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Near-term storage potential for geological carbon sequestration and storage in Poland

Introduction

Of the various types of geologic formations, depleting oil and gas reservoirs has the highest near-term potential for CO_2 storing. This is due to four reasons: (1) verified trapping security – presence of a low permeability seal on the top of the reservoir ensures against the rapid upward migration of CO_2 due to buoyancy forces (2) easy to examine storage capacity; (3) the presence of existing surface and downhole infrastructure; and, (4) the strong base of industrial experience with injecting gases into depleted reservoirs. Oil and gas reservoirs consist of porous rock strata that have trapped crude oil or natural gas for millions of years. The same mechanism would apply to CO_2 storage. Saline aquifers are composed of porous rock saturated with brine. Compared to oil and gas reservoirs, saline aquifers in Poland are more common and offer the higher CO_2 storage capacity. On the other hand, they are not fully recognized and much less is known about the potential of saline aquifers to store and immobilize CO_2. Consequently they need much more time consuming investigations and the present risk of the leakage to the surface is higher for saline aquifers then for oil and gas reservoirs. This means, that storage of carbon dioxide in oil and gas reservoirs is the only immediately-available means for geological sequestration of anthropogenic CO_2 in Poland. Saline aquifers are also of interest but they need much more introductory investigations including drillings, modern geophysics and laboratory measurements. For this reason in this paper we focused our attention on the depleted oil and gas fields and the saline aquifers were excluded from the analyses.

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The all Polish oil and gas reservoirs, that were included in the ministerial report (Przeniosło S. et. al. 2006) were evaluated. The calculations presented in this paper were based on publicly available data including books, reports, conference presentations etc. This allowed us to do a rough evaluation of the storage capacities of the reservoirs but the dynamics of the storage process was not investigated. This could be done with the use of the computer simulation method individually for each reservoir.

1. Criteria for assessing oil and gas reservoirs for CO_2 geological sequestration

In the paper (Bachu, Shaw 2003) a set of 15 criteria, with several classes each, has been developed for the assessment and ranking of sedimentary basins in terms of their suitability for CO_2 sequestration. These criteria included: geology, hydrodynamics, geothermics, oil and gas reservoirs, coal beds, and salt structures. The list can be expanded further or modified if another criteria are developed. In general, the candidate CO_2 storage reservoir should have:

— adequate volume to take the needed volumes,
— injectivity to accept CO_2 at delivery rates,
— confining ability to prevent CO_2 leakage.

Geological characteristics of reservoirs suitable for CO_2 geological storage are:

— adequate depth,
— strong confining seals,
— minimally faulted, fractured or folded,
— strongly homogenous sedimentary sequences,
— no significant diagenesis,
— favorable pressure and thermal conditions,
— favorable flow systems,
— adequate porosity (storage space),
— adequate permeability for injection.

In addition, the safety and effectiveness criteria should be considered:

— avoid contamination of energy, mineral and groundwater resources,
— avoid risk to life (plants, animals, humans),
— avoid, or at least minimize, leakage for the desired time period.

For the near-term screening the most important criterion is Reservoir Availability. The new discovered fields being actually under development (letter R in the 3-th column of Tables 1 and 2) and underground storages of natural gas (letter G in the 3-th column) are excluded from further analysis. Many of the fields with theoretically sufficient capacity are still producing and will not be sufficiently depleted and ready for CO_2 injection for 15 years or more. For this reason, the present recovery factor Rf has been calculated and used as additional criterion. Only the fields with Rf > 60% have been accepted for the further analysis.

2. Review of the oil and gas reservoirs in Poland

2.1. Review of natural gas fields

Natural gas fields in Poland can be found mainly in the Polish Lowland: in Wielkopolska, West Pomerania and Carpathian Foredeep; moreover, small natural gas fields occur in the Carpathian area and in the Polish economic zone of the Baltic Sea. About three quarters of natural gas resources are present in the Miocene and Rotliegendes beds, whereas the remaining ones in the Cambrian, Devonian, Carboniferous, Zechstein, Jurassic and Cretaceous strata (Fig. 1).

Natural gas fields in the Polish Lowland occur in the Fore-Sudetes and Wielkopolska Permian beds; in the West Pomerania they can be found in the Carboniferous and Permian strata. Gas occurs in the massive and block-type reservoirs with water drive mechanism and gas expansion drive mechanism. In this area there are only four high-methane gas fields, whereas in the remaining ones – nitrided natural gas, containing 30 to over 80% methane, dominates. Hence, this is a methane-nitrogen or nitrogen-methane combination. The nitrogen-methane combination (below 30% of methane) was found in 15 reservoirs, unmanaged so far and preliminarily recognized in most cases (Zawisza et al. 2005).

The natural gas fields in the Carpathian Foredeep occur in the Jurassic, Cretaceous and Miocene beds. Most frequently this is high methane, low nitrogen gas. Only in 4 fields nitrided gas occurs. These fields belong to structurally-lithologically multilayered, less frequently massive fields, producing with gas expansion drive mechanism (Zawisza et al. 2005).

