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Environmental Aspects of Shale Gas Recovery in Baltic Basin

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Abstract. Factors limiting shale gas exploration and exploitation in Pomorskie Voivodeship are presented. In particular, ground and surface water availability and land/community impact is discussed. Production from unconventional reservoirs requires proper well completion through hydraulic fracturing, hence voluminous streams of water are needed – in total 8000 to 20000 m^3 per 1000 m of borehole length. 17 major groundwater basins were characterized. Spatial planning related to the management of production areas and protected areas in Pomerania is also addressed. Population density in Pomorskie Voivodeship is 125 person per 1 km^2 and there is 32,7% of protected areas which may interfere with drilling pad site planning. Availability of water in Pomorskie should not hinder shale gas production.

Keywords: Shale gas, water resources, environmental policy, wastewater.

1. Introduction

In the last decade the recovery of unconventional gas increased due to advancements in horizontal drilling and hydraulic fracturing (HF). The described reserves of shale hydrocarbons in Poland have attracted significant attention, since they could improve energy security, reduce gas imports and make the country more energy independent. Extraction of hydrocarbons from unconventional reservoirs is limited by several environmental factors - the most important are: the availability of water and urbanization of the exploration area. Another aspects are: location, vulnerability to pollution, housing in the vicinity of drilling rigs and also type and number of operations required for completion of unconventional reservoirs [1]. There are five phases of shale gas extraction for which environmental considerations, regulations and recommended practices are needed to be considered and approved: (1) selection of drilling site, (2) well design, (3) completion, (4) production, and (5) well abandonment [2].

Environmental requirements are similar for gas and oil recovery from conventional and unconventional reservoirs but there are also significant differences such as water or solid waste management [2]. Producing gas from shales requires vertical and horizontal drillings. Water is required for drilling and stimulation of the shale gas deposit. Drilling operations need smaller quantities of water – typically 400 to 4000 m^3 per well [3]. Drilling mud plays a significant role in drilling operations: maintains wellbore stability, removes cuttings and cools drilling bit [3], [4]. The total consumption of water during hydraulic fracturing is from 1000 to 5000 m^3 per one stage [5] and 8000-20000 m^3 of 1000 m borehole length. The volumetric flow rate of water depends on geological factors and fracturing strategy, and amounts 12 to 15 m^3/min. Also the amount of water used for well stimulation varies, due to shale-gas play geology, well parameters (length, depth, orientation), number of stages and used technologies [6]. Such water needs to be procured, transported and injected under high pressure as hydraulic fracturing fluid (HFF). HFF consist of 99,5 % of water and proppant, while the remaining 0,5% make chemical substances including acids, surfactants, friction reducers and scale formation inhibitors [3]. After fracturing the flow back water contains also constituents leached from the geological

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formation [7]. The amount of water, in general, necessary to produce energy is the smallest for shale gas, as shown in Table 1, however, the aqueous stream is very voluminous during HF operation.

Table 1: Water intensity for energy production [8]

Source	Water consumption m^3/MWh energy	
	Consumption range	Average
Shale gas	0,01-0,09	0,02
Nuclear energy	0,12-0,22	0,17
Oil (conventional)	0,12-0,31	0,22
Coal	0,20-0,50	0,36
Bioetanol from corn	38,94-451,40	245,09
Biodiesel from soy	217,17-1163,40	690,28

Considering urbanization of production area, the impact of the community and of the land is related to area required to construct the drilling site – typically several acres per a single well - road traffic and noise [2], [9]. Additionally, roads, pipelines and well pads have to be available. Thus spatial planning plays a significant role – it should take into account eventual overlap of deposits and protected areas [10]. The limiting factors can be classified into one of the groups, specified by the INECE Unconventional Gas Experts Group, i.e.: water, air and climate, land, ecosystem and community and human health/chemical exposure [2].

