GOSPODARKA SUROWCAMI MINERALNYMI

Tom 23 2007 Zeszyt 4

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Polish hydrocarbon deposits usable for underground CO_2 storage

Key words

Underground CO_2 storage, oil deposits, gas deposits, Poland

Abstract

The paper presents results of studies on posssibilities to use hydrocarbon (oil and gas) deposits as underground sites for storage of CO_2 in Poland. The analyses covered 337 oil and gas deposits from the areas of the Polish Lowlands and Carpathian Mountains and their foreland to show that geological conditions prevailing over vast areas in Poland are favorable for CO_2 storage in oil and gas deposits. However, only a few of these deposts are found to be suitable for this purpose when their exploitation ends. Two such oil deposits and 10 gas deposits have been selected. Extractable original reserves of the deposits recognized as suitable for underground CO_2 storage are estimated at about 47,116,400 tonnes of oil and 189,034 million cu. m of gas, which equals 46% and 56% of extractable original reserves of oil and gas, respectively. The distance between a source of CO_2 emissions and a potential underground storage site is shown to be one of the criteria which will bear a decisive influence on the order in which the sites are selected for use as underground CO_2 storage sites.

Introduction

Possibilities to sequester carbon dioxide by storage in deep-seated geological structures are becoming the subject of growing interest of Polish research institutes, environmental authorities and industry. This growth of interest is mainly due to results of the activity of the Sleipner and Snohvit operations for underground CO_2 storage to reduce emissions of this gas to atmosphere, a few dozens installations to inject CO_2 to enhance recovery from oil fields

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Reviewed by Prof. Eugeniusz Mokrzycki

in the United States and Canada, and the quickly increasing trade of CO_2 emissions credits. The related discussions begin to show that sequestration of CO_2 by injection into deep-seated geological structures is technically feasible and can be commercially successful.

Polish scientific and R&D teams have already some experience in the field of underground injection of carbon dioxide. For example, a team from the Central Mining Institute in Katowice constructed an installation for injecting CO_2 into unexploited, deep-seated coal seams in the Upper Silesian Coal Basin within the framework of the RECOPOL Project (5th Framework Progamme EC), which is aimed at defining possibilities to sequester CO_2 in coal seams and, at the same time, enhance the recovery of coal-bed methane. Furthermore, the Polish Oil and Gas Company S.A., an operator of the majority of hydrocarbon deposits in Poland, is steadily gathering experience in disposal of acid gases (CO_2 and H_2S) by undergound injection. The authors' r research group at the Mineral and Energy Economy Research Institute of Polish Academy of Sciences in Cracow has been carrying out studies on various aspects of underground CO_2 storage. From 2003–2005 analyses were conducted of the possibilities of sequestration of CO_2 by underground storage methods. The studies, financed by the Ministry of Scientific Research and Information Technology, covered sources of CO_2 emissions and screening of geological structures (major aquifers and hydrocarbon deposits) potentially usable for disposal and storage of this gas (Possibilities... 2005; Tarkowski 2005). In the year 2006 the research group completed pre-feasibility studies for a pilot installation for injection of CO_2 into an abandoned oil deposit, ordered by the Ministry of Environment and financed by the National Fund for Environmental Protection and Water Management – "In-situ studies of underground injection of carbon dioxide, using a pilot installation. Stage I – Estimating the possibilities of CO_2 injection into chosen hydrocarbon reservoir". At present, thanks to financing by the Ministry of Science and Higher Education, the research group is carrying out studies on potential storage capacity of deep-seated saline water horizons and hydrocarbon deposits in Poland, possibilities to use fly ash in sequestration of carbon dioxide (Uliasz-Bocheńczyk et al. 2006) and on the influence of CO_2 on reservoir rocks in which it is stored. The above mentioned studies are being conducted within the framework of European Community research projects (6th Framework Progamme EC) concerning sequestration for CO_2 by underground storage (CO2SINK, EU Geocapacity, CO2ReMoVe).

