SHALE GAS

Basic Information

ORLEN

Shale Gas

Basic Information

WARSAW, JULY 2010

FOREWORD

Polski Koncern Naftowy ORLEN intends to actively participate in projects involving exploration for unconventional gas in Poland. This plan is among the Group's strategic priorities. ORLEN Upstream, the Group's company responsible for upstream projects, has already commenced exploration in five licence areas in the Lublin region.

This Report has been prepared as the first attempt in Poland to compile in a systemic way the available knowledge and information on shale gas exploration and production. We aim to provide all interested parties with reliable and complete information on shale gas and PKN ORLEN's activities in this area.

The first section of this Report outlines the basic characteristics of shale gas, such as its geological origin, extraction technology, commerciality criteria, and – what stirs the greatest hopes and emotions in Poland – the potential economic and political impact of its production.

The first country to launch commercial production of shale gas was the United States, therefore a whole chapter is devoted to this market. Shale gas currently accounts for approximately 14% of the U.S.'s total natural gas production. As estimated by the U.S. Department of Energy, a majority (60%) of recoverable gas resources is stored in unconventional reservoirs (shale gas and tight gas).

The final section of this Report examines the prospects of unconventional gas exploration and production in Poland. The estimates of potential shale gas resources published to date have provided a strong stimulus for the imagination. However, it should be remembered that the process of appraisal of potential shale gas reserves in Poland is only at a starting point.

This Report points out to both opportunities and potential barriers for the development of shale gas exploration in Poland, including geological, economic and administrative factors. It must be emphasised, however, that even if only the most conservative estimates of unconventional gas reserves in Poland prove correct, those resources – if their production turns out economically viable – may be sufficient to change the Polish natural gas market.

Jacek Krawiec
President of the Management Board of PKN ORLEN

This Report has been prepared by PKN ORLEN SA on the basis of its in-house information as well as data and opinions available to the general public. This Report was prepared in the period from May to July 2010.

SUMMARY

PART 1: SHALE GAS - GENERAL OVERVIEW

Shale Gas - Overview

- Depending on the nature of rock where hydrocarbons accumulate, deposits are divided into conventional and unconventional. Production of unconventional gas is more expensive and more challenging in terms of technology.
- Unconventional gas resources include shale gas, tight gas, coalbed methane, and gas hydrates.
- Given the current level of technology, it is possible to produce gas from unconventional resources commercially.

Production Technology

- The development of extraction of gas from shale formations has become possible after the cost of the technology of drilling horizontal boreholes and hydraulic fracturing declined.
- In horizontal drilling, a vertical hole is first drilled, and after an assumed depth is reached the borehole turns horizontal and travels along the targeted shale stratum.
- Hydraulic fracturing consists in pumping high-pressure fluid into a selected section of the borehole. The fluid is made of a carrier (mainly water), a proppant filling the fractures (mainly grains of sand of particular size and mechanical resistance) and chemicals (serving chiefly to improve viscosity). The fluid injected by pressure into the well creates fractures in shale formations, while sand prevents fractures from closing and creates new paths for gas to migrate to the borehole.
- The average amount of fluid pumped into one borehole during a hydraulic fracturing treatment ranges from 7.5 to 11.3 million litres of fracturing fluid, while the quantity of sand ranges from 450 to 680 tonnes.

Shale Gas – Commerciality: the U.S. Example

- Commerciality of shale gas production depends on numerous factors:
  - Mechanical properties and composition of the rock
  - Ability to make fissures based on natural fracture patterns in shales
  - Cost of drilling
  - Cost of hydraulic fracturing
- In 2009, Credit Suisse estimated that for the next few years the break-even point for shale gas production will range from USD 0.12 to USD 0.37 per cubic metre of natural gas.
- Due to growing demand for drilling equipment and drills as well as popularisation of the technology, costs can be expected to drop in the coming years.

Shale Gas – Geopolitical Implications

- Higher shale gas production may significantly change the areas of influence and energy dependency of many European countries and the United States.
- Thanks to its own production of shale gas, the U.S. has managed to significantly downsize its LNG imports.
- Shale gas production may reduce the EU's dependence on long-term contracts with Russia.
- Due to low CO_2 emissions, higher production of natural gas may halt investments in energy projects involving coal or oil.

PART 2: SHALE GAS PRODUCTION IN THE UNITED STATES

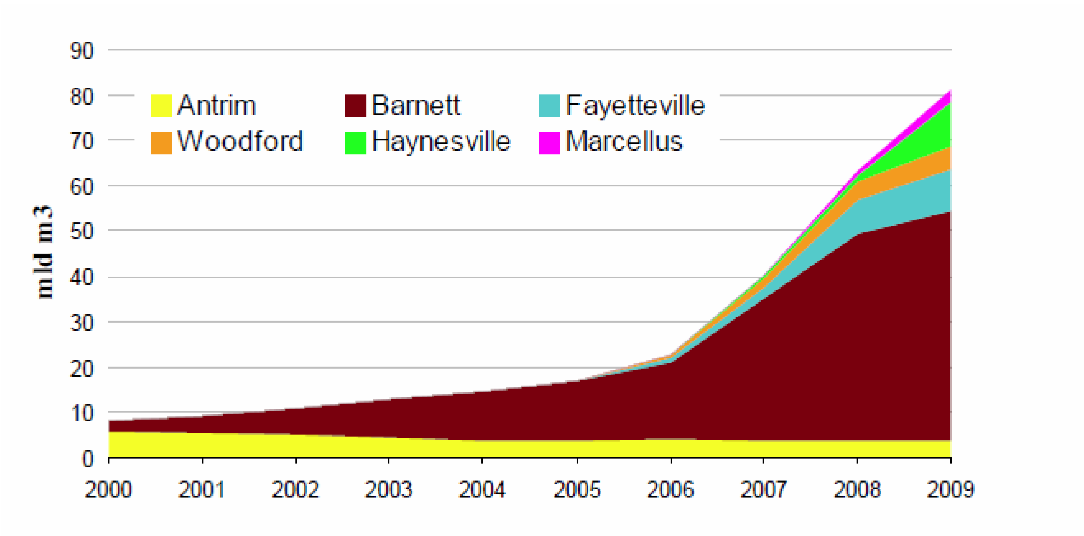
Overview of the American Natural Gas Market

- In 2009, the United States became the largest natural gas producer in the world. Production reached 598.37 billion cubic metres and rose by almost 4% over the previous year. 50% of the output comes from unconventional resources, including tight gas (27%), shale gas (14%), and coalbed methane (9%).
- According to the Energy Information Administration, the U.S. has 50 trillion cubic metres of technically recoverable gas resources, including approximately 60% from unconventional reservoirs.
- At present, shale gas accounts for some 14% of total gas production. In 2008, the shale gas output was 57.25 billion cubic metres and was over 70% higher than in the previous year.
- The United States has not yet become able to fully satisfy its demand for natural gas from domestic production, but gas imports have been steadily falling.

Overview of the American Shale Gas Market

- The recoverable shale gas resources of the U.S. may be as high as 17 trillion cubic metres.
- Production of unconventional gas is by far the largest in Barnett Shale, Texas. Although Haynesville, Fayetteville, Arkoma/Woodford and Marcellus are at an early stage of development, production from those fields is gradually rising (see chart below).

Shale gas production in the U.S. – main production sites[1]



- More than 10,000 boreholes were made in Barnett Shale. One horizontal borehole is made on a field ranging from 24.3ha to 64.7ha on average.
- In the U.S., the cost of drilling one vertical borehole up to the depth of up to 1,500m ranges from approximately USD 0.8m to USD 2m, while the drilling of one horizontal borehole with the length of up to 3km may cost as much as USD 6-8m.

PART 3: PROSPECTS OF SHALE GAS MARKET DEVELOPMENT IN POLAND

- As estimated by the Energy Information Administration, by 2030 shale gas production will account for 7% of the global natural gas output.
- According to Wood Mackenzie, Poland's recoverable reserves of shale gas may reach 1.4 trillion cubic metres. Advanced Resources International's estimates put the reserves at as much as 3 trillion cubic metres.
- Reliable information on the actual resource base will be probably available in four or five years, when exploration and appraisal work carried on under licences granted by the Ministry of the Environment is completed.

- Poland has issued 221 licences for exploration and appraisal of hydrocarbon deposits, of which 63 have been issued for shale gas. Exploration work covers 11% of Poland's area, i.e. 37,000 sq km.

[1] US Department of State, April 2010.

- Poland's shale basin extends from the coast, in the area between Słupsk and Gdańsk, towards Warsaw, and further to Lublin and Zamość.
- According to forecasts, potential shale gas reserves are present at the depth of 1,200-2,500 metres in the northern part of the basin and 2,500-4,500 metres in the southern part.
- The cost of one vertical borehole is estimated at USD 6–13m, depending on the depth.
- Lane Energy Poland Sp. z o.o. was the first company to start drilling (in June 2010, near Lębork).
- No shale gas reserves have been discovered in Poland to date.

Legal Considerations in Poland

- Polish geological and mining law does not envisage any special procedures for exploration, appraisal and extraction of gas from unconventional sources. The procedures are the same as in the case of conventional gas.
- In practice, the State Treasury enters into mining usufruct agreements and issues licences in two stages: first for exploration and appraisal, and then for production.
- A company which identifies and proves an unconventional gas reserve has, for two years, priority over other applicants in the granting of a production licence.
- Royalties in Poland range from 1% to 2.5% of revenue from gas production, depending on production volumes. According to the government's representatives, this should attract to Poland the largest possible number of foreign players with know-how in the area of shale gas production. In a similar way, the U.S. administration introduced tax credits and reliefs for firms developing unconventional gas reserves.

Potential Barriers to Shale Gas Production in Poland

- At present, Poland does not have any proved shale gas reserves.
- The government has not defined any clear policy, backed by the Council of Ministers' regulations, for efforts with respect to activities aimed at the development of the Polish shale gas market.
- Currently, Poland does not have the technology necessary to extract shale gas on a scale needed to ensure low costs, and thus commerciality of projects.
- Europe does not have sufficient drilling equipment to drill shale gas wells.
- There can be local problems with supplying water in quantities required for fracturing.
- Drilling tests may indicate low commerciality of shale gas production under the economic conditions prevailing in Poland at a given time.

Opportunities and Benefits Offered by Shale Gas Market in Poland

- An opportunity for Poland to rely on its own gas resources for many years and potentially to export gas.
- An opportunity for Polish oil sector players to develop and expand internationally.
- Obtaining of state-of-the-art exploration and exploitation technologies and development of management and engineering staff.
- Development of transport and transmission infrastructure necessary to handle produced gas.
- Reduction of national CO_2 emissions if the share of natural gas in the overall energy production in Poland rises.

CONTENTS

INTRODUCTION

"The world has gone crazy about shale gas. It is said that we are now dealing with a gold fever of the 21st century."

\- **Henryk Jacek Jezierski, Poland's Chief Geologist**

The recent decade has seen a strong rise in the interest of oil companies globally, and in Poland, in potential projects involving exploration and development of unconventional natural gas resources, namely shale gas, tight gas, and coalbed methane. This was made possible thanks to the development of advanced technologies, such as horizontal drilling and hydraulic fracturing.

According to recognised international consulting agencies, Poland's reserves of shale gas may be as high as 3 trillion cubic metres, with the market value exceeding tens of billions of dollars.

Exploitation of unconventional gas resources has enabled the United States to considerably reduce gas prices and dependence on other producers.

Is Poland now facing a unique opportunity to end reliance on gas imports and become a huge gas producer on a global scale? Could the discovery of shale gas in Poland be as groundbreaking for the European energy market as was the start of oil production from the Ekofisk field in the North Sea on August 30th 1971 by Phillips Petroleum? Over the next five years we should gain an understanding of the size of unconventional gas deposits in Poland.

PART 1

SHALE GAS – GENERAL OVERVIEW

"[Shale gas extraction is] the most significant energy innovation so far this century" [2]

- **Daniel Yergin, IHS Cera's Chair**

[2] Sasol-Chesapeake-Statoil apply to explore for shale gas in Karoo, Martin Creamer, Mining Weekly, March19th 2010.

1.1 Key Characteristics of *Shale Gas*

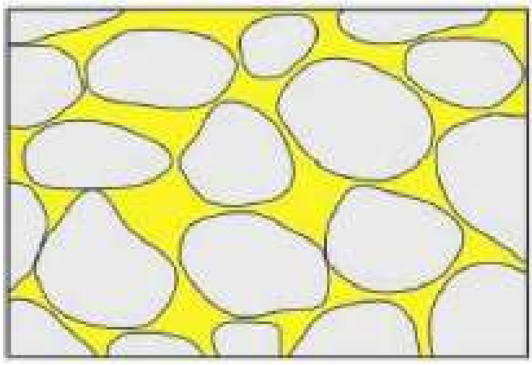
Natural gas can be broadly classified into **conventional** and **unconventional** deposits. People have known how to produce gas from conventional sources since the 19th century and the process has not posed any technological problems for quite some time now. Unconventional gas, on the other hand, is much more difficult and less economical to extract.

The unconventional gas sources include shale gas, gas locked in insulated rock pores (tight gas), coalbed methane and gas hydrates.

1.1.1 Origin of Shale Gas

The processes which gave origin to fossil fuels - including crude oil and natural gas – are extremely complicated. To cut a long story short, Silurian shale gas originated from organic matter made up of decaying plant and animal life. Over hundreds of millions of years, the organic remains accumulated, along with tiny particles of minerals, on the bottoms of sea basins. Over time, the organic matter, buried under layers of mud in anaerobic conditions (without oxygen), gradually decomposed and was converted into petroleum (natural gas or crude oil) by the combined action of heat and high pressure, which compacted the mud and silt into shale. As a result, shale became a source rock for conventional gas. Due to its physi-chemical properties, gas generated in the process migrated towards the surface until it encountered various types of geological traps in the form of porous rock formations tightly sealed by overlying layers of impermeable rock. This led to the formation of conventional gas deposits, resembling gas-soaked sponges (see Fig. 1.1).

