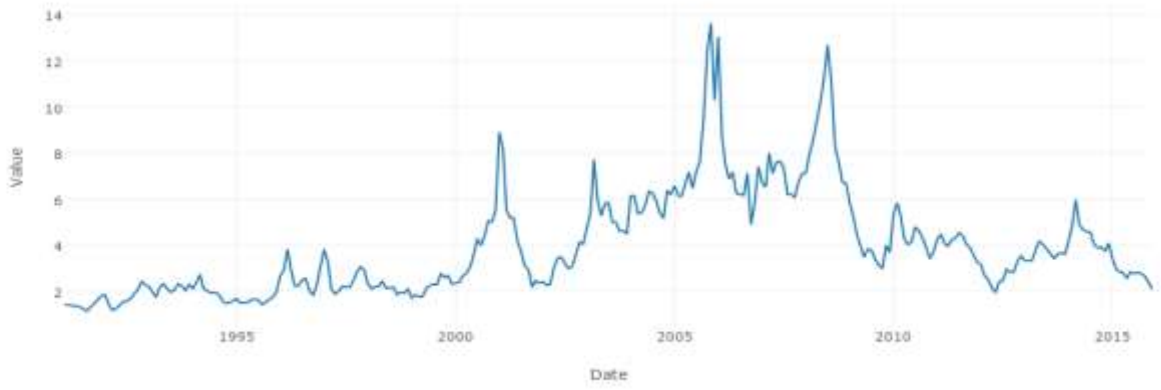

Figure 1. World average price of natural gas, USD per thousand cubic meters

Source: Henry Hub Natural Gas Price

3.1 Technology

Shale gas drilling is technologically difficult. Shale gas is present in shale rock slices, which are situated 400–4000 meters under the ground. The rock does not let the gas escape, thus it remains inaccessible for widely used classical gas-wells, in contrast to the fields with natural gas. Miners use a combination of technologies to harvest the gas. It consists of drilling of long horizontal wells and making fissures in the rock by pressed water with sand.

Shale minerals are located more often in horizontal slices (parallel with surface). Classical vertical wells reach only small part of shale and therefore are inefficient for drilling this type of gas. In shale gas drilling it is necessary to drill long well inside of shale slice because gas can only be drilled in narrow surroundings of well. Miners use combination of wells for shale gas drilling. At first vertical wells are drilled, and afterwards they are followed by horizontal wells. It is not enough to create the well itself because the amount of leaked gas would be very low. That is why the hydraulic fracturing method is used – water together with sand and chemicals is pumped into the well and creates high pressure inside of the well, which causes scratches. Leaking gas is pumped to the surface together with water.

It is obvious that it is necessary to use special heavy machinery for drilling. That is not just the drilling ring itself, but derrick with platforms, special pumps, gastanks, reservoirs for sand and water, and the drilling deliveries as well. That increases initial fixed costs. Drilling is complicated by the fact that gas fields are usually located in badly accessible areas, coupled with no road access. This method did not get under control successfully until 1990s in the US.

3.2 Current reserves worldwide

According to the EIA statistics, which publish the estimations of reserves worldwide, the largest shale plays are located in Siberia, North America, Argentina, Brazil and South-Eastern China. In Table 1 are listed 10 countries with largest reserves of shale gas, according to EIA (2013). However, beside the US, the shale gas has not been drilled for commercial reasons in any other country in 2015. In some countries the exploration wells were initiated (the most notable works were done in China), in others they are being initiated subsequently or are planned in the near future (Argentina, Libya, Algeria). Despite facing the problem of competitivness of Middle Asia countries (Mejstřík & Chvalovská, 2012), Russia does not plan to drill shale gas in near future at all because there is no government support of unconventional methods and Russia is still able to drill natural gas by conventional methods with lower costs. It is not expected that Russia will start with exploration wells at shale plays before any signals of shrinking of natural gas reserves will be circulated.

As a consequence, this section discusses the overview of only few countries with largest reserves (and potential for drilling) – China and Argentina. The shale gas situation of Azerbaijan is analyzed as well in this section because Azerbaijan could be considered as possible shale gas supplier to the EU, due to its location.