The natural gas in the Carpathians occurs in the Cretaceous and Tertiary strata, both in autonomous deposits, and accompanying oil or condensate deposits. Gas exploitation from the Carpathian deposits is performed with gas expansion drive mechanism. The gas is high methane (most frequently over 85% of methane), nitrided (a few percent, on average).

In the Polish economic zone of the Baltic Sea natural gas occurs in the fields B 4 and B 6, and accompanies oil fields B 3 and B 8. Presently these fields are either intensely exploited or just being managed, therefore cannot be considered as a potential place for carbon dioxide disposal. In 2005 about 66% of documented natural gas fields were found in the Lowland area; the resources in the Carpathian Foredeep constituted 29.5% of Poland's resources, Polish economic zone of the Baltic Sea – 3.2%, and the Carpathian resources – only 0.9%. The degree of recognition of the resources and the field status as well as the production from the specific fields (as of 2006) are listed in Table 1.

2.2. Overview of oil and condensate fields

In Poland there are about 86 oil fields, in that 32 in the Carpathians, 11 in the forefield (Carpathian Foredeep), 41 in the Polish Lowland and 2 Polish economic zone of the Baltic Sea. The history of the fields in the Carpathians and the Carpathian Foredeep is long;

TABLE 1

List of natural gas fields in Poland (as of 2006), resources in mln m^3 (source Gientka et al. 2007), Carpathians and Carpathian Foredeep. First 30 sorted according to exploitable resources

TABELA 1

Zestawienie zasobów złóż gazu ziemnego w Polsce (stan na 2006 r.), zasoby w mln m^3, Karpaty i zapadlisko przedkarpackie, 30 największych złóż

No.	Field	State of field managem	Resources		Production
			Exploitable	Economic	
1	Przemyśl	E	11 983.42	5 017.49	683.11
2	Zalesie	E	2 937.95	490.35	52.95
3	Kielanówka-Rzeszów	E	2 865.10	613.03	70.97
4	Żolynia-Leżajsk	E	2 226.21	138.13	43.21
5	Jasionka	E	1 753.70	1 295.59	–
6	Tarnów (miocen)	E	1350.14	1 186.66	65.9
7	Dzików	E	1 162.63	373.4	66.64
8	Pilzno Południe	E	1 117.53	765.99	74.36
9	Jodłówka	E	1 077.82	591.2	38.66
10	Jarosław	E	936.23	221.3	–
11	Pruchnik-Pantalowice	E	817.99	173.15	7.59
12	Palikówka	E	778.81	289.7	16.73
13	Husów-Albigowa-Krasne	E	672.56	232.89	27.54
14	Lubaczów	E	630.34	175.16	39.33
15	Cierpisz	R	603	–	–
16	Rylowa	T	544.68	–	–
17	Wola Obszańska	E	523.68	467.65	52.05
18	Mirocin	E	516.29	280.46	35.12
19	Nosówka (gaz)	B	489.33	292.23	35.19
20	Zagorzyce	E	479.28	106.85	15.33
21	Terliczka	R	474.9	396.26	58.64
22	Buszkowiczki (Przemyśl)	E	461.95	155.65	17.85
23	Raciborsko	E	434.08	18.74	0.42
24	Rudołowice	P	400	–	–
25	Trzebownisko	R	390.92	–	8.77
26	Husów	G	372.88	372.88	–
27	Kuryłówka	E	359.26	253	58.33
28	Grabina-Nieznanowice	E	347.79	36.02	2.51
29	Szczepanów	E	338.97	270.63	47.95
30	Jadowniki	P	330	–	–

E – producing, G – underground gas storage, P – not fully recognized, R – recognized but not producing.

TABLE 2

List of natural gas fields in Poland (as of 2006), resources in mln m³ (source Gientka et al. 2007), Polish Lowland. First 30 sorted according to exploitable resources

TABELA 2

Zestawienie zasobów złóż gazu ziemnego w Polsce (stan na 2006 r.), zasoby w mln m³, Niż Polski, 30 największych złóż