Figure 1.1 – Conventional gas deposit[3]

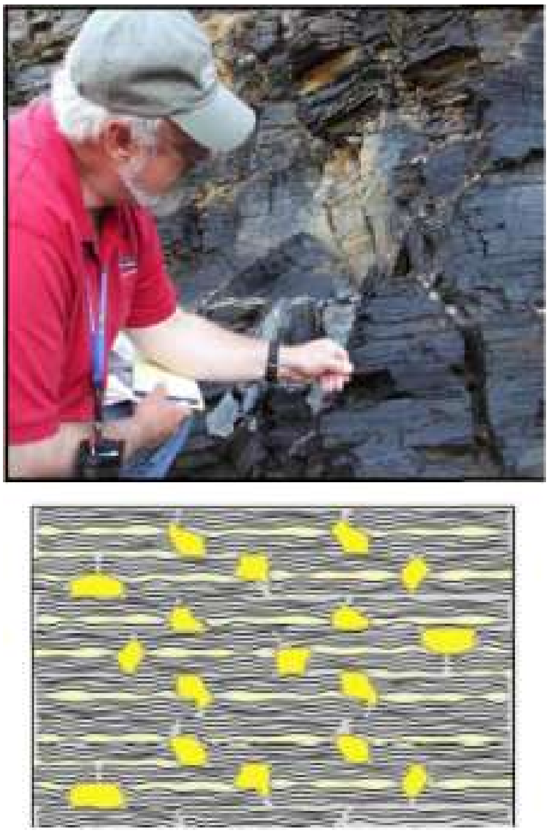


Traps like the ones described above resemble large containers from which conventional gas can b

Historically, gas has been produced chiefly from such traps. There were no technological solutions available to examine hydrocarbon source rocks, given that black shale, containing abundant organic matter, is practically impermeable. Black shale occurring on the Earth's surface is usually split into thin laminae, but at a depth of merely one kilometre its structure is concrete solid. Black shale gas is locked in insulated micropores or physically attached to organic matter through absorbtion (see Fig. 1.2).[4]

[3] "Concession policy and legal regulations for exploration and production of gas", Henryk Jacek Jezierski.
[4] "Wyciskanie Gazu" ("Gas Extrusion"), Mirosław Rutkowski, Polityka.pl - Nauka, Feb 24 2009.

Figure 1.2 – Unconventional shale gas reservoir [5]



In the past, it happened that natural gas trapped within such rocks was extracted, provided that the rock formation contained fractures through which shale gas could be slowly released. The first shale gas producing well was sunk as early as in 1821 in Devonian Dunkirk rocks, in the United States. For many years, the 9.5-metre deep well supplied gas to illuminate the nearby town of Fredonia in the state of New York.[6] However, that development was unique and for decades oil and gas companies did not have the technologies that would enable them to exploit shale gas.[7]

5 Picture - All Consulting, 2008; Drawing – "Concession policy and legal regulations for exploration and production of gas", Henryk Jacek Jezierski.

6 "Modern Shale Gas Development in the United States: A Primer", US Department of Energy, April 2009.

7 "Modern Shale Gas Development in the United States: A Primer", US Department of Energy, April 2009.

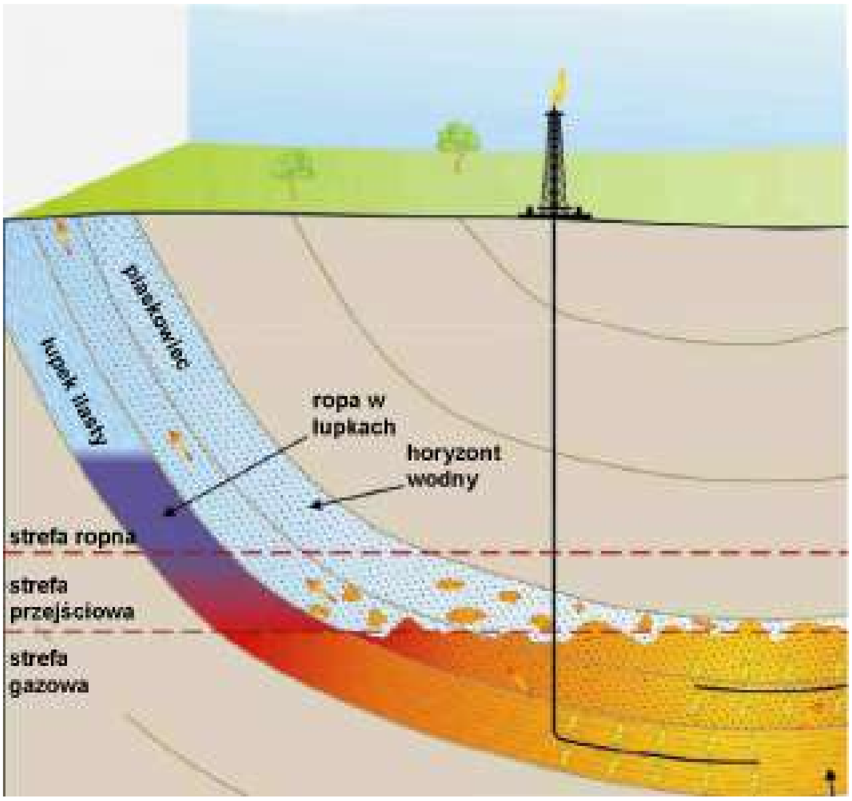
1.2 Shale Gas Production Technology

Development of shale gas resources became possible thanks to advances in production technologies. It was not until horizontal drilling was extensively used and the hydraulic fracturing techniques were improved that commercial production of gas trapped in shale source rocks became viable.

1.2.1 Horizontal Drilling

Only two decades ago, horizontal drilling (see Fig. 1.3) was regarded as an extraordinary technological feat. In mid 1990's, it started to be used to enhance recovery from conventional petroleum deposits, as a result of which it soon gained in both popularity and sophistication.

Figure 1.3 – Horizontal drilling - schematic representation[8]



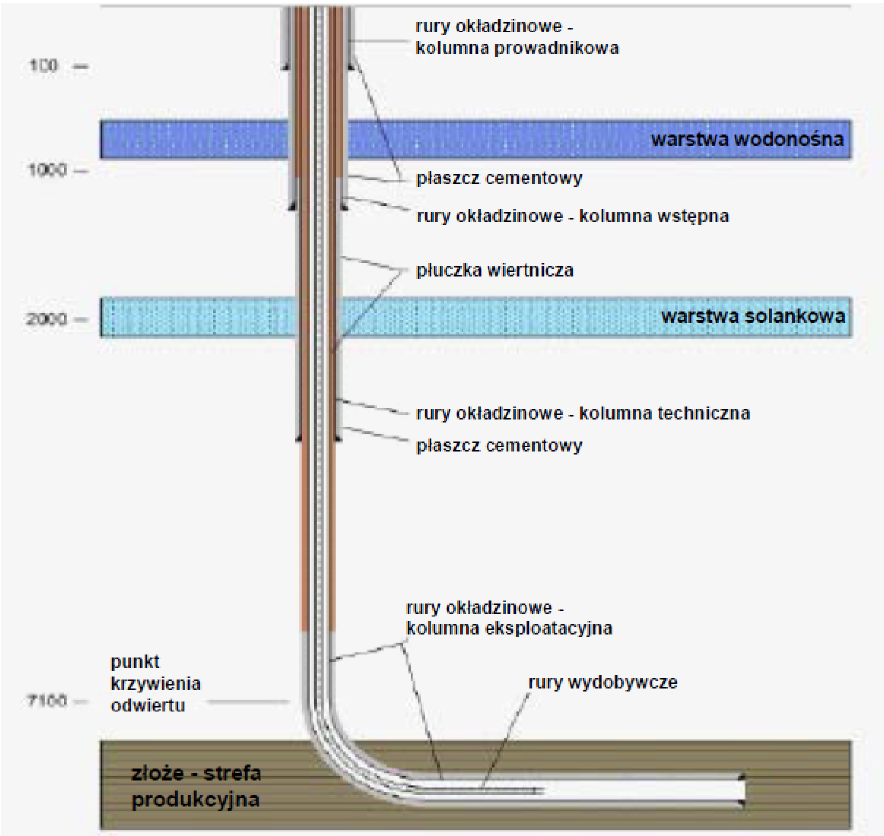
horyzont wodny	aquifer
ropa w łupkach	shale oil
piaskowiec	sandstone
łupek ilasty	shale
strefa ropna	oil-bearing zone
strefa przejściowa	transition zone
strefa gazowa	gas-bearing zone

[8] Source: R.M. Pallestro (2003).

Horizontal drilling involves sinking a vertical borehole and then, after it reaches a specific depth, sidetracking the borehole to a horizontal trajectory, with a view to reaching a target rock formation from one to over three kilometres away from the vertical hole.

The walls of the boreholes are cased, and the space between the casing and the drilled rock is cemented in order to stabilise and reinforce the well, and to isolate it from aquifers and other formations containing undesirable minerals (Fig. 1.4).

Figure 1.4 – Well casing – schematic repersentation[9]



rury okładzinowe - kolumna prowadnikowa	conductor casing
rury okładzinowe – kolumna wstępna	surface casing
warstwa wodonośna i warstwa solankowa	water- and brine-bearing horizon
płaszcz cementowy	cement
płuczka wiertnicza	drilling mud
rury okładzinowe – kolumna techniczna	intermediate casing
rury wydobywcze	production tubing
punkt krzywienia odwiertu	kick-off point
złoże – strefa produkcyjna	reservoir – production zone

9 "Modern Shale Gas Development in the United States: A primer", US Department of Energy, April 2009.

The petroleum industry soon realised that horizontal drilling – allowing operators to access a larger area of the reservoir compared with traditional vertical drilling – can be used to produce gas from black shales, thus far considered not to be economically viable. The existing technologies enable vertical drilling to depths of more than seven kilometres and horizontal drilling of sections more than 3 kilometres long.[10] The record of 11 kilometres was set by Maersk Oil.

Thanks to horizontal drilling, reserves can be recovered much more effectively than in the case of vertical wells. Eight horizontal sidetracks branching off from a single location may access a deposit which, if traditional methods alone were used, would require the drilling of 16 vertical wells.[11]

It should however be noted that – due to ultra-low permeability of shale formations – horizontal boreholes must be spaced more densely than in conventional gas production operations. The average drilling density is 4-8 wells per 2.6 square kilometres.[12]

In the United States, the average cost of drilling and completing a vertical well to the depth of up to 1,000 metres is approx. USD 0.8m, whereas the cost of drilling a well with a horizontal sidetrack of the same depth may reach USD 2.5m.[13]

However, the use of horizontal drilling alone is not enough to ensure effective recovery of unconventional gas. To enable recovery on a larger scale, a network of man-made fractures must be made along the horizontal section of a well and subsequently filled with sand of the appropriate grain size to create new conduits through which gas can flow from the reservoir into the producing well. The process is called hydraulic fracturing.

1.2.2 Hydraulic Fracturing

In 1981 a Texan engineer, George T. Mitchell, experimented with various methods of shale gas extraction. He was the first to apply hydraulic fracturing (or pump fracturing fluid under very high pressure into defined sections of a wellbore) in order to make the formation crack and to extend the existing cracks further into the shale formations. The technology was patented at the end of the 1990's[14] by Mitchell Energy & Development, a firm founded by George T. Mitchell, which was

[10] "Polish shale gas sparks bonanza hopes", Richard Robinson, Fund Strategy, May 23rd 2010.
[11] "Modern Shale Gas Development in the United States: A primer", US Department of Energy, April 2009.
[12] "Modern Shale Gas Development in the United States: A primer", US Department of Energy, April 2009.
[13] "Modern Shale Gas Development in the United States: A primer", US Department of Energy, April 2009.
[14] "The Father of the Bernett", Marc Airhart, Jackson School of Geosciences.

acquired in 2002 by Devon Energy for the price of USD 3.5bn.[15]

Modern hydraulic fracturing (Fig. 1.5) is a strictly controlled process, tested in laboratories and in tens of thousands of wells, which draws on theory and hands-on experience and is frequently protected by patents. It is also a fairly expensive treatment, which may account for as much as 25% of total costs of drilling a well. In its basic version, it involves the injection of so-called fracturing fluid (a mixture of water and various additives) into a wellbore at pressures which may exceed 600 bar. As soon as a sufficient number of cracks are formed within the invaded area, water mixed with sand of the appropriate grain size (so-called proppant) is pumped into the wellbore. The sand is carried into the fractures, preventing them from closing, while providing conductive paths through which gas can flow into the wellbore. There are a wide variety of hydraulic fracturing methods. Fracturing fluids of controlled viscosity, wettability and gravity are mixed with small quantities (up to a few percent) of chemicals which allow the treatment to be properly executed. Apart from sand, other proppants may include ceramic materials, metal and plastic pellets as well as polymer fluids, which form networks of tangled fibres. The quality of the fractures is inferred by way of microseismic monitoring. Most importantly, however, the costly work is usually preceded by an analysis of rock samples, aimed at determining their geomechanical properties as well as stress conditions in the rock mass. Based on the results of such analyses, it is decided what fluids should be injected, under what pressure and how long individual stages of the fracturing treatment should last. The whole process is first digitally simulated. While painstaking and costly, the laboratory stage of the process is also highly effective, as it allows precisely spaced, concentric fracture zones to be achieved with a radius of up to 900 metres (up to 200 metres in sandstones).[16]

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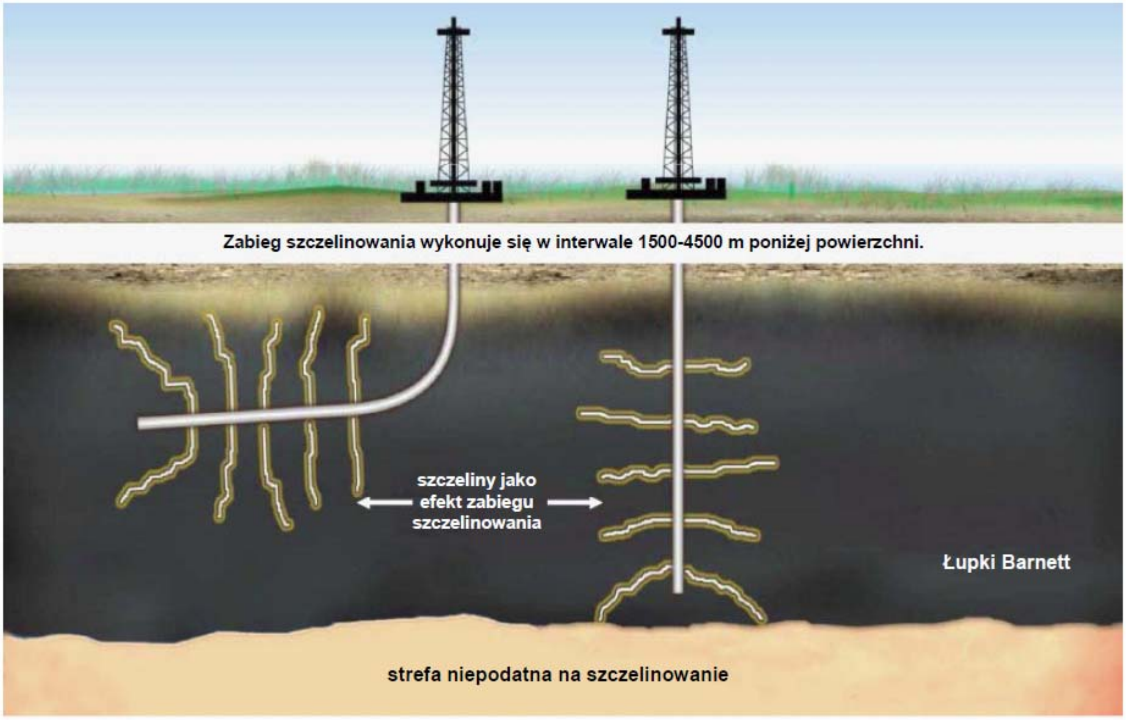
[15] Devon Energy's corporate website- www.devonenergy.com.