This paper presents a summary of the analysis of the possibilities to use depleting and depleted hydrocarbon (oil and gas) reservoirs in Poland for underground storage of carbon dioxide. Results of the national project accomplished in 2005 were used. Basic assumptions of this analysis are given along with results of studies and characteristics of deposits selected for the use as storage sites. The sources for obtaining CO_2 for sequestration, that is major industrial sources of emissions of this gas, are described. Oil and gas reservoirs are characterized and criteria used in selecting those suitable as sites for underground CO_2 storage are given. Subsequently, the results of this selection are given along with general characteristics of deposits found to be suitable for that purpose. Further work is aimed at obtaining detailed geological characteristics of the selected deposits from the point of view of their potential use for underground storage of CO_2.

1. Major sources of CO_2 emissions in Poland

The Polish industry is responsible for fairly large emissions of CO_2 (307,100,000 tonnes in the year 2003) and, therefore, has a correspondingly high share in total CO_2 emissions in Europe. The Energy sector produces about 96.2% of total emissions of CO_2 in Poland, and the Industrial Processes sector about 3.6%. The emissions mainly originate from the production of electricity and heat through of combustion of fossil fuels (mainly coal and, on much smaller scale, gas and oil). The shares of emissions originating from various industrial processes (especially production of cement, ammonia, lime, soda ash, paper and metals) remain clearly subordinate.

The authors analysed major sources of CO_2 emissions in Poland on the basis of statistical data for the year 2003. The analysis made it possible to screen 68 major sources responsible for the emission of over 500,000 tonnes of CO_2 per year (Fig. 1). Major sources of the Energy

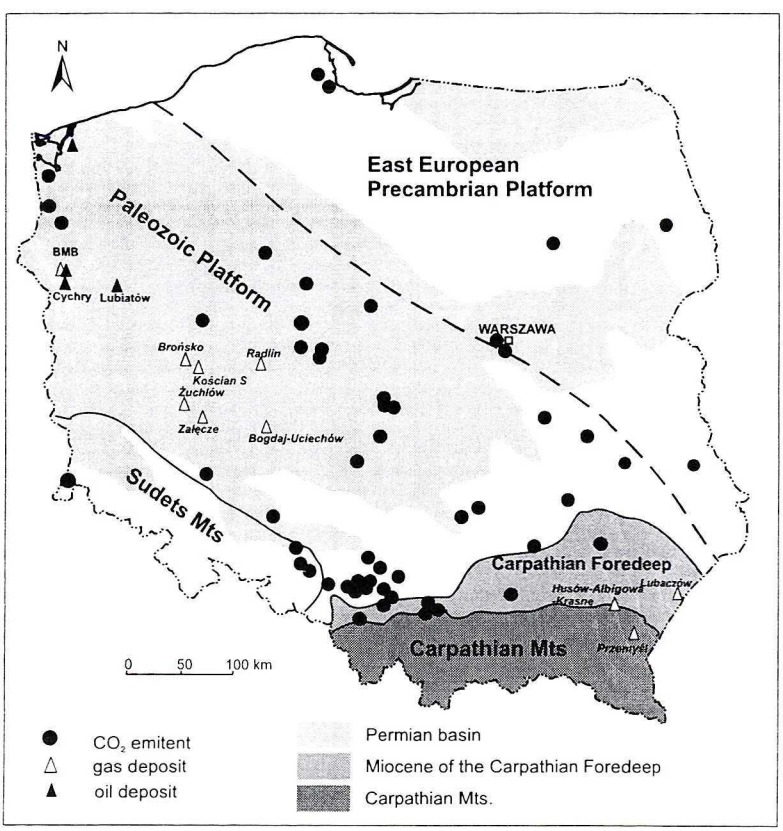

Fig. 1. Oil and gas deposits selected for underground CO_2 storage and distribution of major point sources of CO_2 emission in Poland

Rys. 1. Złoża ropy naftowej i gazu ziemnego wytypowane do podziemnego składowania CO_2 oraz główne źródła emisji CO_2 w Polsce

category include 23 professional power plants and 21 cogeneration (power and heat) plants. The remaining ones are assignable to the category of Industrial Processes and include 8 cement kilns, 4 oil refineries, 2 coking plants, 4 steel mills, 2 paper mills and 4 nitrogen fertilizer plants. The Bełchatów power plant, is the largest professional power plant and its emissions represent about 10% of total emissions of CO_2 in the country.