No.	Field	State of field managem.	Resources		Production
			Exploitable	Economic	
1	Brońsko	E	13 081.34	12 754.20	647.30
2	Kościan S	E	7 812.11	6 235.10	550.88
3	BMB	E	6 284.56	3 120.48	228.78
4	Radlin	E	5 776.45	3 992.43	384.80
5	Międzychód	E	4 525.61	2 401.59	–
6	Bogdaj-Uciechów	E	4 496.75	3 275.30	136.40
7	Wierzchowice	G	4 097.70	4 097.70	_
8	Paproć W	R	3 120.00	–	–
9	Kargowa	R	2 650.00	–	–
10	Zbąszyń	P	2 400.00	–	–
11	Różańsko	E	2 231.51	744.48	0.42
12	Żakowo	R	2 150.00	–	–
13	Zalęcze	E	1 946.70	1 568.96	233.28
14	Lubiatów	E	1 798.28	2 485.22	2.59
15	Wilków	E	1 739.22	1 631.17	125.90
16	Tarchały (d.g.+cz.s.)	E	1 697.82	590.42	19.87
17	Grochowice	E	1 641.92	477.20	64.05
18	Żuchlów	E	1 483.43	1 309.11	470.84
19	Wielichowo	R	1 400.00		_
20	Paproć	E	1 389.03	1 378.40	25.57
21	Daszewo N	E	1 079.59	305.86	9.63
22	Mełgiew A i Mełgiew B	E	1 051.92	424.08	56.29
23	Grotów	R	958.93		
24	Babimost	P	910.00	–	–
25	Górzyca	T	847.27	812.24	36.79
26	Ruchocicc	R	833.00	–	–
27	Nowy Tomyśl	R	622.00	–	–
28	Stanowice	R	602.00	–	–
29	Wrzosowo	P	600.00	–	–
30	Ciecierzyn	E	597.36	384.92	14.13

E – producing, G – underground gas storage, P – not fully recognized, R – recognized but not producing.

Fig. 1. Map of distribution of oil and natural gas fields in Poland (www.pgi.gov.pl)

Rys. 1. Mapa lokalizacji złóż węglowodorów w Polsce

TABLE 3

List of oil and condensate fields, resources in hundreds tons after (Gientka et al. 2007) as of 31.12.2006, Polish Lowland. First 30 sorted according to exploitable resources

TABELA 3

Zestawienie zasobów złóż ropy naftowej i kondensatu w Polsce (stan na 2006 r.), zasoby w setkach ton, Niż Polski, 30 największych złóż

No.	Field	Field status	Resources		Production
			Exploitable	Economic	
1	BMB	E	10 025.25	7 561.80	398.67
2	Lubiatów	E	5 397.92	4 357.13	10.90
3	Grotów	R	1 826.48	“	0.31
4	Cychry	E	1 317.81	62.24	1.60
5	Dzieduszyce	R	518.53	–	1.07
6	Górzyca	T	255.15	226.71	5.61
7	Babimost	P	125.00	–	–
8	Zielin	E	113.35	25.31	5.73
9	Stężyca	B	88.52	–	–
10	Gryżyna	R	72.33	–	–
11	Wysoka Kamieńska	E	66.93	66.91	5.37
12	Kosarzyn (E)	Z	61.96	–	,
13	Żarnowiec	E	43.31	2.66	0.11
14	Gomunice	Z	39.73	–	–
15	Kosarzyn (S)	T	35.64	–	–
16	Lubiszyn	E	26.08	54.20	12.28
17	Sławoborze	E	20.63	20.63	0.15
18	Breslack-Kosarzyn	E	20.23	10.06	2.10
19	Radoszyn	E	19.37	–	4.65
20	Buk	E	19.23	15.28	5.64
21	Jastrzębsko	R	19.00	–	–
22	Żarnowiec W	E	18.57	4.61	0.17
23	Namyślin	R	16.96	–	–
24	Dębki	E	13.93	6.11	1.15
25	Kamień Pomorski	E	12.49	7.96	4.71
26	Kije	E	11.59	10.41	0.94
27	Daszewo	G	6.76	6.85	–
28	Antonin 1	R	6.20	–	–
29	Rybaki	E	4.74	4.78	0.77
30	Mozów S	E	3.59	,	0.94

E – producing, G – underground gas storage, P – not fully recognized, R – recognized but not producing.

TABLE 4

List of oil and condensate fields, resources in hundreds tons after (Gientka et al. 2007) as of 31.12.2006, Carpathians and Carpathian Foredeep. First 30 sorted according to exploitable resources

TABELA 4

Zestawienie zasobów złóż ropy naftowej i kondensatu w Polsce (stan na 2006 r.), zasoby w setkach ton, Karpaty i zapadlisko przedkarpackie, 30 największych złóż