[16] "Wyciskanie Gazu" ("Gas Extrusion"), Mirosław Rutkowski, Polityka.pl - Nauka, Feb 24 2009.

Figure 1.5 – Hydraulic fracturing – schematic representation[17]



szczeliny jako efekt zabiegu szczelinowania	fractures created as a result of hydraulic fracturing
Łupki Barnett	Barnett shales
strefa niepodatna na szczelinowanie	zone resistant to hydraulic fracturing

Once the hydraulic fracturing treatment is completed, the fracturing fluid is taken back from the wellbore and a production test is performed. For some time, in addition to natural gas a well continues to produce flowback frac fluid.

1.2.3 Water Used in Hydraulic Fracturing

The amount of water and sand that needs to be injected into a single wellbore during a hydraulic fracturing treatment is 7.5 to 11.3 million litres and 450 to 680 tonnes, respectively. To compare – an Olympic-size swimming pool holds 2.25 million litres of water.[18]

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[17] "Shale Gas Development in the U.S.", Mark Smith, Interstate Oil & Gas Compact Commission, April 2010.

[18] "Preparing a Well for Production - Hydraulic Fracturing", Fayetteville Shale Natural Gas.

Water needed to support shale gas production is usually stored in man-made tanks or in mobile containers located in the immediate vicinity of a wellbore, with which they remain connected during the entire operation. In order to secure water beforehand, wells are drilled locally or water is delivered from a spring. This forms a closed circulation system, in which water is treated on an ongoing basis and is used for other purposes during drilling or hydraulic fracturing of wells at the same or at different locations. Some of the water may be used to support other production processes.[19]

1.3 Stages of Shale Gas Development: the U.S. Example[20]

Below is presented a schedule of a shale gas development process in the United States.

1. **Acquisition of rights.** Unlike in other countries, in the U.S., companies planning to acquire rights to hydrocarbon exploration and production in a given area negotiate contracts for the lease of a site with its owners (private owners, a state, the federal government). These are complex contracts providing for appropriate compensation for the use of the land and development of reserves (in the U.S. a land owner also owns fossils present under the land surface).

2. **Permits.** An operator is required to obtain a permit for any exploration and production activities, including for drilling a gas well. The application for the permit should be usually accompanied by the results of studies, analyses, drilling designs and other technical information. Before a permit is approved, operators may be required to take special measures to protect the environment.

3. **Drilling.** In designated sites horizontal wells are drilled, with four to eight boreholes per site, usually in pairs, going in opposite directions. The construction of the wells depends on the rock characteristics, recovery enhancement planned for the future, and the envisaged exploitation method.

4. **Hydraulic Fracturing**. Creation of factures in rock formations by means of specially prepared fluids.

5. **Development**. To prepare a field for exploitation it is necessary to design surface infrastructure enabling preparation of gas for transport (cleaning,

[19] "Modern Shale Gas Development in the United States: A primer", US Department of Energy, April 2009.
[20] "Modern Shale Gas Development in the United States: A primer", US Department of Energy, April 2009.

drying, transfer from boreholes to a common collection point, etc.) and its transmission (collection pipeline, distribution pipelines, metering equipment, etc.) to the transmission pipeline system.

6. **Production.** Once extracted from the well, gas undergoes various treatments, to be finally placed on the market (production can last for decades).

7. **Enhanced Recovery Techniques**. Gas production from a well usually decreases over years. Operators normally apply various processes to maintain the level of production. These processes may include simple treatments, such as cleaning of the well, washing of the rock at the point where the hole meets with the deposit, or additional fracturing.

8. **Well abandonment**. Once production from a well reaches the limit of economic viability, a gradual abandonment of a well is commenced. Individual boreholes are permanently plugged (cemented at the bottom of the hole), the area near the well is also liquidated, and the surrounding area is restored to its original condition. Then the entire surface infrastructure is gradually removed.

1.4 Shale Gas – Environmental Impact of Shale Gas Production

Thanks to the development of horizontal drilling, the impact of shale gas production on land environment in the production area is much smaller than in the case of conventional gas production.[21] Devon Energy Corporation has announced that one horizontal well can replace three to four vertical wells.

In the United States, some environmental organisations have been claiming that hydraulic fracturing may cause damage to the natural environment and demanding that the organisation of the process should be subject to governmental regulation. It should be noted, however, that shale gas wells are properly secured (see Fig. 1.4) to prevent chemicals from getting into ground water. On the other hand, if a borehole casing is performed defectively, there is some risk of chemicals mixing with ground water.

In addition, there are no laws currently in force which would require corporations to disclose precisely what chemicals they inject into boreholes to make fractures in rock formations.[22] In practice, however, basically no production firms in the United

[21] "Modern Shale Gas Development in the United States: A Primer", US DOE, April 2009.
[22] "EPA begins study on shale gas drilling", Tom Doggett, Reuters, March 18th 2010.

States conceal the chemical composition of fluids used in hydraulic fracturing.[23]

Production companies assert that modern hydraulic fracturing methods make it possible to produce gas in a manner completely safe for the natural environment. They also add that there is no evidence that hydraulic fracturing in any way affects the resources of drinking water.[24]

On March 18th 2010 the U.S. Environmental Protection Agency[25] announced the launch of a study into the environmental impact of shale gas production. The study will cover mainly the impact of hydraulic fracturing, or in fact the effect of the chemicals used in the process on drinking water. According to EPA representatives, the study could take even two years to complete.[26]

Similar studies are also carried out by the Energy and Commerce Committee[27] and the Penn State University (final report to be released in 2011).[28] The general public is voicing growing concerns and doubts over the impact of chemicals used in hydraulic fracturing on the environment and human health.

The oil spill in Gulf of Mexico after the BP oil rig sinking in April 2010 intensified concerns over the effect of hydraulic fracturing on the environment and human health. One or two more years of research are needed to precisely identify the potential impact. This may be the reason why the Pennsylvania State Senate is preparing a proposal to impose a one-year moratorium on drilling in the Marcellus shale. The most reasonable opinion seems to have been voiced by George Mitchell, the pioneer of hydraulic fracturing, who considers his invention as sound, but not foolproof: “You’ve got to do a good job, or you’ll have trouble.”[29]

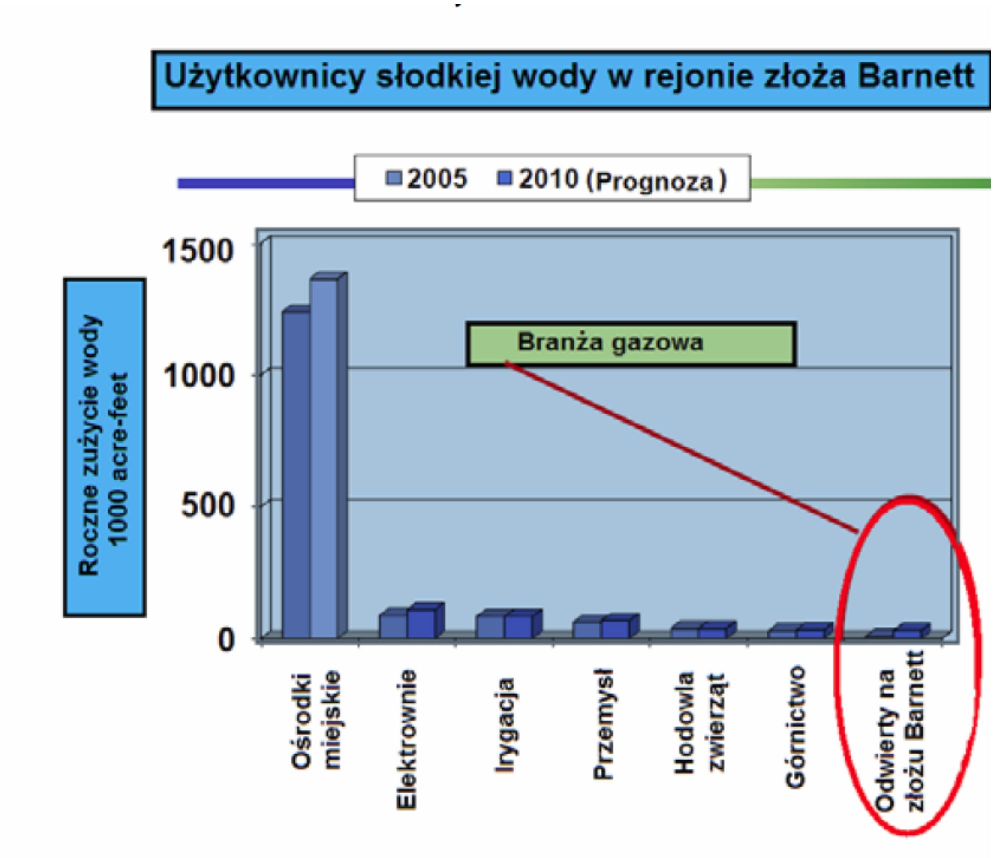
People’s imagination is stirred by the seemingly huge amounts of water needed to make hydraulic fracturing in one well (from 7.5m to 11.3m litres of water, equivalent of three to five Olympic pools).
However, please note how much freshwater is used (or wasted) for other purposes. A comparison of the largest freshwater users in the Barnett Shale region (Fig. 1.6) prepared by Gas Technology Institute shows that freshwater is consumed in the largest amounts for municipal purposes[30]. Shale gas production is one of the least water-

[23] “Modern Shale Gas Development in the United States: A Primer", US DOE, April 2009.
[24] “EPA begins study on shale gas drilling”, Tom Doggett, Reuters, March 18th 2010.
[25] US Environmental Protection Agency, www.epa.gov.
[26] “EPA begins study on shale gas drilling”, Tom Doggett, Reuters, March 18th 2010.
[27] Committee on Energy and Commerce.
[28] “Shale Pioneer sees bright future of technology", Eric Lidji, greeningofoil.com, June 30th 2010.
[29] “Shale Pioneer sees bright future of technology”, Eric Lidji, greeningofoil.com, June 30th 2010.
[30] Guy Lewis, Gas Technology Institute, presentation at “US/Poland: energy roundtable June 2010".

consuming branches of local economy. The greatest savings can still be made by making more efficient use of water in everyday life.

Also in terms of the relation between the surface footprint and energy output, shale gas is more efficient than alternative energy sources. Energy output (measured in British Thermal Units) from one Marcellus well on 0.25 acre of land is equivalent to energy produced by 500 acres of windmills.[31]

Figure 1.6[32]



Użytkownicy słodkiej wody w rejonie złoża Barnett	Freshwater Users in the Barnett Shale Region
Prognoza	Projected
Roczne zużycie wody 1,000 acre feet	Annual Water Use 1,000's Acre*Feet
Ośrodki miejskie	Municipal
Elektrownie	Steam Electric
Irygacja	Irrigation
Przemysł	Manufacturing
Hodowla zwierząt	Livestock
Górnictwo	Mining
Odwierty na złożu Barnett	Barnett Drilling

31 Source: Ray Walker, Range Resources, at Guy Lewis, Gas Technology Institute, presentation at "US/Poland: energy roundtable June 2010"
32 1 acre-foot is the **volume of water sufficient to cover an acre of land to a depth of 1 foot**, approximately 1,233,489 cubic metres.

1.5 Shale Gas – Commerciality: the U.S. Example

Commerciality of shale gas production depends on the existence of a natural network of fractures and on hydraulic fracture treatments. Due to significant differences in deposit conditions – even within a single deposit – commerciality can vary to a large extent. In 2009, Credit Suisse estimated the break-even point for shale gas production as ranging from USD 0.12 to USD 0.37 per cubic metre of natural gas, with the average of USD 0.28 per cubic metre. The internal rate of return, with the price at USD 0.26 per cubic metre, was estimated at 1% to 48% (5% on average). In order to stimulate unconventional gas development, tax credits for producers of unconventional fuels were introduced in the United States in 1980, effective until 2002.[33]

Similar calculations were made by Ben Dell, an analyst from Bernstein Research. According to his estimates, in order to cover all costs of exploration, development and exploitation of shale gas and arrive at an average return on equity the required price is USD 0.26 – 0.28.[34]

It should be noted that recent years have seen a strong drop in costs of shale gas production. At the end of 1990s, the cost of production from the Barnett Shale was more than USD 5 per million BTU[35].[36]

[33] „Shale Gas – Extraction Technology", węglowodory.pl, May 4th 2010.
[34] "The true cost of shale gas production", John Dizard, Financial Times, March 7th 2010.
[35] British Thermal Unit – see *Glossary.*
[36] "How shale gas is going to rock the world", Amy Meyers Jaffe, Wall Street Journal, May 9th 2010.

1.6 Geopolitical Effect of Development of Unconventional Gas Resources

1.6.1 End of Gas and Oil Dependence?

By developing internal production of shale gas, western countries and China will gain access to closer sources of the fuel, and thus undermine the position of key gas exporters. Before shale gas was discovered, it was expected that domestic production of natural gas in the U.S., Canada and North Sea would fall, which at the time when importance of gas as a source of energy was increasingly rising, quickened dependence on imports. More than a half of known natural gas resources was located in Iran and Russia, i.e. regions perceived as relatively unpredictable. The Russian Federation openly used its position to create a cartel of gas producers. The discovery and use of large resources of shale gas will give stability to industrialised countries and may undermine political and gas dependencies.[37]

1.6.2 Chain Reaction

Growth in the trade of LNG, natural gas in its liquid state that may be transported by tankers, has revealed the heavy reliance of many countries on gas imports. However, the developments in shale gas extraction are transforming the gas trading market. Previously LNG was expected to account for half of the international gas trade. Now it seems that share will be more like one-third.[38]

A downtrend in LNG imports is already evident in the U.S.. Import terminals for LNG are almost empty as cargoes of LNG from Qatar are going to European buyers, contributing to a drop in the price of natural gas in Europe. Russia has had to accept far lower prices from customers.