The location of major sources of CO_2 emissions in relation to that of hydrocarbon deposits potentially usable for CO_2 sequestration is important as has a decicive influence on the costs and, therefore, the economic feasibily of such investments. It should be emphasized here that the major sources of CO_2 emissions are located in southern and central Poland, fairly distant from areas where hydrocarbon deposits occur.

2. Oil and gas deposits in Poland

As shown in the "Annual Report of Mineral..." (2005), 337 onshore oil and gas deposits are known in Poland. Most of these deposits are almost depleted and represent potential sites for CO_2 sequestration by underground storage. Experience gathered from in the operation of six underground gas reservoirs in Poland may appear very useful.

Although the number of oil and gas deposits in Poland is high, individual deposits are relatively small and exploitation of large part of them is already coming to the end. Despite of several recent discoveries of oil deposits, production covers merely 5% of total domestic demand. Gas reserves are larger and production covers about 43% of total domestic demand.

In evaluating hydrocarbon resources, concepts of geological and recoverable resources are applied in Poland. Extractable resources refer to that part of economic geological resources of oil or gas which are planned to be exploited by currently available technologies whereas geological resources refer to total amount of raw material in a given deposit (Annual Report... 2005).

Natural gas. Up to the present, 252 gas deposits have been discovered in Poland. The largest are those located in areas of the Polish Lowlands and the Carpathian Foreland whereas only relatively small ones are know from the Carpathians and Polish shelf of the Baltic Sea (Annual Report... 2005). In the Polish Lowlands, gas deposits occur within the Permian (Wielkopolska region and Fore-Sudetic area) or the Carboniferous and Permian (western Pomerania) reservoir rock series. In the Carpathian Foreland gas deposits are stratigraphically limited to Jurassic, Cretaceous and Tertiary, and in the Carpathians Mountains to Cretaceous and Tertiary reservoir rocks (Karnkowski 2006).

The number of exploited gas deposits (84 deposits) is highest in the areas of the Polish Lowlands. Sixtyfive deposits are exploited in the Carpathian Foreland and 33 in the Carpathian Mountains. Recoverable resources (without those of the Baltic deposits) were estimated for the year 2004 at 126,680 million m^3. Of the total gas resources of the country, 64.7% are located in the Polish Lowlands, 34.4% in Carpathian Foreland, and merely 0.9%

in the Carpathian Mountains. Gas production in the year 2004 was 5197.65 million m^3 (Annual Report... 2005).

Original recoverable resources of the majority of gas deposits (191 deposits) are lower than 1 billion m^3, those of 25 deposits are estimated at 1 to 3 billions cu. m and those of 25 deposits at over 3 billions cu. m (Annual Report... 2005) (Fig. 2). Fourteen of the largest gas deposits are known from the Polish Lolands, 10 from the Carpathian Foreland, and only one from the Carpathian Mountains.

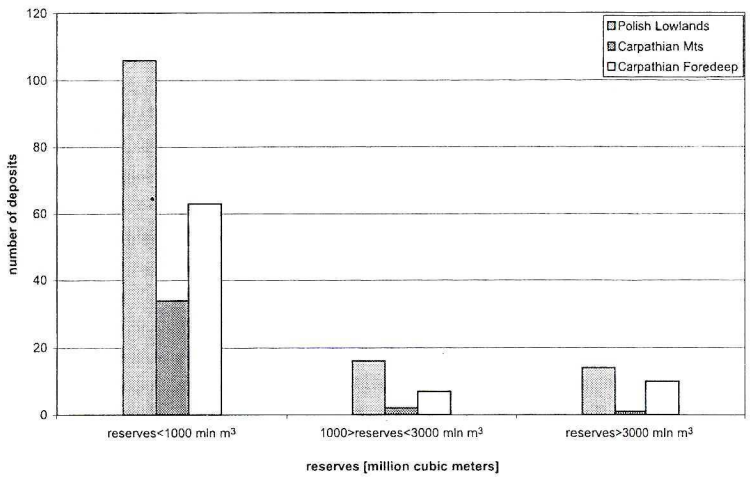

Fig. 2. Natural gas reservoir size in separate regions of Poland (in millions of cubic meters)