No.	Field	Field status	Resources		Production
			Exploitable	Economic	
1	Lubaczów	P	115.93	–	–
2	Grobla	E	87.78	61.40	5.48
3	Osobnica	E	49.51	20.65	2.91
4	Jaszczew	E	43.62	8.30	0.98
5	Wańkowa	E	40.51	3.43	3.49
6	Nosówka	E	36.11	8.42	7.55
7	Gorlice	E	30.29	0.86	0.08
8	Grabownica	E	22.68	22.68	2.72
9	Węglówka	E	19.83	1.92	2.26
10	Brzezówka	E	19.53	11.90	2.00
11	Fellnerówka-Hanka	E	19.31	–	0.36
12	Roztoki	E	18.51	8.85	1.36
13	Kryg-Libusza-Lipinki	E	14.85	1.11	1.66
14	Jastrząbka Stara	E	13.45	13.45	1.43
15	Patok	E	11.09	6.36	0.81
16	Rej. Grabownica Wieś	E	11.09	6.31	0.04
17	Harklowa	E	9.78	6.67	0.76
18	Łodyna	E	8.71	0.13	1.51
19	Turze Pole -Zmiennica	E	5.94	–	0.76
20	Dominik. -Kob.- Kryg	E	5.89	5.89	0.65
21	Turaszówka	E	5.82	5.01	0.51
22	Korzeniów	P	4.80	,	–
23	Pławowice	E	4.66	4.66	4.55
24	Łąkta	E	4.58	–	–
25	Iwonicz Zdrój	E	2.57	2.57	0.55
26	Słopnice	E	1.63	_	_
27	Brzegi Dolne	E	0.87	–	–
28	Biecz	E	no data	–	0.29
29	Bóbrka –Rogi	E	no data	–	2.38
30	Czarna	E	no data	–	0.26

E – producing, G – underground gas storage, P – not fully recognized, R – recognized but not producing.

this region is the World's oldest oil mining area. Presently the fields are almost depleted. In Poland the oil resources found in the Polish Lowland are of greatest economic value.

Oil fields in the Polish Lowland occur in the Permian, Carboniferous and Cambrian beds. These are medium paraffin oils of 4.3 to 7.4% of paraffin, slightly over 1% of sulphur and density from 0.857 to 0.870 t/m^3. These fields are mostly massive, with passive underlying water, with gas-expansive production conditions. The largest field is BMB (Barnówko--Mostno-Buszewo) near Gorzów Wielkopolski. The resources of these fields were twice as big as the Poland's resources before the discovery of the field. Three other significant oil fields in the Lowland are: Lubiatów, Grotów and Cychry.

Oil fields in the Carpathians occur in a few tectonic units, mostly in the Silesian Unit. These are principally structural fields, more rarely structural-lithological, mainly of layered type with bottom water. First the exploitation is made owing to the expansion of the dissolved gas, then the gravity forces dominate.

The Carpathian oil is the methane-type oil. Its density ranges between 0.750 to 0.943 t/m^3 and is sulphur-free oil. The paraffin content ranges between 3.5 and 7%. The Carpathian resources are small; they depend on the magnitude and character of structures in which they occur. Many year's exploitation resulted in a considerable depletion of the region (Zawisza et al. 2005).

In the Carpathian Foredeep oil resides in the Tertiary basement, in sedimentary Mesozoic platform-type strata (mainly in carbonate Jurassic beds, and more rarely in Cretaceous sandstones), mainly under the sealing Miocene clayey beds. These are predominantly layered beds, stratigraphically, lithologically or tectonically screened. Oils in this region belong to light and medium (density 0.811 to 0.846 t/m^3). The paraffin content ranges between 2.32 and 9.37%, and sulphur between 0.45 and 0.85% on average.

In 2005 the exploitable resources in the Lowland constituted 81.6%, Baltic Sea – 15.7%, the Carpathians 1.25%, and the Carpathian Foredeep – 1.4% of Poland's resources. The managed resources cover 85.7% of total Poland's resources (Zawisza et al. 2005). Some oil fields in the analyzed areas contain gaseous components creating an oil condensate. In the Polish Lowland oil condensate mainly occurs in the filed Cychry, and also in smaller quantities in: Babimost, Jastrzębsko and Antonin 1. In the Carpathian Foredeep the condensate can be found in the field Łąkta; in the Carpathians in small quantities in the field Słopnice.

The degree to which the resources have been recognized and managed is presented in Table 2.

2.3. Overall conclusions

Geological validation of the reservoirs from the point of view of CO_2 sequestration leds to the general conclusion that more favorable conditions may be found in the Polish Lowlands than in Carpathians and Carpathian Foredeep. One reason is the size of reservoirs, the second is massive nature of the reservoir in the Polish Lowlands in contrast to strongly layered geological systems in Carpathians and Carpathian Foredeep.

3. Potential for CO_2 storage in oil and gas fields in Poland

The potential for CO_2 storage in depleted oil or gas reservoir can be roughly determined using material balance technique based on initial oil and gas in place and present reservoir recovery level (Rychlicki, Stopa 2004). The storage capacity can be estimated more precisely, using numerical reservoir simulation. In the case of CO_2 injected to a reservoir one may assume, that CO_2 can be present as (Pruess 2001): CO_2-rich gas-like phase, dissolved in the aqueous and/or oil phase, immobilized in solid rocks. Neglecting two last mechanisms, after Bentham (2006), the storage capacities of the oil and gas fields can be assessed assuming, that recovered hydrocarbon will be replaced by the injected CO_2. Mass of CO_2 which can be injected into depleted gas reservoir at the terminal pressure P can be calculated from the following equation:

$$M_{CO_2} = PV_r \cdot \rho_{CO_2,sc}/B_{CO_2} \tag{1}$$

where:

M_{CO_2} – mass of sequestrated CO_2,
PV_r – pore volume "recovered" by the production of gas,
$\rho_{CO_2,sc}$ – density of CO_2 at the standard conditions,
B_{CO_2} – formation volume factor for CO_2.