Tension could be felt among the exporters of LNG to the European and U.S. markets during the Gas Exporting Countries Forum held in Oran, Algeria. According to Chakib Khelil, the Algerian Minister of Energy, demand for gas will return to its pre-crisis level from 2008 no earlier than in 2013, while Jurij Trutniev, the Russian Minister of Natural Resources, confessed to Reuters *"We have a problem with shale gas. And it is not only my point of view but Gazprom's as well."*[39]

Factors such as the self-sufficiency of the U.S. gas industry, growth in the volume of LNG imported by the European countries from sources other than Russia, and sagging

37 "Shale Gas Will Rock the World", Ann Meyers Jafe, *Wall Street Journal*, May 10th 2010.
38 "Shale Gas Will Rock the World", Ann Meyers Jafe, *Wall Street Journal*, May 10th 2010.
39 "Gas Cartel Set to Push Up Prices for Europe", Andrzej Kublik, *Gazeta Wyborcza*, April 20th 2010.

natural gas prices have developed into a problem which for the Russian Federation is primarily an economic one. *Kommiersant*, the Russian daily, disclosed that according to a management report for Gazprom's board of directors the energy giant is set to lose billions of euros. All this put pressure on the economic viability of Gazprom's project involving the development of the Shtokman field in the Barents Sea, which was originally designed as the source of LNG supplies for the U.S. and Canada.

1.6.3 Russia, Iran and Venezuela

Wielding a weapon in the form of natural resources policies and the power to dictate prices, Russia, Venezuela and Iran became more successful in resisting Western interference in their affairs and exporting their ideologies. Handicapped by international sanctions, the Iranian energy sector develops at a sluggish pace. Hence, by the time Iran can get its natural gas ready for export, the marketing window to Europe will likely be closed by launch of shale gas production in the potential customers' countries. In the long run, as crude oil is gradually replaced by natural gas as the primary energy source, the position of OPEC countries on the international arena is likely to weaken.[40]

1.6.4 China

Shale-gas development could also mean big changes for China. In order to satisfy its ever-growing demand for energy sources, China engaged in cooperation with nations such as Iran, Sudan and Burma, making it harder for the West to address the problems those countries create. But if China can tap on its domestic resources of natural gas, partnership with those countries may no longer be so vital. Domestic shale may bring China closer to the U.S., especially in the context of the latter being virtually the only provider of shale gas expertise and innovative exploration and production technologies. Signs of the rapprochement are already emerging. Talks held during a recent visit of the U.S. President in China in May 2010 were focused on a potential bilateral agreement to embark on joint projects involving the development of shale gas technologies and production.[41]

[40] "Shale Gas Will Rock the World", Ann Meyers Jafe, *Wall Street Journal*, May 10th 2010.
[41] "Shale Gas Will Rock the World", Ann Meyers Jafe, *Wall Street Journal*, May 10th 2010.

1.6.5 U.S.' Proactive Foreign Policy

The Obama administration shows interest in promoting shale gas development in China and elsewhere. According to State Department officials, the U.S. has asked nearly a dozen countries (including China and India) if the U.S. can assess their potential shale gas resources. Washington aims to protect the interests of the U.S. energy groups, which at present are the only ones to have mastered the shale gas technology and secured access to financial resources necessary for commercial shale gas production. On the other hand, the technical assistance would enable the U.S. to expand its influence in the potential shale gas-producing regions and undermine the position of countries exporting fuels to such regions.[42]

1.6.6 Impact on Renewable Energy Sources (RES)

Shale gas is also likely to decelerate the implementation of some RES projects whose economic viability may be threatened by the abundant supply of natural gas, a fuel offering low carbon emissions and, potentially, low prices. It should be noted, however, that this may be seen as an opportunity for renewables as well. The funds earmarked for RES implementation projects may be poured into R&D initiatives aimed at improving the efficiency of energy sources such as wind, solar, hydro and biomass.

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[42] "US Pitches Shale Gas Studies Overseas", Ian talley, Dow Jones, April 7th 2010.

PART 2

U.S. SHALE GAS PRODUCTION MARKET

"The shale gale has shifted natural gas from a constrained resource to an abundant one with wide-ranging implications for the energy future in North America"

- David Hobbs, chief strategist at IHS CERA[43]

[43] Sasol-Chesapeake-Statoil apply to explore for shale gas in Karoo", Martin Creamer, Mining Weekly, March 19th 2010.

2.1 Description of the American Gas Market

In 2009, the United States became the world's largest natural gas producer. New technologies which enabled shale gas recovery turned out to be a ground-breaking factor that caused a shift in the structure of energy sources in North America in the last decade. 598.37bn cubic metres of natural gas were produced in 2009, which represents a 3.9% growth over the previous year (576.95bn cubic metres). Between 2007 and 2008, production rose by 6.7%.[44] To compare, gas production in Poland totalled 4.11bn cubic metres in 2008.[45]

Natural gas covers approximately 22% of the U.S. energy demand. It is expected that the share will remain at a similar level for the next 20 years.[46] According to estimates by the Energy Information Administration, the United States has some 50 trillion cubic metres of technically recoverable natural gas, of which approximately 60% are unconventional resources (shale gas, tight sand, coalbed methane). Combined with the estimated shale gas quantity, it provides sufficient gas volumes for the next 116 years.[47]

Figure 2.1 – Natural gas production in the U.S. [48]

A vast majority of the natural gas produced in the U.S. comes from conventional sources. Unconventional gas (including shale gas, tight gas and coalbed methane) accounted for 50% of the country's total production in 2008.[49] Shale gas currently represents some 14% of the total natural gas production.[50] Particularly evident is the growing production rate of shale gas: its output in 2008 came to 57.25bn cubic metres, compared against 33.52bn

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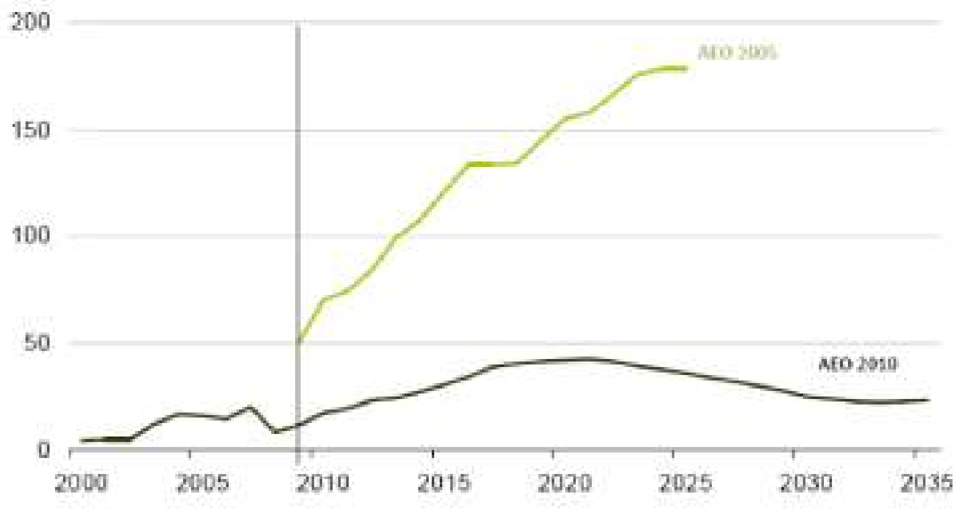
[44] U.S. Energy Information Administration.
[45] Polish Geological Institute - the figure is also quoted in the Ministry of Economy's reports.
[46] "Modern Shale Gas Development in the United States: A Primer", US DOE, April 2009.
[47] "Modern Shale Gas Development in the United States: A Primer", US DOE, April 2009.
[48] U.S. Energy Information Administration.
[49] U.S. Energy Information Administration.
[50] U.S. Energy Information Administration.

cubic metres in 2007, which represents a growth of 70.8%.[51]

To note, the United States has not yet become fully self-sufficient considering the country's demand for natural gas. In 2009, gas imports totalled 105.75bn cubic metres, compared against 112.81bn cubic metres in 2008 (a decline of 6.7%) and 130.47bn cubic metres in 2007.

For the last 2 years, there has been a significant drop in demand for LNG in the U.S., caused primarily by a rise in unconventional gas production, which also affected gas prices globally. An excellent example of the trend is the LNG terminal at Sabine Pass, built in 2005-2009. Since its completion, only 10 gas transports arrived at the terminal. Over half of the American East Coast's loading capacity was unused in 2008.[52] However, the actual impact of the factor on the price movement is difficult to measure, owing to the financial crisis, which had a material effect on the total gas demand. Figure 2.2 shows differences between forecasts (Annual Energy Outlook) of LNG imports developed in 2005 and 2010.

Figure 2.2 – U.S. LNG import forecasts (in billions of cubic metres) [53]



A massive rise in unconventional gas production was made possible by three primary factors:

1. Improvements in horizontal drilling technology
2. Improvements in hydraulic fracturing technology

[51] U.S. Energy Information Administration.

[52] *Gaz łupkowy w USA a sytuacja rynku* ("Shale gas in the U.S. and market situation"), weglowodory.pl, May 14th 2010, after US Energy Information Administration.

[53] The Shale Gale in the United States and Global Gas Markets", Douglas C. Hengel, US Department of State.

3. A surge in natural gas prices on the American market around the mid-point of the previous decade, resulting from a tangible rise in demand for gas.

2.2 Description of American Shale Gas Market

Shale gas is present in most U.S. states. Map 2.1 shows approximate locations of the currently exploited and prospective shale gas reservoirs.

Map 2.1 – Proved shale gas reserves in the U.S. [54]

According to the report published by the Colorado School of Mines in July 2009, the United States' resources amount to 17 trillion cubic metres of shale gas.[55] Figure 2.2 shows the shale gas production growth over the next 8 years as projected by the Energy Information Administration. The estimates by the International Energy Agency, on the other hand, indicate that production from unconventional gas sources will rise from 360bn cubic metres to 630bn cubic metres in 2030.[56]

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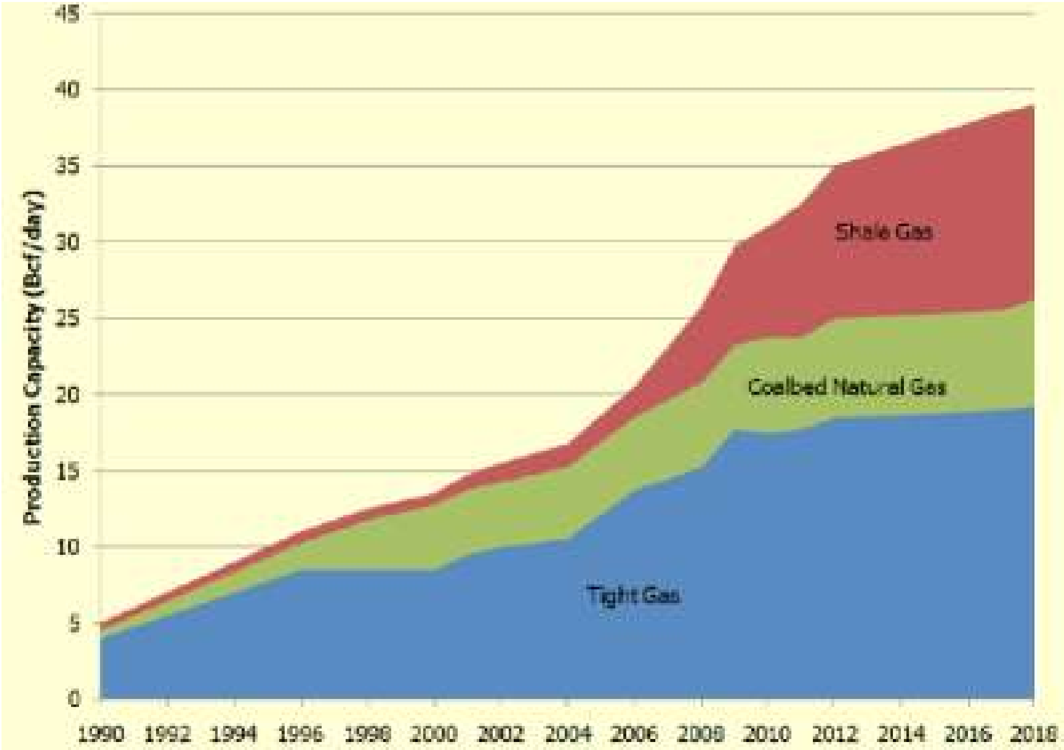
[54] Energy Information Administration.

[55] "Betting Big on a Boom in Natural Gas", Seve LeVine, Adam Aston, Bloomberg Businessweek, October 8th 2009.

[56] "Shale gas estimates Perhaps Optimistic", The Oild Drum, October 14th 2009.

Figure 2.3 – Development prospects for the U.S. unconventional gas market [57]



A growing interest in unconventional gas production is also evident when analysing the growth in the number of drilling rigs used for onshore recovery of unconventional gas. Towards the end of the 1990s, there were 40 such drilling rigs, compared against 519 in May 2008.[58]

Locations where most intense work is in progress are Fort Worth Barnett, Fayetteville, Antrim, Arkoma Woodford, Bakken and Haynesville (Figure 2.3). Importantly, those shale gas reservoirs differ considerably amongst themselves in terms of production characteristics, thus requiring different approaches to production.

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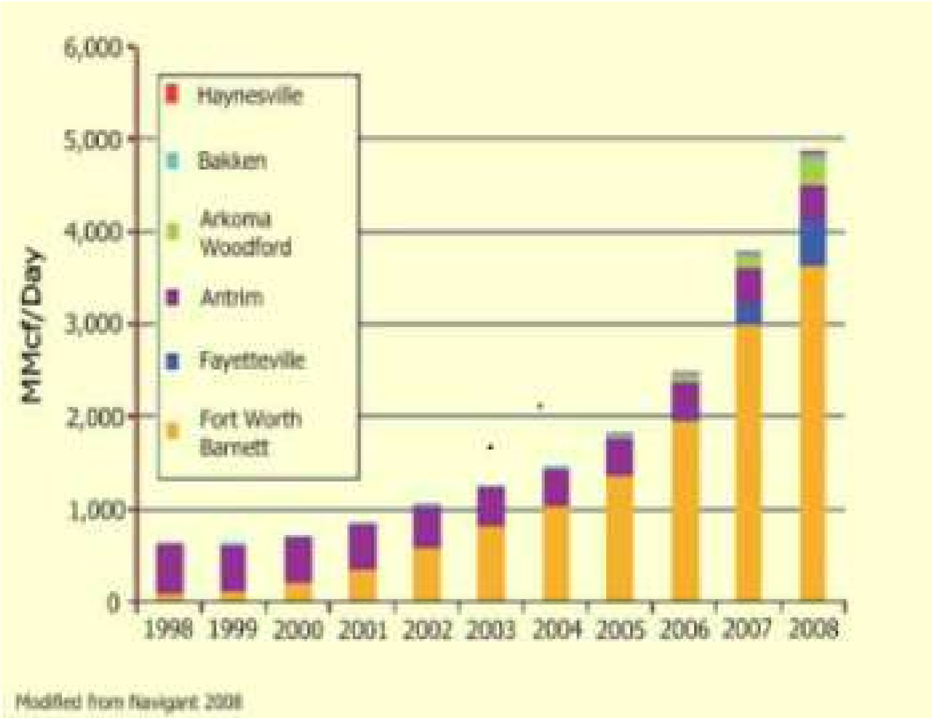
[57] "Modern Shale Gas Development in the United States: A Primer", US Department of Energy, Apr 2009.
[58] "Modern Shale Gas Development in the United States: A Primer", US Department of Energy, Apr 2009.