Rating	Country	Trillion cubic feet
1	China	1115.2
2	Argentina	801.5
3	Algeria	706.9
4	US	622.5

5	Canada	572.9
6	Mexico	545.2
7	Australia	429.3
8	South Africa	389.7
9	Russia	284.5
10	Brazil	244.9

Table 1. Estimated unproved technically recoverable reserves of wet shale gas (2013)

Source: Own table, based on EIA data

3.2.1 China

Despite the production of shale gas is still very low China possesses probably one of the largest reservoirs of shale gas in the world, with estimated 31.57bn m^3 Compared to the estimated reserves of 24bn m^3 in the US in 2012). (EIA Annual Energy Outlook, 2014) However, the amount is not the only factor for comparison. Initial exploration wells showed that shale plays are 1500 – 4000 m underground (compared to 800 – 2600 m in the US), and the majority of the largest plays – Tarim Basin, Junggar Basin, Ordos Basin and others – are located in remote mountains or dessert areas, requiring costly infrastructure with pipelines to be built. (EIA Annual Energy Outlook, 2013) At the same time, a lack of water for hydraulic fracturing in these areas might be a problem, which can also raise prices of final product. In comparison to tedious bureaucratic approaches of European governments regarding hydraulic fracturing, the Chinese government considers the support of shale gas production as highly desirable. Drilling companies are subsidized by lower tax rates, support of technologies development and lower customs for machines. Research is aimed at exploration for water subsidy for water. Private companies do not have chance to outrun the competition because only state companies – CNPC, Sinopec and China United Coal Bed Methan are subsidized. According to the Chinese plan of shale gas production there should be 6,5bn m^3 of gas drilled in 2015. This might be an ambitious plan because only 0,2bn m^3 of shale gas was produced in 2013, while the total consumption amounted to 150bn m^3. (EIA Annual Energy Outlook, 2014)

Another interesting fact is that China massively invests into the American shale gas production – Sinopec bought 33% share of the US company Devon Energy, CNOOC bought Nexen with shale gas plays in Canada, and PetroChina owns 49.9% of shares in Duvernay project for shale gas production in Canada. (BP Statistical Review of World Energy, 2015) It can be expected that China will try to get cheaper gas via import due to significantly increasing natural gas consumption. Considering the current data it cannot be expected that China will initiate significant production of shale gas in the near future.

3.2.2 Argentina

On 30th October 2014, government of Argentina endorsed reform legislation on hydrocarbon production, which should help the country in effective development of the shale gas production and replicate the success of the US in this regard. The new law extends drilling licenses and lowers the level of minimum investments; companies also receive partial freedom in import controls and capital flows. (EIA Annual Energy Outlook, 2015) Specifically, Argentina aims to attract foreign investors to Vaca Muerta plays. Vaca Muerta is the largest and most perspective shale gas playing, discovered in 2011 by state company YPF. Unfortunately, it is disputable whether this law would be enough to promote usage of the technology since Argentina is not sought after economy for investments due to active role of government in the sector.

According to the Ministry of Energy, Argentina had reserves of 21,9 bn m^3 in 2014, which were the third largest reserves after China and the US (EIA Annual Energy Outlook, 2015). On 16th July 2014 the biggest Argentinean oil company YPF announced conclusion of a contract with the US company Chevron regarding the joint production of shale gas on Vaca Muerta plays. Chevron is expected to bring an investment of 1.5 bn USD. On 28th August 2014 YPF signed contract with Petronas, with investment of 475 mil USD. Argentina also considers cooperation with Russian companies, Gazprom CEO Alexey Miller visited Argentina for negotiations in October 2014 but no concrete agreements were concluded. In the end of 2014, the researchers began to work (led by YPF) with not clear prognosis of future development. (BP Statistical Review of World Energy, 2015)

3.2.3 Azerbaijan

Azerbaijan plans to start to work on shale gas plays before 2020, according to SOCAR (State Oil Company of Azerbaijan Republic) representatives. (Socar, 2015) There are several perspective territories in Azerbaijan where the geological investigation can be set – particularly in Gobustankii and Shemahinskii regions. In 2015 SOCAR initiated discussions on the possibility of shale gas mining with several well-known foreign companies. These companies (specific names were not published) should accomplish exploration of wells by 2020 and afterwards effectiveness of drilling will be evaluated by local government. (Socar, 2015) The news has not gone unnoticed at the local energy market – not just in Baku but also in many other countries. Azerbaijan is one of the significant players in the international energy market, therefore any news about the country is welcome by public. At international conference Caspian Oil & Gas 2015 Khoshbakht Iusifzad, vice-president of SOCAR, stated that shale gas revolution in Middle East is not a fantasy anymore but true reality. Progressive technology of hydraulic fracturing allowing drilling oil and gas from shale plays has considerably re-shuffled the international energy market, which appeared to be stable forever.