The "recovered" pore volume can be estimated as:

$$PV_r = R_g \cdot G \cdot B_{g,i} \tag{2}$$

where:

G – gas resources,
B_{gi} – initial gas formation volume factor,
R_g – gas recovery factor.

Assuming that terminal pressure is equal to the original reservoir pressure and combining equations (1) and (2) yields:

$$M_{CO_2} = Rg \cdot G \cdot \rho_{CO_2,sc} \cdot B_{gi}/B_{CO_2,i} = Rg \cdot G \cdot \rho_{CO_2,sc} \cdot Z_{gi}/Z_{CO_2,i} \tag{3}$$

where:

Z_g, Z_{CO_2} are reservoir gas and CO_2 compressibility factors respectively, and index i denotes initial reservoir conditions.

For the oil reservoirs the difference in solubility of the CO_2 and hydrocarbon gas should be considered.

Defining oil and gas recovery factors as ratio of produced and total oil and gas volume, available reservoir volume can be determined as follows:

$$PV_r = R_o \cdot N \cdot B_{oi} + R_g \cdot (G - N \cdot R_{si}) B_{gi} \tag{4}$$

where:
- PV_r – "recovered" pore volume,
- R_o – oil recovery factor,
- R_g – gas recovery factor,
- N – oil resources.

Obtained equation is a function of reservoir pressure, temperature and gas-oil properties and represents part of total pore volume which can be occupied by injected CO_2.

Mass of CO_2 which can be injected in depleted reservoir can be calculated from the equation (1). Additional volume of injected carbon dioxide is related to solubility of CO_2 in the remaining oil and water. Taking into consideration CO_2 solubility in remaining oil, equation (1) can be rewritten as:

$$M_{CO_2} = \frac{PV_r + V_{os}}{B_{CO_2}} \cdot \rho_{CO_2,sc} \tag{5}$$

where:
- V_{os} – volume of CO_2 soluted in remaining oil.

Additional volume of CO_2 connected with water solubility, depends on the volume of aquifer surrounding the reservoir and the displacement efficiency. The numerical simulations results show that CO_2 solubility in oil and water enables increasing the storage potential by 20–50%. This value can be greater in the case of a large aquifer, when injection operations are processed not directly in oil zone but in water.

The storage capacities for CO_2 were calculated using the presented above, simplified technique, for selected, depleted oil and gas reservoirs in Poland using available data (Przeniosło et. al. 2006; Karnkowski 1999).

The results of calculations are presented in Tables 5 to 8, where only 15 reservoirs of largest capacity are reported. In the case of oil reservoirs, different probable recovery factors have been assumed. The results of the calculations for all gas fields are presented in the form of frequency histograms in Fig. 2 and Fig. 3.

Because of the relatively lower Z factor for CO_2 as compared to hydrocarbon gas, for a given reservoir volume, a larger surface volume of CO_2 gas can be stored as compared to the surface volume of hydrocarbon gas. Furthermore, a change in Z factor due to a change in gas composition from hydrocarbon gas to CO_2 causes the similar effect. This phenomenon has been described in details by Lawal A.S. and Frailey S.M. 2004 and also reported by Stopa et. al. 2008, where the predicted values of the ratio $Z_{gi}/Z_{CO_2,i}$ against the reservoir pressure for the selected reservoirs in Poland were presented.

TABLE 5

Calculated capacities for CO_2 sequestration in gas fields. Polish Lowlands.
First 15 sorted according to storage potential

TABELA 5

Obliczone pojemności magazynowe dla sekwestracji CO_2 w złożach gazu, Niż Polski
15 złóż uszeregowanych według pojemności magazynowej

No.	Original reservoir pressure [MPa]	Reservoir temperature [K]	Storage potential [10^6 tons]
1	14.66	322.00	131.03
2	15.10	318.00	114.79
3	15.77	330.00	83.97
4	24.61	365.80	59.92
5	55.13	388.00	56.67
6	24.69	366.90	44.43
7	35.22	385.40	43.59
8	15.48	320.00	26.97
9	16.31	326.60	25.88
10	29.67	371.00	21.28
11	18.21	335.00	19.11
12	17.24	334.00	17.69
13	15.12	322.00	10.61
14	30.75	370.00	10.07
15	15.57	320.00	9.34

TABLE 6

Calculated capacities for CO_2 sequestration in oil fields.
Polish Lowlands. First 15 sorted according to storage potential

TABELA 6

Obliczone pojemności magazynowe dla sekwestracji CO_2 w złożach ropy naftowej, Niż Polski
15 złóż uszeregowanych według pojemności magazynowej