Figure 2.4 – Shale gas production trends in the U.S. by location [59]



An undisputed leader in unconventional gas production is Barnett Shale, Texas. Although production from the Fayetteville and Arkoma/Woodford fields is still at an early development stage, it is gradually rising (Fig. 2.3).

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[59] Modern Shale Gas Development in the United States: A Primer", US Department of Energy, April 2009.

2.3 Barnett Shale – Discussion

Barnett Shale is located in the Forth Worth Basin in north-central Texas. Shale deposits are buried at depths ranging from 1,950 to 2,600 below the ground level, with lime rock below and above.[60]

There are over 10,000 boreholes in the area. One horizontal borehole covers an area from 24.3 to 64.7 hectares.[61] Production from the Barnett Shale is a genuine breakthrough in unconventional gas recovery. Operations of companies active in that area represent a roadmap of how to produce gas from shale deposits.

Barnett Shale occupies an area of approximately 13,000 sq km, whereas the thickness of the gas-bearing layer is from 30 to 185 metres. Gas resources there range from 8.5 cubic metres to 10 cubic metres per tonne of rock.

Map 2.2 Barnett Shale deposits in the Forth Worth basin [62]

60 Modern Shale Gas Development in the United States: A Primer", US Department of Energy, April 2009.
61 Modern Shale Gas Development in the United States: A Primer", US Department of Energy, April 2009.
62 Modern Shale Gas Development in the United States: A Primer", US Department of Energy, April 2009.

2.4 Top American Shale Gas Market Players (Table 2.1)[60]

NAME	HQ	NET REVENUE (USD)	NOTES
Andarko Petroleum Corporation	Texas	3.29bn (2008)	
Burlington Resources	Texas	1,5bn (2005)	Acquired by ConocoPhillips in 2006.
Carrizo Oil & Gas Co.	Texas	-66.2m (2008)	
Chesapeake Energy Corp.	Oklahoma	723m (2008)	StatoilHydro is a strategic partner
Contango Oil & Gas Co.	Texas	55.9m (2008)	
Devon Energy Corp.	Oklahoma	2.48bn (2008)	Licences shared with Total S.A. in France.
EnCana Corp.	Alberta (Canada)	749m (2009)	
EOG Resources Inc.	Texas	1,089bn (2007)	
Infiniti Oil & Gas	Colorado	-8m (2008)	
Mainland Resources, Inc.	Texas	13m (2009)	
Marathon Oil Corp.	Texas	3.53bn (2008)	
Murphy Oil Corp.	Arkansas	767m (2007)	
Noble Energy Corp.	Texas	944m (2007)	
Newfield Exploration Co.	Texas	524m (2009)	
Nexen Inc.	Alberta (Canada)	536m (2009)	
Parallel Petroleum Corp.	Texas	210m (2008)	In 2009, acquired by Apollo Global Mngmt.
Penn Virginia Corp.	Pennsylvania	114m (2009)	
Petrohawk Energy Corp.	Texas	1.55bn (2009)	
Questar Corp.	Pennsylvania	393m (2009)	
Quicksilver Resources Inc.	Texas	557m (2009)	Collaborates with ENI since May 2009
Royal Dutch Shell	Hague (the Netherlands)	12.52bn (2009)	Holds production sites at Barnett
Range Resources Corp.	Texas	53m (2009)	
Southwestern Energy Co.	Texas	960m (2007)	
Talisman Energy Inc.	Alberta	437m (2009)	
Occidental Petroleum Corp.	California	5.4bn (2008)	
XTO Energy Inc.	Texas	1.92bn (2008)	Acquired by ExxonMobil in 2009

[60] Corporate websites and press releases by the respective companies.

PART 3

DEVELOPMENT PROSPECTS FOR SHALE GAS MARKET IN POLAND

3.1. Potential Shale Gas Resources in Europe and Current Activity

In 2009, Realm Energy International Corporation, in a collaborative effort with Halliburton Consulting, commenced the appraisal of shale gas resources worldwide. The initial survey covers Europe, and the results are due in 2011.[64]

As estimated by the Energy Information Administration, shale gas production will account for 7% of the global natural gas production by 2030.[65]

The table below (Table 2.2) shows shale gas quantity estimates for the selected regions of the world.

Table 2.2 Estimates of world shale gas resources[66]

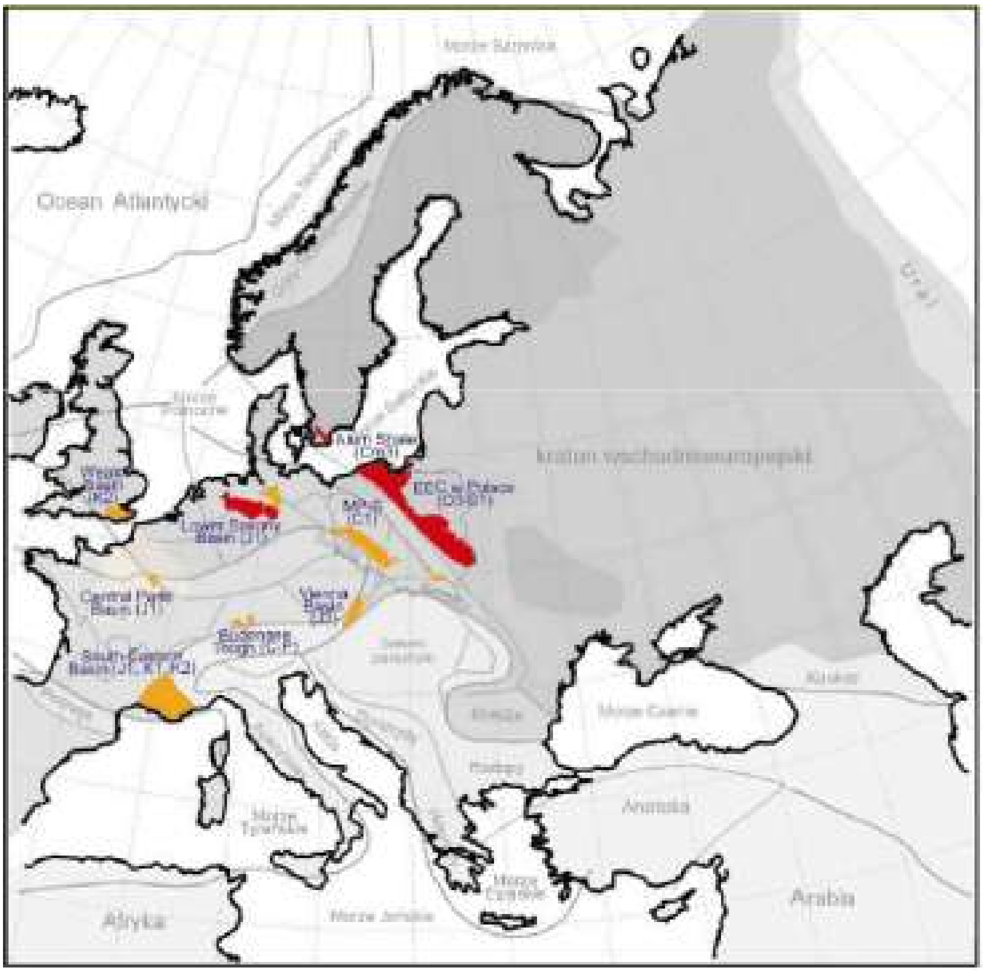
Region	Resources (trillions of cubic metres)	Source
World	184	IEA 2009 WEO
Outside North America	140-450	CERA 2009
OECD in Europe	3	EIA 2010
Poland (licence areas)	3	ARI 2009
Austria (licence areas)	0.85	ARI 2009
Sweden (licence areas)	0.3	ARI 2009

64 http://realm-energy.com/

65 "The shale gale in the United States and Global Gas Markets", Douglas C. Hengel, U.S. Department of State, April 8th 2010.

66 "The shale gale in the United States and Global Gas Markets", Douglas C. Hengel, U.S. Department of State, April 8th 2010.

Map 3.1 – Unconventional gas resources in Europe [67]



As in the rest of Europe, Poland attempts to attract international corporations to invest in appraisal, and then production of gas from unconventional sources.

3.2. Potential Shale Gas Resources in Poland

As estimated by various consulting firms, natural gas resources in Lower Palaeozoic shale formations in Poland may range from 1.4 trillion cubic metres (Wood Mackenzie) to 3 trillion cubic metres (Advanced Resources International).[68] It is difficult to verify the estimates reliably at present.

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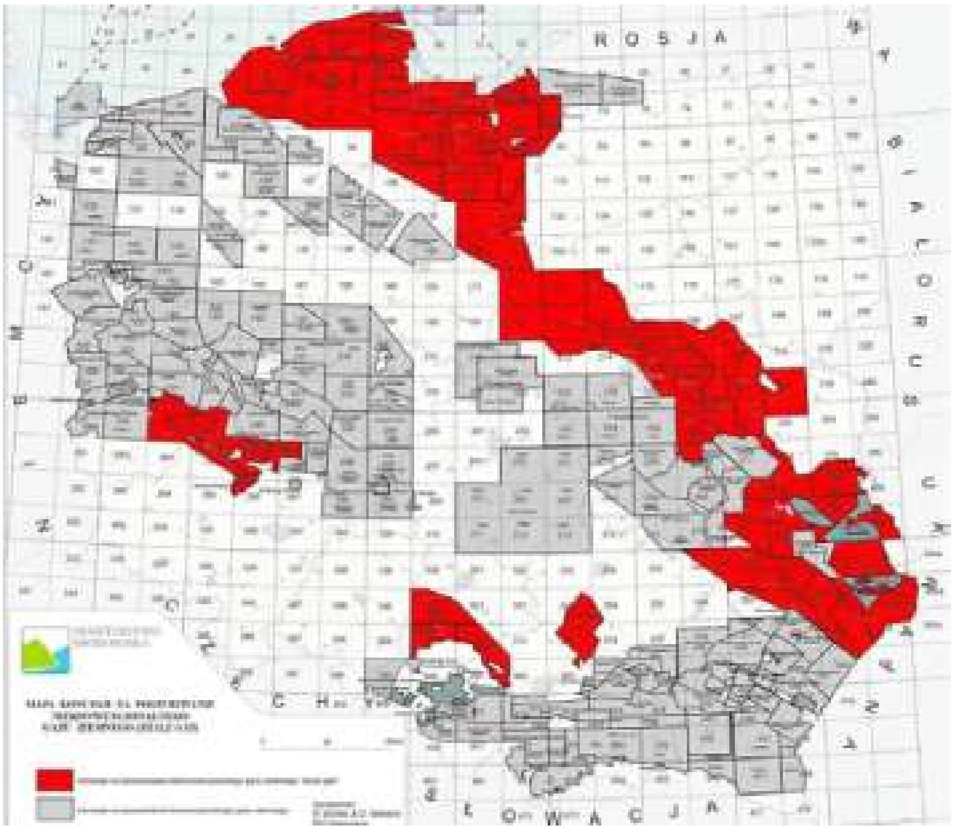
[67] "Concession policy and legal regulations for exploration and production of gas", Henryk Jacek Jezierski, April 2010.

[68] "Poland 'Bubbles Up", Bloomberg.com, December 9th 2009.

Map 3.2 – Shale gas exploration licences [69]



The actual size of the resources will be determined in the course of work under the licences granted by the Ministry of the Environment.[70] The questions whether shale gas is present in Poland and in what quantity should be answered within the next 4 years, which is the average period for which the exploration licences have been granted. Areas covered by shale gas exploration licences are highlighted in red on Map 3.2.

The shale basin in Poland extends from the coast, in the area between Słupsk and Gdańsk, towards Warsaw, and further to Lublin and Zamość. According to forecasts, potential shale gas reserves in Poland lie at the depth of 2,500 to 3,000 metres in the eastern part of the basin, and from 4,000 to 4,500 metres in its western part.[71]

At present, considering the depth of deposits as stated above, the cost of a single vertical borehole may range from 6 to 13 million dollars on average.

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[69] Ministry of the Environment.

[70] See chapter 3.2. Current situation in the Polish shale gas market.

[71] "*Gaz z łupków nie szkodzi elektrowni atomowej*", (Shale gas does no harm to nuclear power plant) Bankier.pl, interview with Henryk Jezierski, PhD, Piotr Siekański, April 22nd 2010.

3.2. Exploration and Appraisal of Shale Gas in Poland

As at July 1st this year, there were 224 active exploration and appraisal licences for crude oil and natural gas in Poland[72] (see Exhibit 1: List of Licences for Exploration and Appraisal of Oil and Gas Deposits in Poland). The figure comprises exploration and appraisal licences for both conventional and unconventional hydrocarbon deposits. Exploration areas currently cover 11% of Poland's territory, that is 37,000 sq km.

Under 11 licences granted by the Ministry of the Environment, two companies with American equity participation, that is Exxon-Mobil Exploration and Production Poland Sp. z o.o. and Mazovia Energy Resources Sp. z o.o., and one with Australian equity participation, that is Strzelecki Energia Sp. z o.o., conduct exploration projects for unconventional natural gas only. Further 14 Polish, American, Canadian, British and Australian-owned entities hold 40 licences for exploration and appraisal of both conventional and unconventional hydrocarbons.

One company with British equity participation (Energia Zachód Sp. z o.o., in which the majority stake is held by Aurelian Oil&Gas) runs exploration and appraisal projects under a single licence for appraisal of tight gas deposits. Additionally, with respect to the licence areas located within prospective tight gas regions (e.g. part of the licences granted to PGNiG S.A.), the licensees do not report their intention to explore for this type of deposits, and only plan shale gas exploration.[73]

As argued by numerous experts, it is not possible to precisely estimate the resources of unconventional natural gas in Poland at the present stage the appraisal process. The actual size of the resources will be ascertained in the course of work in progress under the granted licences. Exploration and appraisal licences for shale gas were granted in 2007-2010. The scope of work under the licences primarily covers analysis of historical data, its interpretation, seismic field work, as well as exploration and appraisal drilling.