However, in case of Azerbaijan this information might be misleading – shale gas technique is still risky and ecologically doubtful, while in Baku there are large plays of natural gas and oil with old conventional drilling technology on hand. Additionally, the fact, that Azerbaijan, for which shale gas revolution might not be economically effective (shale oil and gas can lower the prices of traditional oil and gas – the main exporting items of country), gives an indication for this revolution, be worth mentioning. This can be highly effective favorable in long-term. If the revolution cannot be stopped, then it is valuable to actively participate in it.

3.3 Role of environmental issues

Environmental issues are one of the most significant barriers to shale gas production expansion worldwide and as is described later, the most "common" barrier in the EU. Before some of the main environmental effects of hydraulic fracturing methods will be described, it should be noted that there is no clear evidence of environmental impacts of unconventional method of drilling in the world. These activities have been the topics of both academic and technological journals but no harmful effects on health or negative effects on the environment as a result of hydraulic fracturing were detected or proved.

Impacts on environment may play the most important role in shale gas drilling, particularly the method of hydraulic fracturing of shale massifs using chemicals, water and sand, which contains the risk of underground water contamination. The issue is apparent in the US and that is why US government representatives already started drafting legal standards. For example, the parliament of the state of New York has already prohibited using hydraulic fracturing of shale rocks on its territory. This regulation will stay valid until the safety of the new shale gas drilling method is proved. Lastly, West Virginian representatives have issued regulation significantly constraining possibility of shale gas drilling (EIA Annual Energy Outlook, 2015).

Within the space of the European Union, there have been few notable studies of the environmental impacts published since shale revolution in the US. In 2012, The Royal Society and The Royal Academy of Engineering (2012) published environmental study, which concluded that the regulated hydraulic fracturing *should* be safe. The paper analyzed possible impacts of hydraulic fracturing on groundwater and its contamination, well integrity, risk of leakages of gas, climate affects and chemicals used in shale gas drilling. It also provides technical aspects of all risks – environmental, health and safety risks and concludes with the approval of shale gas drilling, since no significant issues are detected (when following all current regulations and directives).

However, in 2014, a new British study with opposite conclusions was published. According to Walport & Craig (2014), main British government science consultant, mining method called „hydraulic fraction“ plays the same risk as it was observed in the past at scientific and technical innovations like asbestos, tobacco or insurant thalidomide. Walport & Craig (2014) show the examples of innovations, which were broadly accepted precipitately and did have negative consequences on the environment and human health conditions. For example thalidomide, agent used in 1950s and 1960s as a medication preserving pregnancy sickness, was later discovered to cause higher probability of child limbs deformation. Walport & Craig (2014) claim that in all of these and many other cases the late acknowledgement of negative effects does not depend only on health conditions or environment, but also on massive expenditures and competitiveness lowering of companies and public economies following the wrong path. This can also be the case for hydraulic fraction. The study warns against contamination of ground water in the area of shale gas plays and points to the negative aspects of increased truck transport in the agricultural areas. Walport & Craig (2014) support the idea of solving the increasing energy demand only by renewable resources; however this goes against the interests of the sector.

Broomfield (2012) published official environmental study for the European Commission. Study reviewed all of the available information and was based mainly on the experience from the US. It identified a number of potential risks and issues presenting high risk for the EU inhabitants and the climate environment. The study stated water contamination risk and air and noise pollution due to high traffic level as two major risks. According to Broomfield (2012), hydraulic fracturing is activity with significant risks for human health and environment. Some of the impacts could turn into long-term and global problems (e.g. a massive explosion on the shale gas well in Chesapeake plays in Pennsylvania in April 2011). The rupture on drilling pipeline caused the leak of toxic water with chemicals into surroundings and 38 000 liters of water contaminated fields and a river. The long-term consequences of this accident are still unknown since the area has not been cleaned yet.

4 Case: “Shale revolution” in the US – suitability of this model in the EU space

4.1 Introduction

The US became the biggest producer of gas in the world in 2009, as a result of the development of shale gas drilling.

American shale gas boom has the changed world energy market. Gas market in the US was saturated already in late 2000s, domestic prices fell down and unused gas was transported as LNG to Europe. This led to a decrease of prices on European spot markets but at the same time the need for gas export in the form of LNG was created in the US. Projects of building new import terminals started to be considered as unnecessary and were changed to projects of building new factories for manufacturing of gas and export terminals of LNG. Federal authority has started to issue permissions for these projects. According to EIA statistics (2014) the shale industry has created around 2.1 million of direct or indirect job positions.