Oil recovery factor	60%	20%	40%
Gas recovery factor	85%	80%	80%
	CO_2 capacity	CO_2 capacity	CO_2 capacity
	10^6 tons	10^6 tons	10^6 tons
1	62.659	20.886	41.773
2	3.866	1.289	2.577
3	3.408	1.643	2.501
4	1.856	1.541	1.654
5	1.467	0.489	0.978
6	1.136	0.629	0.871
7	0.835	0.278	0.557
8	0.669	0.223	0.446
9	0.666	0.222	0.444
10	0.390	0.130	0.260
11	0.316	0.105	0.211
12	0.280	0.093	0.187
13	0.229	0.076	0.153
14	0.209	0.070	0.139
15	0.209	0.070	0.139

TABLE 7

Calculated storage capacity for CO_2 in gas fields. Carpathian Foredeep.
First 15 sorted according to storage potential

TABELA 7

Obliczone pojemności magazynowe dla sekwestracji CO_2 w złożach gazu,
Karpaty i zapadlisko przedkarpackie
15 złóż uszeregowanych według pojemności magazynowej

No.	Original reservoir pressure [MPa]	Reservoir temperature [K]	Storage potential [10^6 tons]
1	18.06	332.89	330
2	12.02	310.92	47
3	9.28	312.70	33
4	10.63	317.29	33
5	6.10	307.40	29
6	18.39	334.00	18
7	15.70	336.00	18
8	24.17	345.67	18
9	14.61	320.86	17
10	14.88	323.03	17
11	7.16	310.67	15
12	24.46	337.19	14
13	24.65	350.33	13
14	4.28	295.01	13
15	11.61	325.05	10

TABLE 8

Calculated storage capacity for CO_2 in oil fields. Carpathians and Carpathian Foredeep.
First 15 sorted according to storage potential

TABELA 8

Obliczone pojemności magazynowe dla sekwestracji CO_2 w złożach ropy naftowej,
Karpaty i zapadlisko przedkarpackie
15 złóż uszeregowanych według pojemności magazynowej

Oil recovery factor	60%	20%	40%
Gas recovery factor	85%	80%	80%
	CO_2 capacity	CO_2 capacity	CO_2 capacity
	10^6 tons	10^6 tons	10^6 tons
1	1.05	0.35	0.70
2	0.77	0.26	0.51
3	0.49	0.16	0.33
4	0.25	0.16	0.20
5	0.24	0.08	0.16
6	0.16	0.05	0.11
7	0.15	0.05	0.10
8	0.14	0.08	0.11
9	0.13	0.04	0.09
10	0.12	0.04	0.08
11	0.07	0.03	0.05
12	0.04	0.01	0.02
13	0.03	0.01	0.02
14	0.03	0.01	0.02
15	0.01	<0.01	<0.01

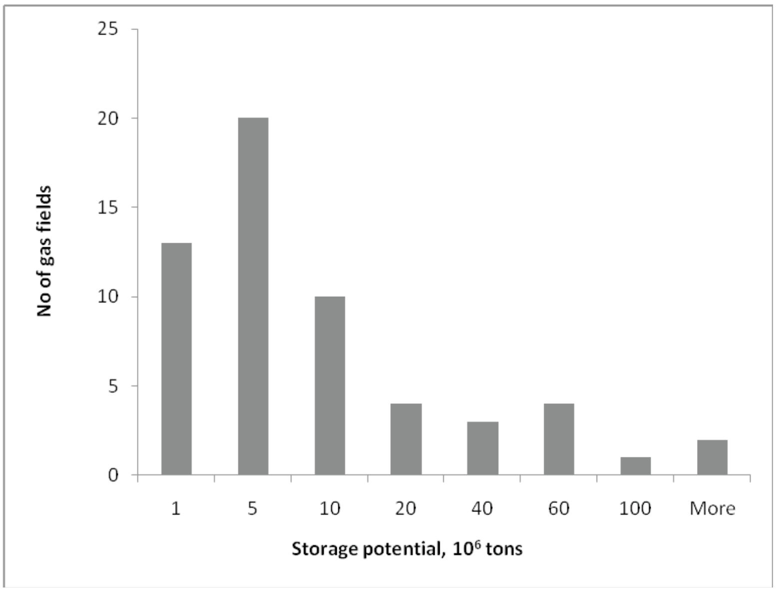

Fig. 2. Histogram of the estimated storage potential for CO_2 sequestration in depleted gas fields in Polish Lowlands

Rys. 2. Histogram potencjalnej pojemności magazynowej dla CO_2 w złożach na Niżu Polskim