Rys. 2. Złoża gazu ziemnego w poszczególnych regionach Polski (w mln m^3)

Oil. The largest of 85 onshore oil deposits of Poland are situated in the Polish Lowlands whereas only smaller ones have been discovered in the Carpathian Mountains and the Carpathian Foredeep. In the Polish Lowlands the deposits occur mainly within Permian, Cambrian and Carboniferous strata; in the Carpathian Foredeep within Jurassic and, on a smaller scale, Cretaceous strata beneath thick Tertiary cover. In turn, oil deposits in the Carpathian Mountains are related to Cretaceous and Tertiary reservoir rocks occurring in the Carpathian Flysch series.

As in the case of the Polish onshore gas deposits, the number of producing oil and condensate deposits is highest in the Polish Lowlands (40 deposits). There are 34 deposits in the Carpathians Mountains, and 11 in the Carpathian Foreland. Recoverable reserves of oil and condensate in onshore areas of Poland were estimated at 19,519,000 tonnes for the year 2004. The share of recoverable resources in deposits from the Polish Lowlands was 96.9% of the total resources, and those of the Carpathian and Carpathian Foreland deposits – 1.9% and 1.2%, respectively. Production of oil and condensate in the year 2004 was equal 442,000 tonnes (Annual Report... 2005).

The majority of Polish oil deposits (46) are characterized by original recoverable resources smaller than 100,000 tonnes. Resources of 25 deposits are estimated at 100,000 –

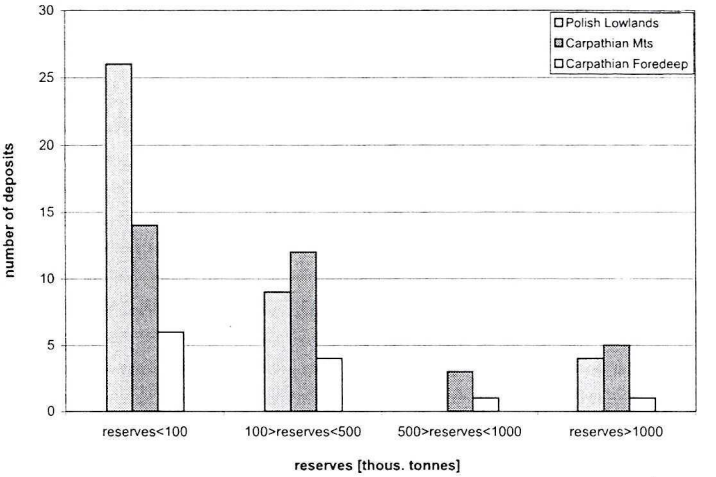

Fig. 3. Oil reservoir size in separate regions of Poland (in thousands of tonnes)

Rys. 3. Złoża ropy naftowej w poszczególnych regionach Polski (w tys. ton)

500,000 tonnes, those of 4 deposits – at 500,000 – 1,000,000 tonnes and 10 – at over 1,000,000 tonnes. The last group comprises the four largest deposits in the Polish Lowlands, 5 deposits in the Carpathian Mountains and one in the Carpathian Foredeep (Fig. 3).

3. Analysis of hydrocarbon deposits

Oil and gas deposits of Poland were analysed from the point of view of their suitability for underground storage of carbon dioxide. The analysis was primarily aimed at checking whether or not these deposits match a number of criteria described in the following:

1) structural criterion: the geological structure (such as deep-seated saline water horizon or oil or gas deposit) should represent a structural or stratigraphic trap,
2) reservoir criteria: the reservoir rocks should be characterized by appropriately high porosity and permeability, parameters necessary for determining the storage capacity and injectivity of a reservoir,
3) containment criterion: an underground CO_2 storage site should be covered by thick series of impervious rocks,
4) depth criterion: Moreover, such site should be seated at appropriate depth (depth criteria).