In June 2010, Lane Energy, in collaboration with ConocoPhillips, commenced preliminary drillings at the Lębork site. The drilling rig is supplied by Poszukiwania Nafty i Gazu "Nafta" of Piła, whereas maintenance, as well as measurement and enhanced recovery work is performed by Schlumberger. The project is due to continue until the end of 2010. Lane Energy is the first company to start shale gas appraisal drilling in Poland. As reported by other companies, their seismic and drilling work is due to start by the

[72] *Koncesje na poszukiwanie i rozpoznawanie złóż węglowodorów w Polsce w tym shale gas i tight gas* (Exploration and appraisal licences for hydrocarbon deposits in Poland, including shale gas and tight gas), Ewa Zalewska, Przegląd Geologiczny,vol. 58, No 3, 2010.

[73] *Koncesje na poszukiwanie i rozpoznawanie złóż węglowodorów w Polsce w tym shale gas i tight gas* (Exploration and appraisal licences for hydrocarbon deposits in Poland, including shale gas and tight gas), Ewa Zalewska, Przegląd Geologiczny,vol. 58, No 3, 2010.

end of this year.[74]

Until now, no shale gas deposits have been found in Poland. Experts agree that the presence of shale gas in Poland will be verified within the next 4 to 5 years, that is the period for which many exploration and appraisal licences were granted. A prerequisite for ascertaining the presence of shale gas is the completion of geological surveys by the licensees, in particular drilling in the most promising areas.[75]

In Poland, these are the Lublin Region, the Pomeranian Region, Mazovia, and Greater Poland. If exploration confirms the presence of shale gas, and its production proves economically viable, the development of new deposits could begin in approximately 10 years.[76]

3.3 Licensing Procedure for Companies Exploring for Shale Gas Accumulations in Poland[77]

Pursuant to the Polish Geological and Mining Law of February 4th 1994 (Dz.U. of 2005, No. 228, item 1947, as amended), operations involving exploration and appraisal of hydrocarbon deposits (including unconventional sources) require a licence, which is granted by the Minister of the Environment. The application for the licence to conduct such operations may be filed by any entrepreneur who operates under the Freedom of Economic Activity Act of July 2nd 2004 (Dz.U. of 2007, No. 155, item 1095, as amended), including an entrepreneur with foreign equity participation.

Requirements to be met by the licence application are set forth in the Polish Freedom of Economic Activity Act and Geological and Mining Law. A geological survey plan should be attached to the application for the licence for exploration and appraisal of mineral resources. Specific requirements to be met by the geological survey plans are listed in the Minister of the Environment's Regulation of December 19th 2001 on geological survey plans (Dz.U. 153, item 1777). Parties applying for a licence for exploration or appraisal of mineral resources are entitled to use, free of charge, geological data in the State Treasury's possession to draft geological survey plans.

Since the Polish Act on the provision of information on the environment and its protection, public participation in environmental protection and environmental impact assessments, dated October 3rd 2008 (Dz.U. No. 199, item 1227), and secondary

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74 State Geological Institute, website on May 24th 2010.
75 Koncesje na poszukiwanie („Exploration licences"), Ewa Zalewska, etc.
76 Koncesje na poszukiwanie („Exploration licences"), Ewa Zalewska, etc.
77 Based on answers provided by the Geology and Geological Licences Department at the Ministry of the Environment.

legislation thereto (the Council of Minister's Regulation of November 9th 2004 on types of undertakings which may exert a significant impact on the environment and detailed conditions regarding classification of undertakings as requiring environmental impact reports (Dz.U. No 257, item 2573, as amended), projects which involve exploration and appraisal of natural gas, crude oil or its derivatives from deposits may be classified as having a significant impact on the environment, and thus requiring environmental impact reports. If this is the case, the competent environmental protection authority (e.g. village or town mayors, or regional environmental protection directors) conducts the environmental impact assessment procedures pursuant to the said Act, which leads to the issue of the environmental requirements decision.

In conducting the exploration and appraisal licence procedure, the licensing authority (Minister of the Environment) consults authorities competent for the location of the licence area, that is village or town mayors. Their opinions are not binding on the licensing authority, but represent a supplementary item in the licensing procedure.

Pursuant to Art. 11.2 of the Polish Geological and Mining Law of February 4th 1994, making areas available for e.g. hydrocarbon deposits exploration and appraisal (including unconventional deposits) takes the form of a tender for the mining usufruct right. The successful bidder applies for the exploration and/or appraisal licence regarding the mineral resource in question.

Importantly, mining usufruct encompassing exploration and appraisal of natural gas (including shale gas), coalbed methane, crude oil and its natural derivatives, may also be established in a non-tender procedure, pursuant to Art. 11.2a of the Polish Geological and Mining Law of February 4th 1994, if at least one of the following conditions is met:

1) list of areas where the non-tender procedure may be applied was communicated to the general public and published in the Official Journal of the European Union;

2) the area to be covered by the proposed mining usufruct has been subject to a tender procedure but no mining usufruct was granted.

In view of the above, the list of areas where the mining usufruct can be established in a non-tender procedure was notified to the European Commission, with a request for publication in the Official Journal of the European Union, on October 7th 2005. On April 26th 2006, the European Commission published in the Official Journal of the European Union the *Communication from the Government of the Republic of Poland concerning Directive 94/22/EC of the European Parliament and of the Council of May 30th 1994 on the conditions for granting and using authorisations for the prospection, exploration and production of hydrocarbons and the competent authorities specified* *pursuant to Article 10 of Directive 94/22/EC (OJ C 98 of 26.4.2006, pp. 22-24).*

Since April 26th 2006, the Minister of the Environment as the licensing authority can therefore establish mining usufruct rights for exploration and appraisal of natural gas (including unconventional gas), crude oil and its natural derivatives as well as coal-bed methane, to the areas specified by the Minister, following a tender-based or non-tender procedure.

To note, licences for exploration and appraisal of unconventional (shale) gas deposits granted by the Minister of the Environment to date are not licences for production of gas from the deposit.

Under the Polish Geological and Mining Law, an entrepreneur who was granted a licence is required to pay the licence fee. Pursuant to Art. 85 of the Law, in the case of exploration and appraisal of mineral resources the fee is a product of the fee rate (PLN 217.76 in 2010) and the number of square kilometres of the area where the operations are conducted. The amount, deadline and method of payment are indicated in the licence. 60% of the fee represents revenue of the municipality where the operations are conducted, and 40% is revenue of the National Fund for Environmental Protection and Water Management (Art. 86. 1 of the Polish Geological and Mining Law).

On being granted a licence for exploration and appraisal of mineral resources, the licensees sign a mining usufruct agreement with the State Treasury. The fee for the establishment of the mining usufruct varies depending on the size of the area where the operations are conducted. The entire fee represents the State Treasury's revenue (Art. 83 of the Polish Geological and Mining Law).

Importantly, in the course of their exploration and appraisal operations, entrepreneurs obtain geological data owned by the State Treasury. Further, they are required to submit to the licensing authority reports on geological surveys conducted, samples of drilling cores, as well as results of work specified in the licence. This data is added to the repository of data on Poland's geological structure and stored at the Central Geological Data Bank (Centralne Archiwum Geologiczne). Each licence provides for a specific scope of exploration and appraisal activities (e.g. number and depth of boreholes, scope of seismic work, etc.) and other non-financial obligations, if any. All licences are available in the public data register pursuant to the Act of October 3rd 2008 (Dz.U. of 2008 No 199, item 1227, as amended).

In the event that obligations under the licence are not complied with or are performed in gross breach of the relevant laws, the licensing authority may, under Art. 27 of the Polish Geological and Mining Law and Art. 58 of the Freedom of Economic Activity Act, withdraw the licence or modify its scope. Further, under Art. 85a of the Polish Geological and Mining Law, an additional charge may be levied on exploratory and appraisal operations conducted in gross breach of the licence conditions, totalling three times the fee indicated in the licence.

3.4 Legal Aspects of Shale Gas Exploration and Production in Poland[78]

Before becoming involved in any natural gas exploration, appraisal and production projects in Poland, an investor must first of all assess the attendant legal risks. The Polish Geological and Mining Law does not provide for any special procedures with respect to exploration, appraisal and production of gas from unconventional sources. Accordingly, investors should proceed as in the case of other hydrocarbons.

As a first step, an investor interested in obtaining a licence should enter into a mining usufruct agreement with the State Treasury (under which it will have the right to use the area of a given deposit of minerals owned by the State Treasury) and then apply for the license (under which it will be permitted to carry out specific operations within the area). Mining usufruct and licences may convey the right to explore and appraise minerals, or to carry out either of the two activities.

Another stage of the process, entailing the execution of another agreement, is the production of approved reserves. In line with the regulations currently in force, an entity which appraised a natural gas deposit, evaluated its reserves and prepared the relevant geological documentation may – within two years of a written notification of acceptance of the geological documentation by the competent geological authority – demand the establishment of mining usufruct for its benefit, claiming priority over other applicants. What it means in practice is that within such two-year period the entity in question may also claim priority to be granted a gas production licence.

An investor looking to become involved in exploration and appraisal, and subsequently production, of natural gas from unconventional sources in Poland may consider several legal ways of entering that market.

First of all, it may step into the place of an entrepreneur which already holds the

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78 "*Prawne aspekty poszukiwania, rozpoznania i wydobycia gazu łupkowego (shale gas) i gazu zamkniętego (tight gas) w Polsce*" ("Legal Aspects of Exploration, Appraisal and Production of Shale Gas and Tight Gas in Poland"), Ewa Rutkowska-Subocz, the Wierciński Kwieciński Baehr Law Office, 2010.

relevant mining usufruct and licence. In such a case, the mining usufruct and the licence may be assigned to another entity. Typically, the detailed conditions under which mining usufruct may be assigned are set out in the agreement establishing the mining usufruct, which may include the obligation to seek the State Treasury's approval of the assignment. As for a licence, it may be transferred by the licensing authority, upon the consent of the entrepreneur to whom it was originally granted, after the transferee fulfills certain statutorily defined conditions. The licensing authority may refuse to transfer a licence only in circumstances specified by the Law (e.g. where it conflicts with an overriding interest of the national economy).

An option which some investors might find worth considering involves the transfer of only a part of mining usufruct rights and rights under a licence. The new practice of transferring an interest in mining usufruct appeared in Poland as a response to expectations expressed by some investors. However, Polish law precludes the possibility of transferring an interest in a licence.

Another way for an investor to become involved in activities related to unconventional gas resources and carried out by another entrepreneur is by gaining corporate influence over the entrepreneur being party to a mining usufruct agreement and a licence holder, through acquisition of shares in the entrepreneur, merger or transformation of the licensee. Given a wide range of available options, it is possible to develop and explore a number of different entry scenarios.

Yet another option involves the creation of legal and contractual links equivalent to a farm-out agreement, well known and widely used in Anglo-Saxon countries. It is a civil-law agreement whereby one party acquires the right to a share in the production profits in return for financial and technological support of the exploration and appraisal (and subsequently the production) of minerals. The implementation into Polish law of the legal and contractual framework equivalent to a farm-out agreement may prove difficult (due to differences between the two legal systems) but is permitted by law and achievable.

In Poland, royalty payments range from 1% to 2.5% of gas production revenues, depending on production volumes. Elsewhere, royalties are several times higher – for example in the United States they amount to twenty odd percent. The government in Warsaw has strategic reasons for offering such uniquely attractive conditions. According to the government's representatives, this will attract to Poland the largest possible number of firms with know-how in the area shale gas production.[79]

[79] [79]The Ministry of the Environment's announcement of March 11th 2010.

In the United States, development of the unconventional hydrocarbons market was spurred by a package of tax credits and reliefs, which had the effect of encouraging investors, who were able to spend more on exploration work as well as on new technologies. A factor that also mattered was the awareness that the system of government charges was stable, which helped investors properly assess the business risk involved.

In Poland, royalties are set as a percentage of volumes produced, rather than a percentage of sales. Given the market prices of natural gas, proceeds from royalties based on production volumes are much lower than proceeds from sales-based royalties. For instance, in 2009 the royalty fee for 1,000 cubic metres of high-methane gas produced amounted to PLN 5.63 (PLN 4.68 in the case of other gases, except for coalbed methane). To compare – in the same year, the average price paid by households for one cubic metre of gas was PLN 2.41 (including transmission charges).[80]

Although the currently applicable statutory royalties are low[81], no assurance can be given that they will not be significantly raised in the future if the wells yield promising results.[82]

The state is equipped with certain tools designed to counteract potential abuses which may occur during the process of acquiring production licences:

According to Art. 26b. of the Polish Geological and Mining Law:

The grant of a licence may be refused if the contemplated activity would violate the environmental protection requirements, including standards pertaining to sustainable management of mineral resources, also with respect to production of associated minerals, or would prevent the use of the properties in accordance with their intended purpose. The grant of a licence for storage of waste in the rock mass, including in underground mine workings, may also be refused if the waste can be utilised or neutralised otherwise than through storage, with the use of technically, environmentally and economically feasible methods.

Despite the fact that the existing laws seem to provide a stable, albeit rather poorly developed, legal framework for activities related to unconventional gas resources in Poland, it needs to be borne in mind that a draft amendment to the Polish Geological and Mining Law is now passing through Parliament. The draft provides for a number

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[80] Energy Regulatory Office, May 2009.
[81] News wire by RMF FM, May 14th 2010.
[82] News wire by RMF FM, May 14th 2010.

of changes, e.g. by implementing into Polish law the provisions of the so-called Hydrocarbons Directive (No. 94/22/EC), of which the most consequential one is the requirement to hold an open tender procedure for granting authorisations to explore, appraise and produce hydrocarbons. The current wording of the draft Law (as opposed to the Law now in force) does not warrant the conclusion that an entrepreneur who appraised a deposit of minerals will still enjoy priority (and a guarantee) with respect to the establishment of mining usufruct (and granting of a production licence).

3.5 Potential Issues on the Way towards Shale Gas Production in Poland

- Lack of clear government policy, backed by the Council of Ministers' regulations, with respect to activities aimed at the development of the Polish shale gas market.

- The drilling costs alone are much higher in Europe than in the U.S. In Europe, prospective shale formations are often buried deeper underground than similar shales in the U.S., which means higher drilling costs.[83]

- Polish companies do not have the technology necessary to produce shale gas in a relatively cost efficient way, while their position and presence on international markets is insignificant.

- According to Baker Hughes, a U.S.-based oilfield services company, in May 2010 there were 88 operational drilling rigs in Europe, of which 46 were onshore rigs, whereas the remaining ones were offshore rigs. At the same time, the number of operational drilling rigs in the U.S. was over 1,500.[84] According to estimates, in Poland there are 27 drilling rigs, but only some of them are currently operational. Meanwhile, importing such equipment from overseas may pose difficulties due to the fact that the U.S. and Canada rely on different computation and certification methods from those used in Europe.