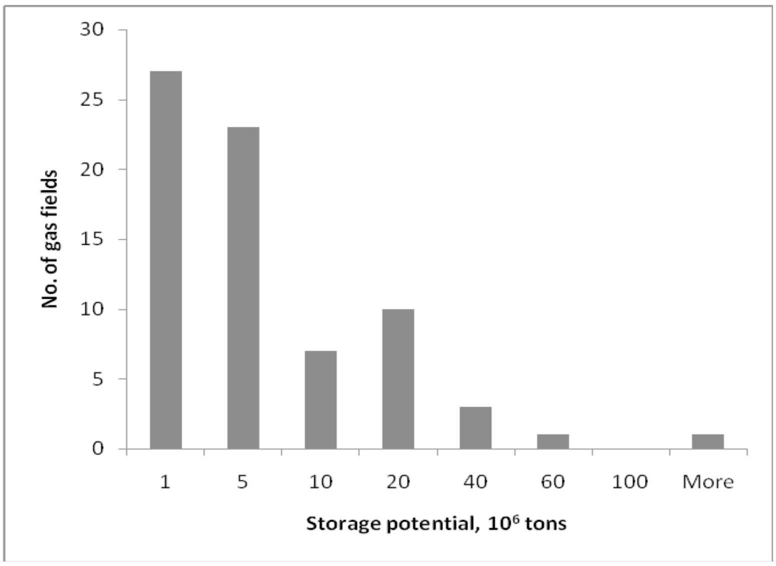

Fig. 3. Histogram of the estimated storage potential for CO_2 sequestration in depleted gas fields in Carpathians and Carpathian Foredeep

Rys. 3. Histogram potencjalnej pojemności magazynowej dla CO_2 w złożach w Karpatach i zapadlisku przedkarpackim

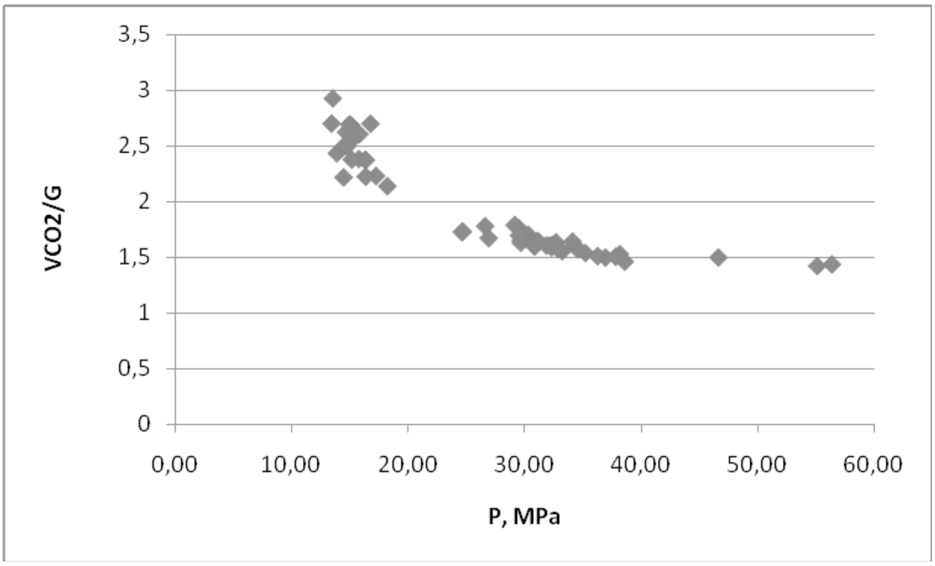

Fig. 4. Predicted values of the ratio of the volumetric storage capacity (VCO_2) to the gas resources (G) against the reservoir pressure for the gas reservoirs located in the Polish Lowlands

Rys. 4. Prognozowane współczynniki pojemności magazynowej w funkcji ciśnienia złożowego dla złóż na Niżu Polskim

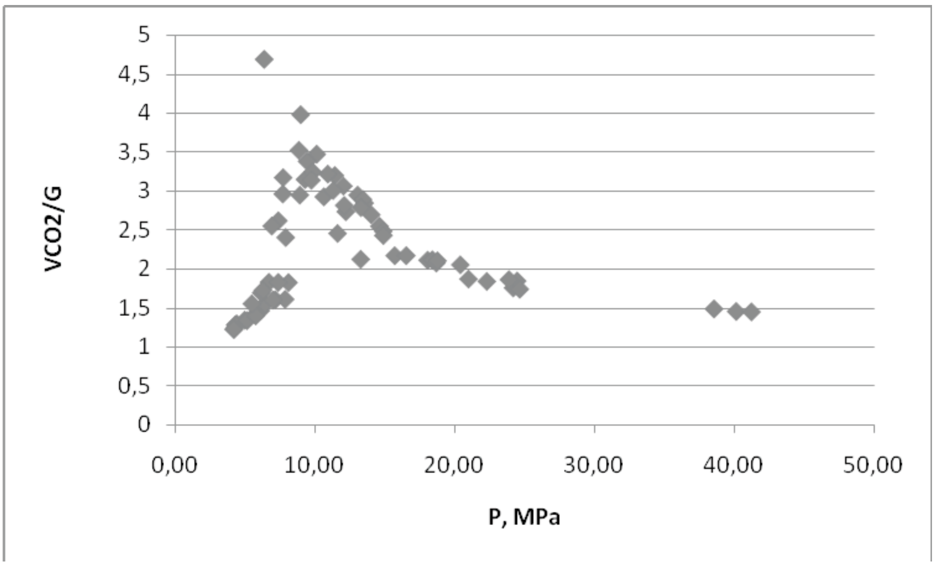

Fig. 5. Predicted values of the ratio of the volumetric storage capacity (VCO_2) to the gas resources (G) against the reservoir pressure for the gas reservoirs located in Carpathians and Carpathian Foredeep