In the case of hydrocarbon deposits, the majority of these criteria are well matched. This is especially the case of criteria of containment, shown to be matched by the very existence of a gas deposit (Tarkowski, Uliasz-Misiak 2005).

Special attention was paid to the criteria of size of a deposit (that is its original recoverable resources) and depth of occurrence. The size of deposit appears to be of utmost importance for classifying a deposit as potentially useful for underground storage of carbon dioxide. Under Polish conditions only large deposits were taken into account and, therefore,

the analysis was limited to oil deposits with original recoverable resources over 5 million tonnes and gas deposits with such resources exceeding 5 billion m^3. These limitations made it possible to focus attention on potential storage sites sufficiently large to sequester emissions of a plant producing 500,000 tonnes of CO_2 per year for the period of 10 years or more.

Because of physico-chemical parameters of carbon dioxide and economy of future sequestration operations, the analysis was limited to oil and gas deposits situated at depths between 800 and 3500 meters.

Additional parameters taken into account in the analysis included a degree of depletion of the deposit, current status and forecasts of the time to depletion. These data show much of the original recoverable resource is still left for further exploitation and when the deposit may be used for storing carbon dioxide. In the case of oil deposits these data also show whether or not it is possible to inject CO_2 to enhance oil recovery. When this is the case, CO_2 injection carried out to achieve advantageous environmental effects (by reduction of emission to atmosphere) may be successfully combined with enhanced oil recovery. The information on status of a deposit and forecasts of time of further exploitation may also cast some light on the available infrastructure and possibilies of its use in installations for injecting carbon dioxide.

Further steps in the analysis, currently carried out, comprise a review of all the available detailed geological data on the selected hydrocarbon deposits, such as:

— geological data (type of geological structure, geological containment, depth to the top surface of a structure/deposit, character of caprock, that is type rocks which form sealing horizon, type and lithology of reservoir rocks, stratigraphy and depth at which the reservoir is situated);

— parameters of hydrocarbon deposit (status of deposit – exploited, unexploited, abandoned, date of start of exploitation, type of deposit, reservoir parameters – original and present-day pressure, temperature conditions, effective thickness, porosity and permeability of reservoir rocks, number of wells, including wells which reach the deposit, geological and recoverable resources, coefficient of exploitation of resources, the existing wells and their technical quality).

4. Selected hydrocarbon deposits

The analysis of usability of hydrocarbon deposits for underground CO_2 storage made it possible to select two oil deposits and ten gas deposits (Fig. 1). These are oil deposits with original recoverable resources over 5,000,000 tonnes, situated in area of the Polish Lowlands (Barnówko-Mostno-Buszewo and Cychry deposits) and gas deposits with original recoverable resources over 5 billion m^3, seven of which are situated in the Polish Lowlands (Barnówko-Mostno-Buszewo, Bogdaj-Uciechów, Brońsko, Kościan S, Radlin, Załęcze and Żuchlów), and three in the area of the Carpathian Foreland (Husów-Albigowa-Krasne, Lubaczów and Przemyśl). Table 1 shows the general characteristics of these deposits.

TABLE 1

Oil and gas deposits selected for underground CO_2 storage in Poland
(data: Karnkowski, 1999, 2006; Annual report... 2005)

TABELA 1

Złoża gazu ziemnego i ropy naftowej wytypowane do podziemnego składowania CO_2 w Polsce
(na podstawie: Karnkowski 1999, 2006; Annual report... 2005)