World energy market is changing. Many countries (consumers of natural gas) have tried to recreate American success in the past several years and have focused on their own unconventional gas resources. Meanwhile the development of new technologies was supported in the US and was extended not only to gas-drilling but also to another energy sectors. New factories producing mineral fertilizers and plastic materials were built, companies are transferring their own consumption from coal to gas and large projects creating production of liquid engine gas fuel, gas-to-liquids (GTL) has began to be developed. Fuel type of public transportation such as buses, cruises, taxis and road-trains is also considered to be changed to gas-fuel. Abundance of cheap gas creates new demand.

Market participants are obliged to admit that the US shale gas revolution took place and the consequences are long-term and irrevocable. Sellers and consumers of energy have no more hope for escaping this bubble and everything will remain as it was before. The producers of plastic materials for oil drilling became involved shortly after shale gas miners. As a consequence, countries of North America have chance to become fully energetically independent already in this decade, possibly till 2020.

Ideas of freedom and independence are traditionally important for US society. That is the reason why the idea of full energy independence is so popular. It is not likely to be abandoned now even if the US eventually recognizes some mistakes or discovers inaccuracy of assumptions. If the technologies of shale-gas drilling meets unexpected economy or ecology barriers, it is presumable they will be replaced by another technologies. So strong public demand, which we can see on the US market, cannot be left unsatisfied and be neglected without offering another alternative.

Possibly, American ideas and technologies of adapting unconventional resources of natural gas will find more effective application in other countries in near future but in this particular case the experience of the US shale gas market participants has to be analyzed and studied properly. Current level of globalization of energy market will be always connected to shale gas boom in the US.

The geology of each shale gas resource varies and so does performance of wells. In the US, the production of shale gas wells is invariably increasing in large amount of gas wells because of the higher precision and efficiency of horizontal drilling and hydraulic fracturing in gas extraction. Many producing platforms (e.g. Marcellus or Haynesville) are experiencing an increasing profit. Nowadays, US mining companies are producing more shale gas than at any time in the past. Five of the six biggest US shale players have increased gas production over the last 7 years. As it can be seen from the Figure 2, the leader of gas production at the US market is Marcellus Shale, which produced 6 million cubic feet of gas per day in April 2014. (EIA: Annual Energy Outlook, 2015)