Rys. 5. Prognozowane współczynniki pojemności magazynowej w funkcji ciśnienia złożowego dla złóż w Karpatach i zapadlisku przedkarpackim

The formation volume factors are complicated functions of reservoir fluids composition and reservoir temperature and pressure, and have been calculated individually for each reservoir including the predicted recovery factors.

As may be seen from the presented results, only a few gas reservoirs have large storage potential that may be of interest for new building power plants. In spite of lower storage potential, other reservoirs may be also considered in view of large adjacent aquifers and favorable pressure and depth. They may be of interest for storage of the gaseous emissions from chemical plants or smaller existing power plants.

Conclusions

The rough assessment of the potential for storing CO_2 in depleted gas fields in Poland have been made. The estimated storage potential has been calculated for all producing fields with the use of the simplified mass balance technique. It was found that the storage capacity for most of the known depleted reservoirs was not huge but still interesting, especially for smaller power and chemical plants. Only a few gas reservoirs have large storage potential that may be of interest for new building power plants.

As may be deduced from Fig. 4 and Fig. 5, there is a group of gas fields offering most favorable reservoir conditions for sequestration where the initial reservoir pressure is about 10 MPa. It may be stated that the most favorable reservoir conditions for sequestration have the gas fields which are rather large and have the great reserves, with gas expansion drive mechanism, and which have homogenous and isotropic parameters (also large thickness and high permeability). These gas fields are mainly connected with lower Permian strata.

The bad reservoir conditions for sequestration (where the ratio VCO_2/G ranges between 1 and to 2 for the initial reservoir pressure lower than 10 MPa.) have the gas fields which are rather small and which have heterogenous and anisotropic reservoir parameters (Fig. 5).

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POTENCJALNE MOŻLIWOŚCI GEOLOGICZNEJ SEKWESTRACJI I SKŁADOWANIA DWUTLENKU WĘGLA W POLSCE

S ł o w a k l u c z o w e

Sekwestracja, pojemność magazynowa, podziemne magazynowanie gazu

S t r e s z c z e n i e

Wśród różnych typów formacji geologicznych możliwych do wykorzystania w procesie sekwestracji geologicznej, szczerpane złoża węglowodorów mają największe możliwości wykorzystania do składowania CO_2. Wynika to z dużego zweryfikowanego bezpieczeństwa składowania oraz wieloletnich doświadczeń przemysłowych związanych z zatłaczaniem gazu do złóż. Rozpoznanie geologiczne głębokich poziomów wodonośnych nie jest zazwyczaj duże, co niesie ze sobą znacznie większe ryzyko ucieczki gazu w porównaniu ze złożami węglowodorów.

W pracy przedstawiono charakterystykę polskich złóż węglowodorów z uwzględnieniem możliwości składowania CO_2. Potencjalne pojemności składowania dla szeregu polskich złóż zostały określone w oparciu o metodę bilansu masy. Przedstawiono korelacje pomiędzy głównymi parametrami złożowymi a potencjalnymi pojemnościami magazynowymi. Z analizy wynika, iż dostępne pojemności większości złóż nie są duże, jednakże mogą być wykorzystane w skojarzeniu z mniejszymi elektrowniami i zakładami chemicznymi.

NEAR-TERM STORAGE POTENTIAL FOR GEOLOGICAL CARBON SEQUESTRATION AND STORAGE IN POLAND

K e y w o r d s

Carbon sequestration, storage potential, underground gas storage

A b s t r a c t

Of the various types of geologic formations, depleting oil and gas reservoirs has the highest near-term potential for CO_2 storing. This is due to verified trapping security and the strong base of industrial experience with injecting gases into depleted reservoirs. Saline aquifers are not fully recognized and consequently the risk of the leakage to the surface is higher for saline aquifers then for oil and gas reservoirs.

In the paper, the brief characterization of the oil and gas fields in Poland have been presented in the context of CO_2 storing. The estimated storage potentials have been calculated for many fields with the use of the mass balance technique. The paper presents selected statistical properties of the results and correlations between reservoir conditions and storage potential. It was found that the storage capacity for most of the known depleted reservoirs was not huge but still interesting, especially for smaller power and chemical plants.