Deposit	Stratygraphy	Opening data	Depth [m]	Recovery reserves
Gas deposists [mln m^3]				
BMB	Permian	1999	3 100–3 200	9 870.0
Bogdaj-Uciechów	Permian	1970	1 520–1 620	15 782.4
Brońsko	Permian	2002	2 200	14 875.0
Kościan S	Permian	1995	2 100	10 088.1
Radlin	Permian	1992	3 127	11 070.0
Załęcze	Permian	1973	1 400	20 400.0
Żuchlów	Permian	1979	1 390	22 000.0
Husów-Albigowa-Krasne	Miocene	1962	200–2 800	6 688.0
Lubaczów	Jurassic, Miocene	1957	600–1 000	8 437,5
Przemyśl	Miocene	1958	600–2 600	69 823.1
Oil deposits [thous. tonne]				
BMB	Permian	1999	3 100–3 200	10 140.0
Cychry	Permian	2000	–	11 689.8

The selected oil deposits, Barnówko-Mostno-Buszewo (BMB) and Cychry (oil condensate field) are the largest in Poland. They were discovered at the end of the 20th century and further prospecting works may show that their resources are higher than hitherto expected (Karnkowski 2004). Six of the selected gas deposits (Bogdaj-Uciechów, Załęcze, Żuchlów, Husów-Albigowa-Krasne, Lubaczów and Przemyśl) were discovered in the 1960s and 1970s, and the remaining four (BMB, Brońsko, Kościan S and Radlin) were discovered and started production in the 1990s and at the beginning of this century. Production of all the selected gas deposits from the Carpathian Foreland is expected to come to an end in the next decade (Karnkowski 2006; Wagner, Pokorski 2003), which will make it possible to use them as reservoirs for underground storage of carbon dioxide. Therefore, detailed analysis of their geological-deposit parameters should be given a priority.

Exploitation of the remaining gas fields is still at a very early stage and their recoverable resources are fairly large. Therefore, the deposits should rather be treated as potential future sites for underground CO_2 storage.

Distance between the above listed hydrocarbon deposits and the nearest major source of CO_2 emissions is larger than 50 km.

Conclusions

The studies show that there are some geological limitations to the sequestration of CO_2 by underground storage in oil and gas deposits in Poland. Only some deposits appear suitable for that purpose when their exploitation ends. Two oil deposits and 10 gas deposits were found to be matching the requirements of that method of sequestration. Original recoverable reserves of deposits selected for underground CO_2 storage are equal about 47,116,400 tonnes of oil and 189,034 millions m^3 of gas, that is about 46% of total original recoverable rosources of oil and about 56% of those of gas. Distance between such potential underground storage site and source of CO_2 emissions will be one of criteria bearing decisive influence on decisions which deposits are first chosen to be used as underground storage sites.

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ZŁOŻA WĘGLOWODORÓW W POLSCE DO SKŁADOWANIA CO_2

Słowa kluczowe

Podziemne składowanie CO_2, złoża ropy naftowej, złoża gazu ziemnego, Polska

Streszczenie

W artykule przedstawiono wyniki badań dotyczące możliwości wykorzystania złóż węglowodorów (ropy naftowej i gazu ziemnego) w Polsce do podziemnego składowania CO_2. Przeanalizowano dane dotyczące 337 złóż ropy naftowej i gazu ziemnego z obszaru Niżu Polskiego, Przedgórza Karpat i Karpat. Stwierdzono, że w Polsce istnieją uwarunkowania geologiczne dla podziemnego składowania CO_2 w złożach ropy naftowej i gazu ziemnego. Tylko nieliczne z nich mogą być rozważane dla podziemnego składowania dwutlenku węgla, po ich sczerpaniu. Wytypowano 2 złoża ropy naftowej i 10 złóż gazu ziemnego. Pierwotne zasoby wydobywane wytypowanych do podziemnego składowania złóż wynoszą około 47 116,4 tys. ton dla ropy naftowej i 189 034 mln m^3 dla gazu ziemnego, co stanowi odpowiednio 46% wydobywanych zasobów pierwotnych ropy naftowej i 56% wydobywanych zasobów pierwotnych gazu ziemnego. Podkreślono, że odległość złoża od emitenta CO_2 będzie istotnym kryterium, które zadecyduje o kolejności wyboru złoża do podziemnego zatłaczania tego gazu.