2. Water Management - the Issue of Groundwater Resources

One of the most significant and widely addressed problems in shale gas development is water availability and management. Water resources for drilling and hydraulic fracturing include surface and underground reservoirs, which have limited capacity. The available water resources have been assessed only for 46% of Poland. The disposable reservoirs make 37, 3 mln m^3 per day [11]. The most promising boreholes of the Baltic Basin are located in Pomerania where the utilization degree of disposal groundwater is lower than 30%, only for one part G-18 the disposal is between 30 and 60%. The groundwater available to the Gdansk regional water management authority amounts 3928275 m^3 per day [11]. Flowing resources in Poland are less than 40 billion m^3 during dry and over 90 m^3 during wet periods of the year (with annual average of 62 billion m^3) [10]. In this regard, water resources in Pomorskie Voivodeship should not hinder shale gas exploration and exploitation.

In the voivodeship there are 17 major groundwater basins (mainly Pleistocene and one from Cretaceous). The total documented available groundwater resources amount to 1322700 m^3 per day [12]. The table below shows the characteristics of available and perspective groundwater resources (Table 2). Major groundwater basins (GZWP) are shown in Figure 1. Pleistocene reservoirs are usually renewable resources, contrary to the deeper ones like GZWP 111 Gdansk Subbasin. Renewability of resources determines the possibility of their utilization - poorly renewable water resources should be reasonably managed.

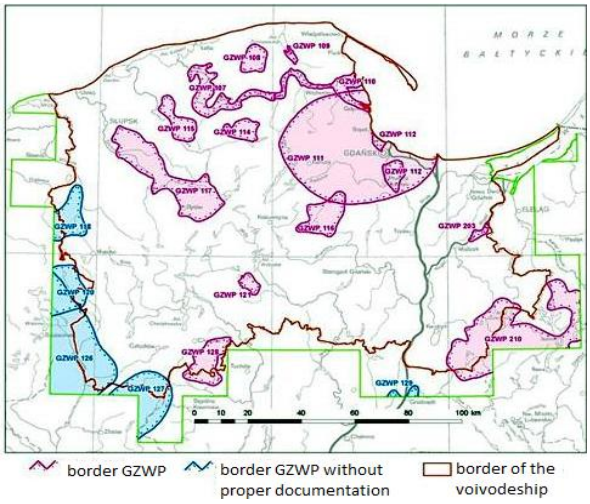

Fig. 1: Major groundwater resources in Pomorskie Voivodeship [13]

Another important issue is volumetric flow rate of water which is typically12 to15 m^3/min. New technologies such as the Flow-Chanell Hydraulic Fracturing Service HiWAY of Schlumberger could decrease the amount of water up to 60% [14]. The technology is based on pumping proppant in pulses which provides better conductivity between fractures. Also fluid flow rate is much lower. Improved stimulation technologies, besides higher efficiency of shale gas recovery, have lesser impact on the environment and local community: the total number of tracks and pumps is smaller, the traffic noise is smaller and the energy demand for the process is smaller.

3. Spatial Planning

3.1 Legally Protected Areas

Recovery of hydrocarbons is not permitted in national parks and nature reserves. It may be acceptable in other areas of nature protection such as landscape parks, protected landscape zones and Natura2020 ecological network under specified circumstances [11]. Protected areas in Pomorskie Voivodeship are mentioned in Table 3. Pomeranian province is rich in agricultural land (927057 ha) and coniferous and deciduous forests as well as woody and bushy land (686414 ha) [14]. Only 225 ha of agricultural land are designed for non-agricultural purposes and 19 ha of forest land are designed for non-forest purposes - 26 ha of these areas are designed for minerals exploitation [14]. When selected as a potential well site, land reclassification toward non-agricultural and non-forest purposes is required. The reclassification could be made only by changes in the local development plan, after obtaining relevant approvals and permits [15].

Table 2: Groundwater resources in Pomorskie Voivodeship [11]