- Exploration and production may present a considerable challenge, given that the land which is to be covered by such operations is heavily developed.[85]

[83] "Poland's paltry shale gas indicators" Kate Mackenzie, Financial Times, April 19th 2010.
[84] Baker Hughes, June 2010.
[85] "Poland's paltry shale gas indicators" Kate Mackenzie, Financial Times, April 19th 2010.

- Little is known about the actual resources – only five wells have been drilled so far within the Baltic Sea basin in north-western Poland.

- It is a plausible scenario that after millions of złoty have been spent on technologies and test wells, production will be not viable in economic terms.

3.6 Opportunities and Benefits Arising from the Growth of Poland's Shale Gas Market

- Poland stands a unique chance to completely remodel its energy market. If Wood Mackenzie's or Advanced Resources International's estimates are confirmed, Poland may turn from a gas importer into a net exporter.

- Polish firms that will become actively involved in exploitation of unconventional gas deposits will stand a chance of strengthening their position on international arena.
- Acquisition of state-of-the-art appraisal and production technologies will provide a springboard for a "technology leap" of Poland's upstream sector.

- Production of unconventional gas will boost the development of transport and transmission infrastructure across almost the whole of Poland. In addition, fees and taxes levied in connection with natural gas production will contribute to the municipal budgets.

- A potential rise in natural gas consumption will help Poland meet the EU-imposed requirements sooner than it might otherwise have done, by reducing carbon emissions.

SUMMARY

The ongoing improvement of production technologies has enabled access to unconventional gas resources present in source rocks.

Whether Poland is going to see a gas revolution depends chiefly on the geological conditions. At this point it is difficult to estimate the actual size of Poland's shale gas resources and commerciality of shale gas production. First results will be known in the next four or five years, when operators complete the work under exploration and appraisal licences granted to them by the Ministry of the Environment. Polish government is offering licences on exceptionally favourable terms as an incentive for research on unconventional gas resources. Such an approach is driven by the strategic objective of ending Poland's reliance on foreign sources of natural gas in the future.

Shale gas will not change Poland's and the region's energy landscape instantaneously. As in the case of all commodity and energy revolutions, changes occur slowly, but shale gas development offers huge opportunities for a permanent shift in the Polish and European energy sectors. Poland stands a chance of becoming fully independent on natural gas imports, and Polish companies – a chance of improving their international standing.

EXHIBIT 1

LIST OF LICENCES FOR EXPLORATION AND APPRAISAL OF OIL AND GAS DEPOSITS IN POLAND (as at July 2010)[86]

[86] "*Koncesje na poszukiwanie i rozpoznawanie złóż ropy i gazu ziemnego w Polsce (na dzień 1 lipca 2010 r.)*" ("Licences for Exploration and Appraisal of Oil and Gas Deposits In Poland (as at July 1st 2010)") – Ministry of the Environment.

Company	Number of all licences for exploration and appraisal of conventional and unconventional hydrocarbon deposits*	Number of licences for exploration and appraisal of only conventional hydrocarbon deposits*	Number of licences for exploration and appraisal of both conventional and unconventional hydrocarbon deposits	Number of licences for exploration and appraisal of only unconventional hydrocarbon deposits
CalEnergy Resources Poland Sp. z o.o.	4	4	-	-
Celtique Energie Poland Sp. z o.o.	3	3	-	-
Chevron Polska Exploration and Production Sp. z o.o.	3	-	3	-
Chevron Polska Energy Resources Sp. z o.o.	1	-	1	-
Cuadrilla Polska Sp. z o.o.	2	-	2	-
DPV Service Sp. z o.o.	21	21	-	
Energia Cybinka Sp. z o.o. Sp. kom. (Aurelian Oil & Gas Poland Sp. z o.o.)	1	1	-	-
Energia Kalisz Sp. z o.o. Sp. kom. (Aurelian Oil & Gas Poland Sp. z o.o.)	1	1	-	-
Energia Karpaty Wschodnie Sp. z o.o. Sp. kom. (Aurelian Oil & Gas Poland)	2	2	-	-
Energia Karpaty Zachodnie Sp. z o.o. Sp. kom. (Aurelian Oil & Gas Poland Sp. z o.o.)	4	4	-	-
Energia Torzym Sp. z o.o. Sp. kom. (Aurelian Oil & Gas Poland Sp. z o.o.)	1	1	-	-
Energia Zachód Sp. z o.o. (Aurelian Oil & Gas Poland Sp. z o.o.)	3	2	1	-
ExxonMobil Exploration and Production Poland Sp. z o.o.	5	-	2	3
FX Energy Sp. z o.o.	21	21	-	-
Gas Plus International Sp. z o.o.	1	1	-	-

Helland Investments Sp. z o.o. (Realm Energy International Co.)	1	-	1	-
Indiana Investments Sp. z o.o. (BNK Petroleum)	3	-	3	-
Joyce Investments Sp. z o.o. (Realm Energy International Co.)	1	-	1	-
Lane Energy Poland Sp. z o.o. (3Legs Resources Plc)	6	-	6	-
Lane Resources Poland Sp. z o.o. (3Legs Resources Plc)	3	-	3	-
Liesa Investments Sp. z o.o. (San Leon Energy)	2	-	2	-
Marathon Oil Poland Sp. z o.o.	7	-	7	-
Maryani Investments Sp. z o.o. (Realm Energy International Co.)	1	-	1	-
Mazovia Energy Resources Sp. z o.o. (EurEnergy Resources Corporation)	7	-	-	7
Oculis Investments Sp. z o.o. (San Leon Energy Plc)	3	-	3	-
LOTOS Petrobaltic S.A.	8	8	-	-
PGNiG S.A.	89	82	7	-
Orlen Upstream Sp. z o.o. (PKN Orlen S.A.)	5	-	5	-
PL Energia S.A.	2	2	-	-
RWE Dea AG S.A.	5	5	-	-
Saponis Investments Sp. z o.o. (BNK Petroleum)	3	-	3	-
Strzelecki Energia Sp. z o.o.	1	-	-	1
Vabush Energy Sp. z o.o. (San Leon Energy Plc)	1	-	1	-
Total	221	158	52	11

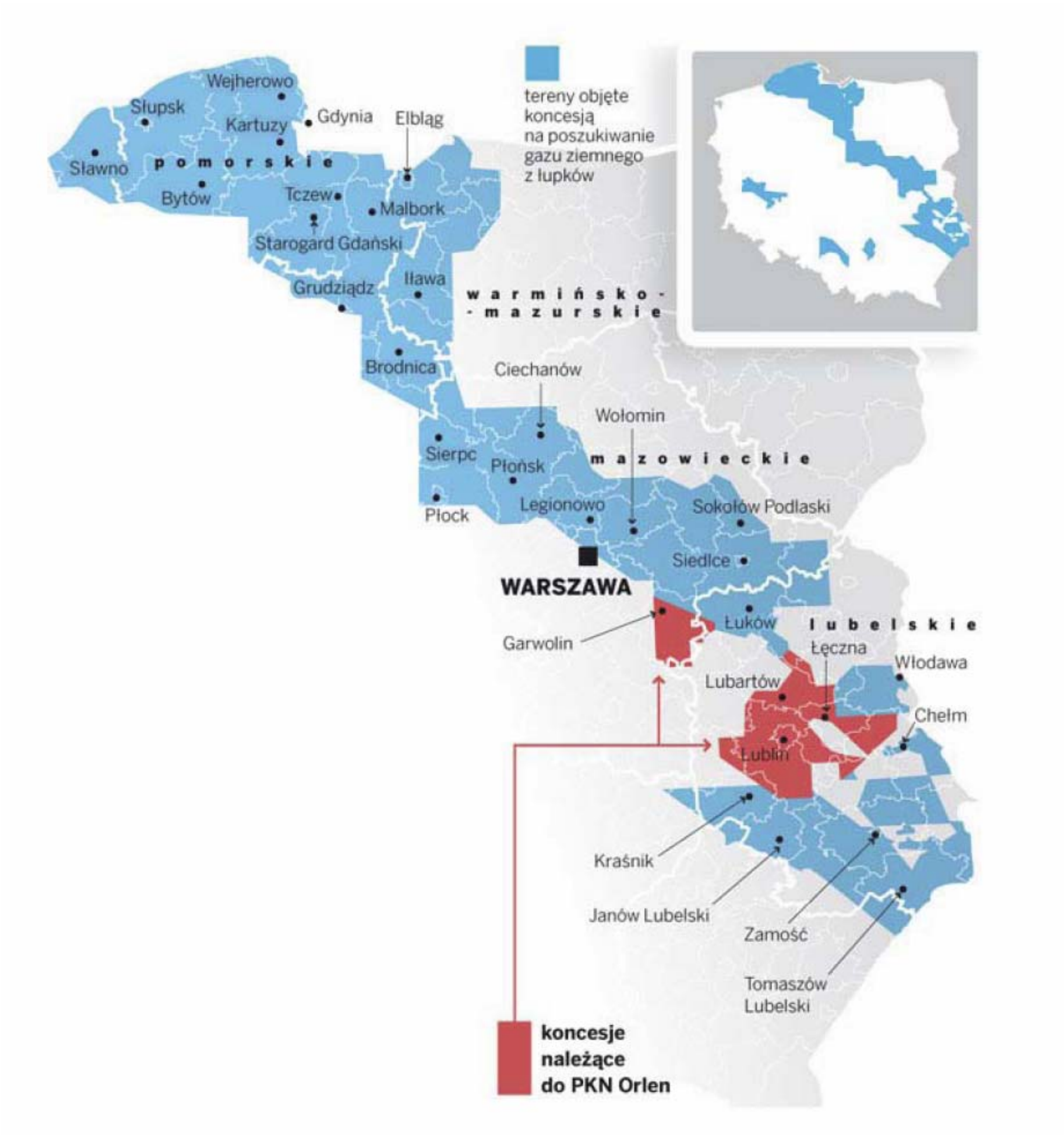
EXHIBIT 2

CASE STUDY – EXPLORATION FOR SHALE GAS ON THE PKN ORLEN EXAMPLE[87]

[87] Information sourced from PKN Orlen.

PKN Orlen holds five licences for exploration and appraisal of hydrocarbons in the Lublin region, obtained in November 2007. The licence area is approximately 5,000 sq km. Areas of presence of conventional resources potentially overlap with areas of presence of unconventional resources. PKN Orlen's subsidiary responsible for fuel exploration, including shale gas exploration, is Orlen Upstream.

Map – Areas covered by PKN Orlen's Licences[88]



Tereny objęte koncesją na poszukiwanie gazu ziemnego z łupków	Areas covered by licences for shale gas exploration
Koncesje należące do PKN ORLEN	PKN ORLEN's licences

88 Source" Dziennik Gazeta Prawna February 25th 2010.

Surveys[89]

PKN Orlen has completed the first phase of surveys under the licences for the Lublin basin. PKN Orlen analysed historical geological data, well data, including geophysical and seismic measurements. The surveys covered prospects within Carboniferous and Devonian formations. There was also work carried out with the aim of documenting the appraisal of early Palaeozoic formations (late Ordovician and early Silurian shale formations) in the most prospective sections of PKN Orlen's licence blocks.

Following the surveys, the most prospective conventional resources and potentially prospective unconventional resources were selected for further seismic tests. Initial estimates of recoverable reserves have also been made.

The main horizons which seem the most prospective and where the largest conventional resources were discovered are sand and siltstone Carboniferous formations at 1,500 to more than 3,000 metres below the site level and Early Palaeozoic shale formations at 1,500 – 4,000 metres below the site level.

New seismic surveys were carried out on the Garwolin licence block. The surveys included on-site reflection seismic 2D surveys along targeted profiles. The seismic tests are performed principally by Geofizyka Kraków Sp. z o.o., which has the required equipment and many years of experience in carrying out such surveys in Poland and around the world.

The first interpretation of the seismic surveys will probably be possible in August 2010.

Further Surveys

At present[90], further seismic surveys are underway. By the end of October 2010 a total of 2,300km of 2D seismic lines will have been analysed. Tests will be carried out to determine the shale's susceptibility to hydraulic fracturing stimulating gas migration into the borehole, all gathered data will be analysed to confirm the depth of prospective resources, and the location of the first appraisal boreholes will be set.

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[89] As at June 8th 2010.
[90] As at June 8th 2010.

The amount which PKN Orlen plans to allocate for the first phase of shale gas exploration exceeds PLN 100m.

Planned Drilling

By 2012 drillings will be performed to confirm the physical and mechanical properties of the rock and to determine the composition and maturity of organic material. These characteristics predetermine the amounts of recoverable gas.

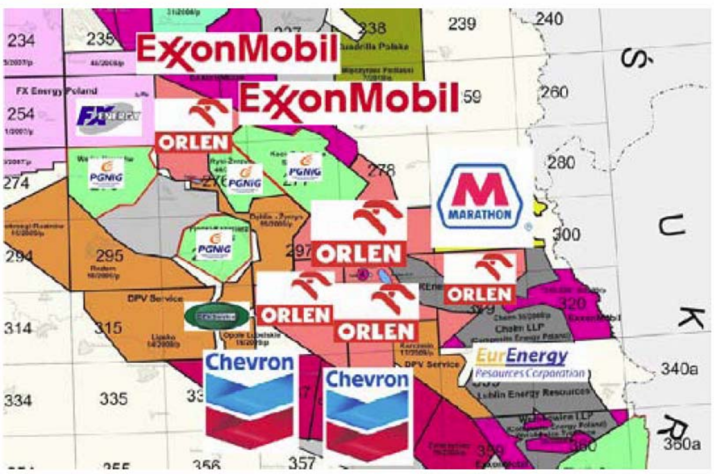
In 2012–2013, first drillings are planned to test production capabilities. The years 2014–2016 will see the drilling of first exploitation horizontal wells with the length of 1 to 2km.

Financing of Surveys and Future Development

Orlen Upstream is financing the exploration work with its own funds. At present[91], talks are underway with partners potentially interested in cooperation, who have the technology and experience required for exploration and development of shale gas. At a later stage, the investment will be most probably carried out on a project finance basis.

Natural partners for potential cooperation are companies whose licence areas are adjacent to the borders of PKN Orlen's five licence areas in the Lublin region, namely ExxonMobil, Chevron, and Marathon Oil. Orlen has signed 15 agreements with other companies, based mainly in the U.S., but also in Italy, Canada, Austria, the Netherlands, and the United Kingdom (including Lane Energy, South West Energy, Eni, Shell).

Map – Licensees in the Lublin region[92]



[91] As at June 8th 2010.
[92] Source: PKN Orlen.

Implementation of such innovative projects in cooperation with experienced partners offers tangible benefits:

- Access to know-how and appropriate technologies
- Minimised exploration risk, with priority over other applicants to be granted rights to produce from the discovered reserves.