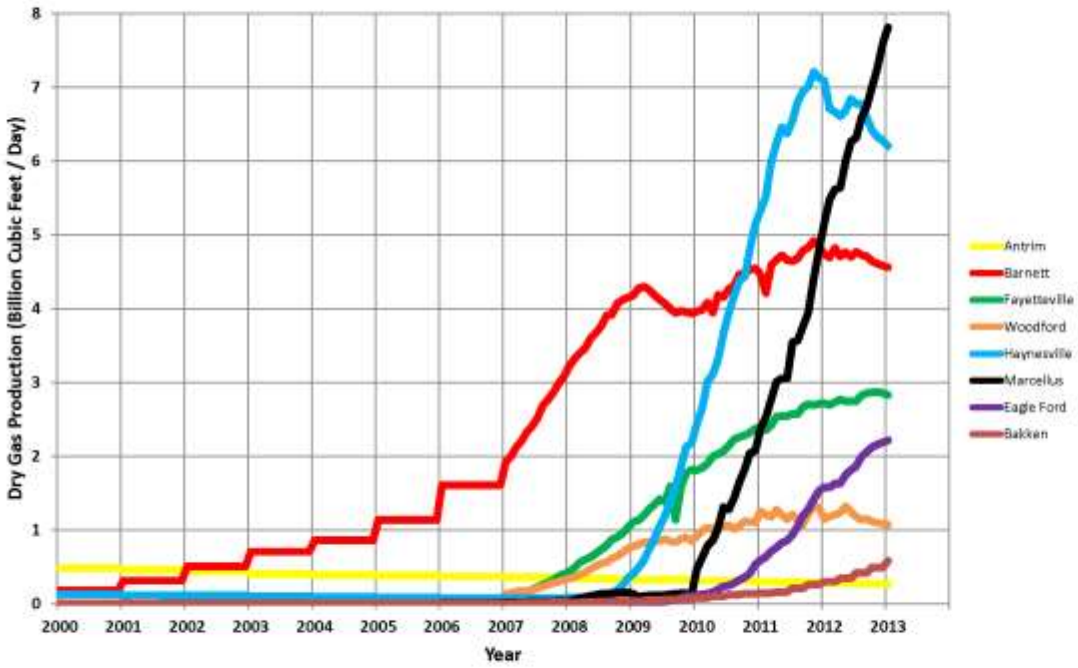

Figure 2. Uncoventional gas production per rig by shale play

Source: EIA,2014

4.2 Price, drilling and forecast

Fluctuation of oil and gas prices at American market is affected mostly by the amount of extracted fuel from unconventional resources. This is why the forecast of drilling and price provided by the EIA is highly valued by analysts and market participants. They are interested not only in the price itself but also in changes of this price since the previous year. The way predicted price is changing over the years helps us to understand the level of optimism of American experts with regard to shale gas and hardly-extractable oil drilling economics.

According to EIA: Annual Energy Outlook (AEO) (2014), the amount of oil extraction rose from 6.5 million barrels per day (324 billion kg per year) in 2012 to 9.6 million barrels per day (478 billion kg per year) in 2014. That is 22% more than AEO 2013 had predicted. Despite of the expected decrease of extracted amount after 2019 (a reason is not stated), the total extracted amount in the US will remain above 7.5 million barrels per day till 2040. The main contribution to these numbers will have the oil extraction. Review of this prognosis is linked to higher recent growth of drilling, where producers prefer to extract expensive oil than cheap gas. Furthermore, oil-drilling companies have learned to identify more reliably the so called "sweet spots" – the most attractive parts of shale plays. The shale oil extraction grew from 2.3 million barrels per day in 2012 (35% of total oil extraction in the US) to 4.8 million barrels per day in 2013 (51% of total extraction), according to AEO 2014. EIA: Annual Energy Outlook (2013) predicted fall of extracted shale oil after 2021, when the drilling should move to less productive areas.

In the last 2014 prognosis (AEO 2014) the possibility of exhaustion is not mentioned at all, but the beginning of decrease in extraction moved from 2021 to 2019. Keeping in mind that the EIA is preparing reports trying to prove the effectiveness of drilling and stating the new technologies allow lesser drilling and extracting more, the contradiction is quite obvious. Growth of effectiveness of drilling (with higher amount of estimated reserves) leads to lower oil extraction in the US. The answer to this puzzle may be simple – with higher amount of wells the amount of estimated reserves should be larger, which has not been observed yet. Therefore, the shale oil and gas extraction should slow down. This prognosis may be corrected in the future.

The EIA predicted accumulated gas extraction to grow from 2012 to 2040 by additional 11% in comparison to previous statistics released in 2013. Again, this is primarily due to the boom of shale gas extraction. In Figure 3 the effect of shale gas drilling since 2007 is visible. The second reason for this growth is the LPG (wet gas) growth and the rising amount of mined crude oil, which is always extracted together with gas. Prognosis of EIA (2014) of accumulated extraction of shale gas is 36% higher than the previous year. Gas prices are higher than the level estimated by the last year prediction due to fast growing demand of the industry. Spot prices for Henry Hub (in relation to AEO 2014 prognosis) will reach 4.80 USD for 1 MBTU (one thousand of British thermal units) in 2018, compared to the price of 4.03 USD for 1 MBTU predicted by EIA Annual Energy Outlook (2013).