No. Major groundwater resources	Name	Stratigraphy	Available groundwater resources [1000 m^3/d]	Nature of the reservoir	Minimum depth / average thickness [m]	Maximum depth [m]	Area [km^2]
107	Łeba Urstromtal river	Q	125	porous	5	50	212
108	Salino Intermoraine Reservoir	Q	45	porous	10	40	80
109	Żarnowiec Valley	Q	14	porous	5	50	15
110	Kaszubski Urstromtal	Q	194	porous	5	10	146,9
111	Gdańsk Subbasin	Cr	61,68	porous	/ average 150	-	1800
112	Żuławy Gdańskie Reservoir	Q	116	porous		-	158
114	Maszewo Intermoraine Reservoir	Q	43	porous	10	50	81,8
115	Łupawa Intermoraine Reservoir	Q	30	porous	/average 50	-	118
116	Gołębiewo Intermoraine Reservoir	Q	25	porous	/ average 100	-	170
117	Bytów	Q	150	porous	10/35	80	537,4
118	Polanów Intermoraine Reservoir	Q	40	porous	10	50	215
121	Intermoraine Reservoir Czersk	Q	50	porous	10	50	39
126	Szczecinek Polanów	Q	99	porous	50/90	150	1345,5
127	Piła Złotów Strzelce Polanów	Q	100	porous	/ average 100	-	3876
128	Ogorzeliny Intermoraine Reservoir	Q	50	porous	/ average 50	-	180
203	Letniki Valley	Q	10	porous	/ average 15		18,5
210	Iławski Reservoir	Q	180	porous	3/53	103	1159

Figure 2 shows spatial arrangements of areas available for shale gas production. Exclusion criteria incorporate e.g. national parks and nature reserves, mining sites, residential and services areas, areas with high flooding risk, etc. [15].

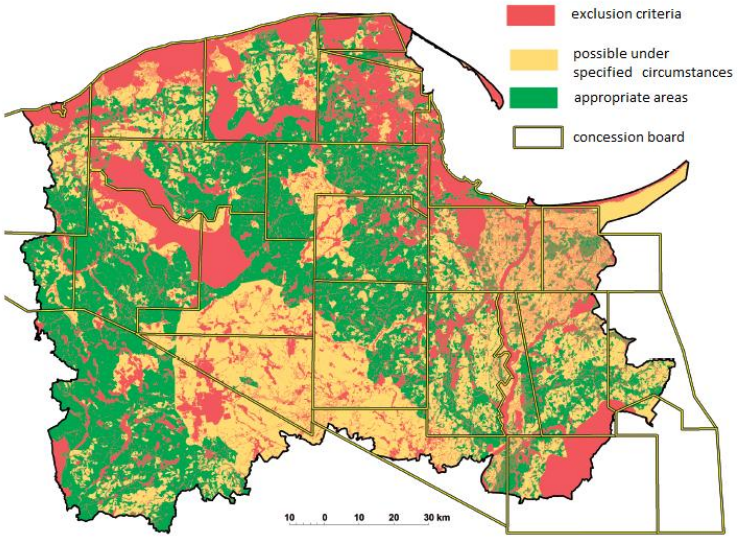

Fig. 2: Available areas and exclusion criteria in Pomorskie Voivodeship [16]

3.2 Management of Oil and Gas Production Area

An important factor in shale gas exploration and exploitation in Pomerania is the level of urbanization and population in territorial profile. According to the Central Statistical Office there are 123 persons per 1 km^2 in Poland [17] (comparing USA: 34 persons per 1 km^2 [18]). The population density in Pomerania is similar to that in Poland – 125 persons per 1 km^2, which is almost four times more than for the United States, therefore, shale gas production could have bigger impact on the community in this area.

International Gas Union recommendations regarding best industry practices include: planning well sites with minimum impact on land and local communities and also maximizing multiple wells from one well pad [9], [19]. It is especially important in Pomorskie Voivodeship where the drilling sites maybe close to towns and agricultural areas.

Table 3: Protected areas in Pomorskie Voivodeship [16]

Type	Name	Area 1000 ha	% of voivodeship area
National parks	Słowiński Bory Tucholskie	26,2	1,4
Nature reserves	-	8,7	0,5
Landscape parks	-	155,1	8,5
Protected landscape areas	-	390,4	21,3
Other	-	17,7	1,0

4. Final Comments

Factors which limit shale gas exploration and exploitation - besides social and economic issues - include water availability, water management and spatial planning in relation to protected areas. Access to water in Pomorskie Voivodeship is very favourable because of the presence of 17 major groundwater reservoirs but also surface waters, not mentioning slightly saline surface waters of the Baltic Sea. The level of urbanization and population density, and the extent of protected forest and agricultural areas may be an obstacle. The best practice and solution will be the application of advanced drilling and stimulation technologies used on multiple well pads. Highly efficient technologies will lead to increased gas recovery, savings in water and chemicals consumption, water recycling and minimization of operation foot-print.

5. Acknowledgements

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