Further Licences

Currently[93], studies are being performed in order to identify further potentially prospective areas of unconventional gas resources in Poland.

[93] As at June 8th 2010.

EXHIBIT 3

COALBED METHANE BOOM OF 1990s

In 1990s, a great uproar was raised by photographs taken by an American satellite, showing clouds of methane over Silesia. Methane in the atmosphere came from coalbed methane resources. Proved coalbed methane reserves are present in 51 fields in the Upper-Silesian Coal Basin.

Coalbed methane resources according to AGH University of Science and Technology of Kraków (Akademia Górniczo-Hutnicza w Krakowie):

- proved, recoverable, reported methane reserves – 89.5 billion cubic metres
- methane in producing fields – approximately 26 billion cubic metres
- methane in developed fields – 3.6 billion cubic metres
- methane in undeveloped reserves or more than 1km below the site level – approximately 60 billion cubic metres
- potentially recoverable coalbed methane – approximately 350 billion cubic metres.

Foreign companies, like Amoco, Texaco, McCormic, made more than a dozen wells in 1990s testing the flow of gas directly from coal deposits, but the results were not satisfactory and further work was abandoned. As in the case of shale gas, extraction of methane from coalbeds requires rock disintegration. Polish coal deposits are characterised by low fracturing and low permeability, which means that a large number of boreholes are required to extract methane from a small area. Due to the characteristics of Polish coal deposits, foreign players abandoned their plans to extract methane in Poland through drilling.

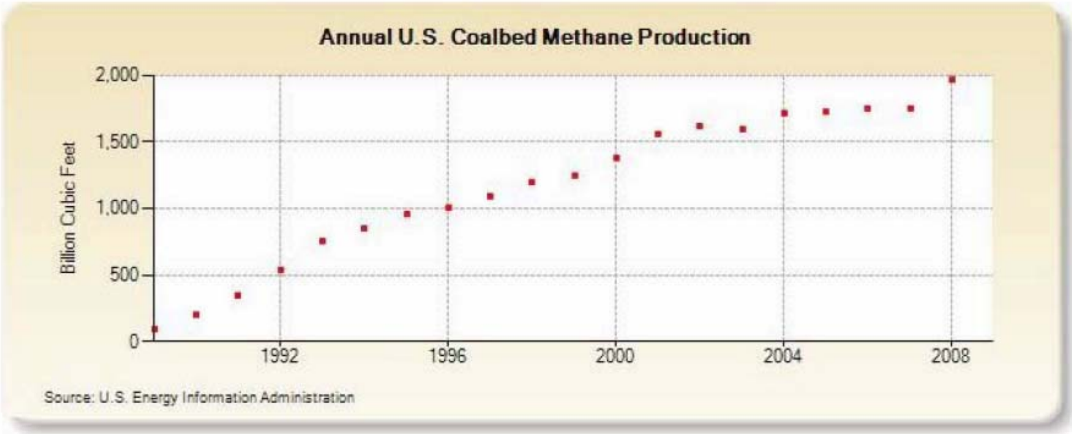
The largest producers of coalbed methane are currently the following coalmines:

1. KWK Brzeszcze – 109.80 million cubic metres annually (Kompania Węglowa)\
2. KWK Krupiński – 99.72 million cubic metres annually (Jastrzębska Spółka Węglowa)
3. KWK Zofiówka – 52.63 million cubic metres annually (Jastrzębska Spółka Węglowa)

To compare, the U.S. resources of coalbed methane are estimated at 588.9 billion cubic metres. The annual U.S. production of coalbed methane in 1990–2008 rose ten-fold: from 5.55 billion cubic metres to 55.67 billion cubic metres.[94]

www.eia.doe.gov.

Figure 4.1 – Annual U.S. Coalbed Methane Production (billions of cubic feet)



Clouds of methane photographed by the American satellite were created by gas flowing into the atmosphere from ventilation systems of coalmines and through rock mass cracking. Such methane is hard to extract.

Now the quantities of extracted methane depend on coal production. Methane is extracted to ensure miners' safety and serves as a source of energy for coalmines.

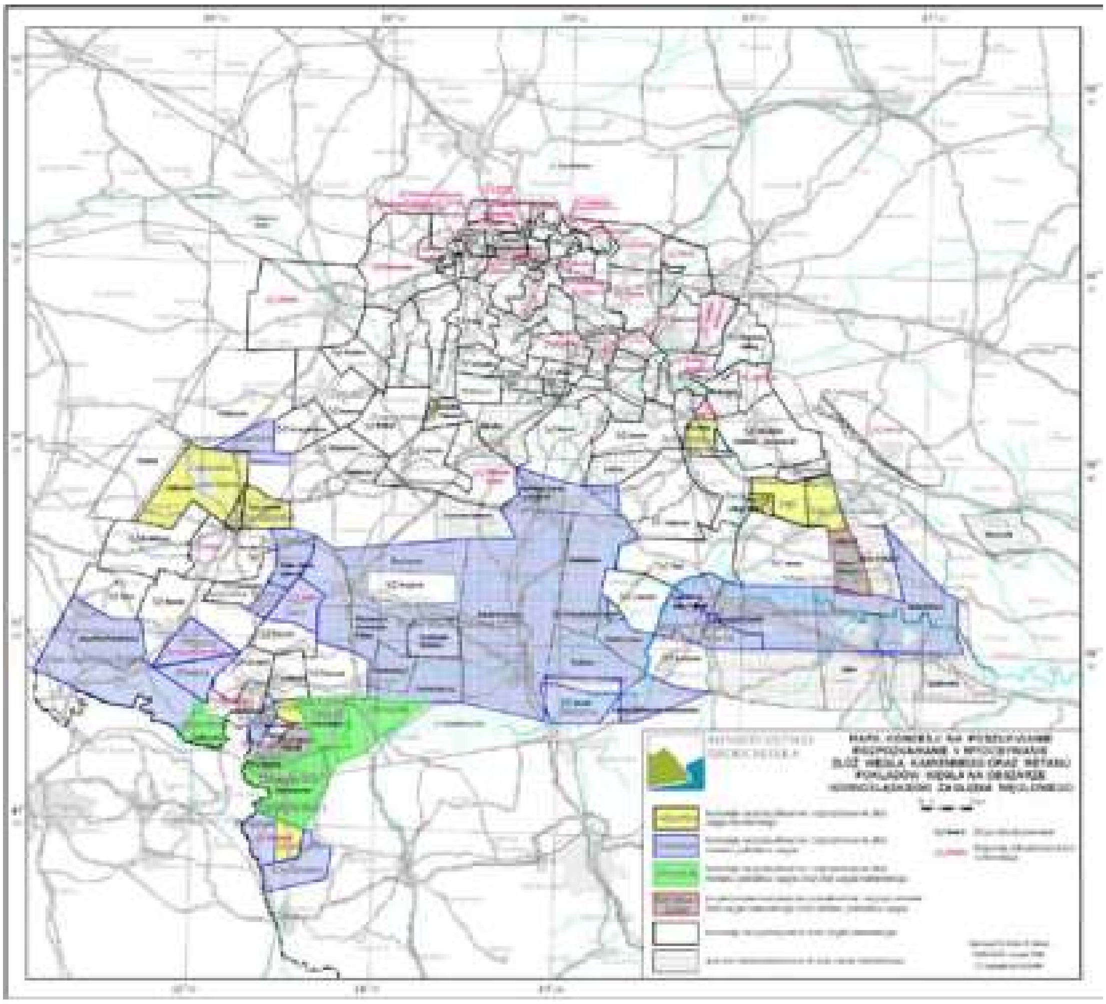
In Poland, methane is used chiefly by coalmines, to produce heat and power and to provide electricity for coal dryers and air-conditioning systems.

Alternatively, methane can be used for municipal purposes. Jastrzębska Spółka Węglowa, whose mines are assigned the highest (4th) category in terms of methane bearing capacity, plans to launch a pilot project in the Moszczenica coalmine, closed down in 2000. Jastrzębska Spółka Węglowa also wants to sell methane in cylinders. The project is to be launched in 2011 by CNG Jastrzębie. Methane would be sourced from the Budryk, Pniówek and Krupiński coalmines.

The only company whose sole business is methane production is KARBONIA PL, a subsidiary of New World Resources, owned by Zdenek Bakala, Czech coal magnate. Methane is produced in the former Morcinek coalmine in Kaczyce (near the Czech border) and sent mainly to Czech consumers (smaller quantities to Polish, including municipal, consumers).

A source of additional revenue from methane production is sale of units. Methane's global warming potential is 21 times higher than that of carbon dioxide. By expanding methane degassing facilities and using gas for industrial purposes Polish companies obtain CO_2 Emission Reduction Units (ERUs), which can be traded on the international market. First such transaction was carried out by JSW, when it sold ERUs to Chugoku Electric Power, a Japanese power concern (its annual revenue from sale of ERUs is approximately PLN 1m). A similar multi-year contract, valued at approximately PLN 30m, was signed with Chugoku by Kompania Węglowa.

Map 4.1 – Licences for exploration, appraisal and production of coal and coalbed methane in the Upper-Silesian Coal Basin [95]



95 Polish Geological Institute.

Why does the shale gas market stand a better chance of developing than the coalbed methane market?

- access to shale gas deposits is easier (methane is found in coal beds that in a majority of cases are controlled by coal mining conglomerates)
- over the last decade, the cost of exploration and production has fallen
- stronger emphasis is placed on environmentally friendly technologies and implementation of international climate standards

Table 4.1 – Companies holding licences to produce methane as the main mineral[96]

Company	No. of licences	Capital	Licence type
Fiten Gaz Sp. z o.o. (Cetus - Energetyka Gazowa Sp. z o.o.)	6	PGNiG	Licences for exploration and appraisal of methane
Werbkowice LLP, Chelm LLP Composite Energy (Poland) Sp. z o.o.	2	Owned by UK-based exploration company Composite Energy Ltd., which holds licences in England, Scotland and Poland (the province of Lublin, areas in the vicinity of Chełm and between Tomaszów Lubelski and Hrubieszów) www.composite-energy.co.uk	same as above
EurEnergy Resources Poland Sp. z o.o.	3	A subsidiary of U.S.-based exploration company EurEnergy Resources Corporation, which holds licences in the U.S., Bulgaria, Poland, Romania, Ukraine, Kazakhstan, Libya, the Carribeans and Columbia.	same as above

96 www.mos.gov.pl

European Diversified Resources Sp. z o.o.	1	A private company registered in Poznań, whose shareholders are Ian Macgregor Thom, Bolesław Kozyrski and Anthony Scott Veitch.	same as above
Pol-Tex Methane Sp. z o.o.	2	Owned by Consolidated Seven Rocks Mining (whose shareholders include Polish engineer Bohdan Żakiewicz, PhD, and Przemysław Koelner).	same as above (including one "combined" licence, currently in the exploration and appraisal phase)
Urządzenia i Konstrukcje S.A.	1	Construction of machinery for the coal industry, including Katowicki Holding Węglowy; www.uiksa.pl	Licence for exploration and appraisal of methane
NWR Karbonia PL Sp. z o.o.	1	New World Resources (Zdenek Bakala) www.newworldresources.eu	(Licence for exploration, appraisal and production; currently in the production phase)
Metanel S.A.	1		Licence for production of methane from "Silesia Głęboka"

CH4 Sp. z o.o. (Pol-Tex Methane Sp. z o.o.)	2	Licences for production of coal and methane (“Strumień").	Licences for exploration and appraisal of coal and methane
Jastrzębska Spółka Węglowa S. A.	3		same as above
NWR Karbonia Sp. z o.o.	1	New World Resources (Zdenek Bakala) www.newworldresources.eu	same as above

EXHIBIT 4

LIST OF FIGURES, MAPS AND CHARTS

EXHIBIT 5

GLOSSARY OF NAMES AND TERMS

ARI - Advanced Resources International Inc. (www.adv-res.com) - a U.S.-based research and consulting firm which has provided services related to geologic studies since 1970s. It specialises in unconventional petroleum resources, enhanced oil recovery and carbon sequestration.

BTU - British Thermal Units (BTU) - units of energy used predominantly in the U.S.. One BTU corresponds to the amount of energy needed to heat one pound of water by one degree Fahrenheit. 1 BTU equals about 1,054 J to 1,059 J.

CERA - Cambridge Energy Research Associates (more precisely: IHS CERA) - a renowned U.S.-based consulting and business intelligence firm specialising in energy resources, having its seat in Cambridge, Massachusetts. The company's founder and president is Daniel Yergin, a recognised expert in geopolitics and economics of energy resources (mainly oil) and a Pulitzer Price winning author of *The Prize: The Epic Quest for Oil, Money and Power.* CERA is a member of IHS (Information Handling Services) Inc., a publishing (e.g. Jane's Defence Weekly) and business intelligence group listed on the New York Stock Exchange.

EIA - Energy Information Administration (www.eia.doe.gov) - a unit of the U.S. Department of Energy. EIA collects information and publishes analyses on energy resources, as well as on the U.S. and global energy markets.

IEA - International Energy Agency (www.iea.org) - an organisation of 28 countries, including Poland (since 2008), established in the wake of the oil crisis of 1973-1974. Initially, it was dedicated to coordinating actions at times of oil supply disruptions, but its current role is to develop common energy security policies and to promote economic development and environmental protection.

HORIZONTAL DRILLING – a technique involving the initial drilling of a vertical wellbore, deviating it at a pre-determined depth to a horizontal trajectory and drilling on into the target rock formation for a distance which may exceed one kilometre from the derrick (the record length was 11 kilometres).

DRILLING MUD – a fluid used when drilling boreholes into the earth which has a number of important functions, such as removing and carrying out drill cuttings, cooling and lubricating the drill bit and the drill pipe, securing the stability of the borehole walls in drilled intervals, controlling subsurface pressures, and providing information on drilled rocks. In horizontal drilling, it also provides hydraulic power to the drill bit and sets it in a rotary motion.

HYDRAULIC FRACTURING – if a sufficient number of fractures are created within the zone undergoing the treatment, a mixture of water and sand with the grain size suited to the rock porosity is pumped into a wellbore, invading the fractures and preventing them from closing, while providing natural passageways for gas flowing into the wellbore. Hydraulic fracturing may be performed in a variety of ways. A fracturing fluid of controlled viscosity, wettability and gravity may be mixed with a small quantity (up to a few percent) of chemical additives which enable proper execution of the treatment. Apart from sand, alternative proppants include ceramic materials, metal and plastic pellets and polymer fluids, which form a network of tangled fibres. The opening of the fractures is controlled by means of microseismic probes and fibre optic.

Tcf - trillion cubic feet (U.S.), 1 cubic foot equals 0.028316846592 cubic metre.