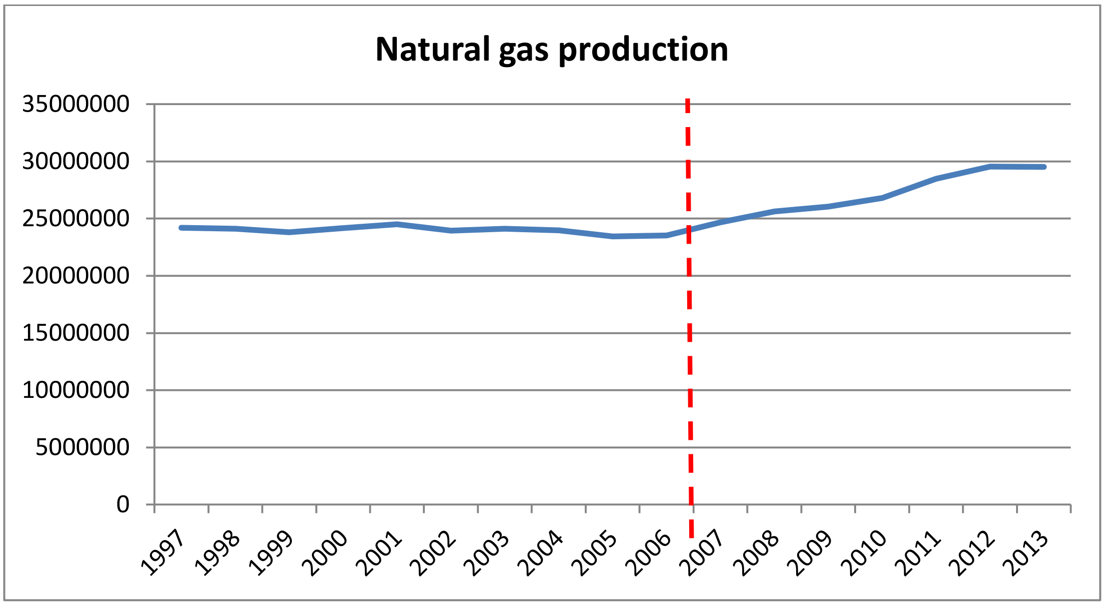

Figure 3. Natural gas production in the US (in million cubic feet)

Source: own figure, based on EIA data.

4.3 Shale gas drilling – direct way to debts and insolvency?

Companies that invested to shale gas and oil mining with conception of fast enrichment are starting to be depressed. Their debts are growing much faster than their incomes. Some investors have already had to provide more capital to ensure the survival of their companies, owing to high investing neediness of horizontal wells, followed by hydraulic fracturing. Companies need an increasing amount of new wells to replace natural decrease of gas and oil.

Total debt of mining companies in the US doubled in last four years and reached USD 163.6 billion, while the income from gas and oil sales increased only by 5.6%, based on the data from the 61 biggest mining companies in the US (EIA: Annual Energy Outlook, 2014) One fifth of these companies spend 10% of their income just to repay debt interest. For example, Texan company Quicksilver Resources admits they spend 45% of income on debt interests. Even though they have stated they have taken measures to lower debts (Quicksilver Resources, 2014), this effort may cause bankruptcy. Companies need to borrow money to excavate more wells in order to preserve stable capacity of mined gas and oil.

Investors have already forced 26 out of 61 companies to cut expenses on wells. However, lower amount of new wells leads to a decrease of mining and therefore decrease of income. Debt burden therefore becomes more sustainable (BP Statistical Review of World Energy, 2015). Miners slowly move from gas mining, which is not able to cover all mining costs, to more cost-effective shale oil. Shale mining of oil has raised domestic US production to 8.4 million barrels per day in 2014, which is the highest level since 1986, and 16% more than in 2013.

Shale plays need more wells that conventional plays and therefore the capital costs have to raise as well. Mining company Goodrich Petroleum tries to push down the one-well-expenses to USD 11.5 million. Despite this, the company had loss of USD 52 million in the first quarter of 2014. (BP Statistical Review of World Energy, 2015) Some of the miners have already tried to solve debts problems by selling of licenses or lands with shale plays. Some of them try to look for help abroad; e.g. Swift Energy has created the joint venture with one of the Indonesian state companies to pay its debts.

Browning et al. (2013) from The University of Texas in Austin provides cost effectiveness study on ten productive desks of Barnett Shale. According to Browning et al. (2013) the wet gas drilling from shale plays is cost-effective with no profitability from 2 USD/MBTU. He also proved that shale gas production is sensitive to market price of oil and LPG. He provided the analysis of few major US drilling companies and concluded that the wet shale gas drilling is profitable only together with shale oil drilling and that the economic situation of the major US drilling companies is stable. Browning also noted that the resources at shale plays are exhaustible quicker than conventional resources and therefore companies are forced to drill four times more wells per year than in the in case of using conventional gas wells. He also noted that pipeline connection among states is still missing in the US and therefore the price of natural gas for final consumer varies from 8 to 18 USD per thousand cubic feet. The situation is likely to change after the opening of the Keystone-XL Pipeline project.

5 Conclusion

To conclude, this paper provided an analysis of U.S. shale gas development in context of energy security. The goal of this work was to make updated research on shale gas, to explain its specifics, to describe strengths and weaknesses of US model and to discuss the possible impacts on the EU energy market. Due to recency of topic, not many works had been written on this subject. In our work we have provided the literature review of all significant works, which are valuable for our research. The “shale revolution”, which occurred in the US, was complexly analyzed – the history, legal background, sufficiency, economic validity, and, born on EIA data, we discussed the prediction of evolving shale gas industry in the US.

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