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PRINCIPLES AND POTENTIAL FOR SEQUESTRATION OF CO_2 IN GEOLOGICAL SECTION OF BULGARIA

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ABSTRACT

Nowadays, there is a consideration that anomalous accumulation of greenhouse gases in the atmosphere is caused b the anthropogenic activity of mankind. The CO_2 represent the major technogeneous emission and it is believed to be holding the decisive role in formation of greenhouse effect. The present contribution is focused on the issue of CO_2 deposition in appropriate geological structures.

In compliance to the Minutes of Kyoto, Bulgaria has undertaken the responsibility to reduce emissions of greenhouse gasses with 8 % in comparison to 1988 r. and for the years 2008-2012 they should not exceed 92.261 MT/per year of CO_2 equivalent.

The option for significant reduction of emissions by catching and deposition of CO_2 within natural hosting medium are estimated as the most prospecting approach. It is practiced in two major versions: deposition in the deep water of the world ocean; deposition in natural geological reservoirs. The second version most often consists in deposition of mined out coal deposits; exhausted oil deposits, deeply deposited aquifers, non-economical gas localizations, water traps, oil-bearing layers of slight permeability, etc.

Based on the experience of studying the reservoir properties of Mesozoic and Neozoic section in North Bulgaria, it may be estimated that professionals from the petrophysical sector of applied geology are able to deliver acceptable and economically advisable decisions for significant emitters of Bulgarian industry and transboundary exchange, as well.

INTRODUCTION

The objective of the present work is focussing the attention on the role of greenhouse gases and in particular on the issue of CO_2 deposition into appropriate geological structures. That idea is comparatively new in world practice and it has not been a subject of detailed study yet in Bulgarian specialized literature. Emphasizing the above topic, the author believes that new opportunities will open for Bulgarian geologists and engineers and together with professional from the energy sector they will be able to suggest a platform for implementation of activities for reducing CO_2 emissions in the atmosphere. At present Bulgarian enterprises emit greenhouse gasses below the critical boundary of accepted responsibilities, however, standards are expected to become stricter in the nearest future and therefore the topic will become debatable.

GENERAL INFORMATION ABOUT HARMFUL EMISSIONS AND THEIR ROLE FOR CLIMATE CHANGE

Nowadays, it is considered that anomalous accumulation of greenhouse gases in the atmosphere is caused by the anthropogenic activity of mankind and, in particular, by the industrial revolution, which originated at the end of the 17 century. The major technogeneous emission consists of CO_2, which is believed to play a decisive role in the formation of greenhouse effect.

Series of models (emission scenarios for estimation of greenhouse effect) are developed to solve the issue, and the main working scheme for prediction and management of emissions of greenhouse gases is derived. That scheme is based on the individual warming effect, the index Greenhouse warming potential – GWP compared to the basic greenhouse gas - CO_2. The GWP index shows the cumulative increase of greenhouse potential for a unit mass of any particular gas, compared to the greenhouse effect of the basic gas. The index shows not only the link to basic gas, but also allows a prediction in inverse direction, i.e. in case of reduction of CO_2 what is the equivalent that may be expected for the other greenhouse gases (table 1). A large scope of information is collected, according to that scheme, and its balance witnesses the decisive role of anthropogenic activity of mankind on the global climate change. Based on the above analyses, numerous international forums alarm about the need of international agreements on issues of climate. As a result of those efforts the UN General Assembly established an *Intergovernmental Panel on Climate Change-IPCC* in 1990 with the general goal of developing a Framework Convention on Climate changes – FCCC. It was approved on May 9th 1992 in the UN Centre in New York. It is approved by 154 countries in June 1992 in Rio de Janeiro, including the countries of the European Union. A top body of the Convention is the Conference of the countries, which holds its first meeting in 1995 in Berlin, then in 1996 in Geneva and in December 1997 in Kyoto. In fact, the principal document, known to the world society as the Minutes of Kyoto was approved at the last meeting. Formally, the 39 National Assembly of the Republic of Bulgaria ratifies the Minutes on 17th July 2002 and thus take the responsibility to reduce emissions of greenhouse gases for the period of years 2008-2012 with 8 % in comparison to the basic year of 1988.

According to Annex A of the Minutes, the greenhouse gases comprise carbon dioxide (CO_2), methane (CH_4), fluor-

hydrocarbons (HFCs), per-fluor-carbons (PFCs), sulfur hexa- fluoride (SF_6) (table1).

Table 1. Predicted values for CO_2 generation from Bulgarian industry for the period up to 2015, equaled to CO2 equivalent (MT/year) and a reserve quotation according to the limit of the Minutes of Kyoto (according to data of Ministry of Environment and Waters, the quotation of the Minutes of Kyoto represents 92. 261 MT/year

Year	Total emissions of CO2 equivalent (MT/year)					
	General scenario		Sub-scenario with reduced export		Sub-scenario with incrased export	
	Mass Emissions	Reserve according to Minutes of Kyoto	Mass Emissions	Reserve according to Minutes of Kyoto	Mass Emissions	Reserve according to Minutes of Kyoto
1998	57.4		57,4		57,4	
2005	63.2		57,1		68,3	
2010	73.4		67,0		79,9	
2015	77.9		73,4		85,2	
2008-2012 (average)	72.9	18,7	66,6	25,66	78,5	13,79

Brief information about emissions of greenhouse gases from economic medium in Bulgaria.

According to the Minutes of Kyoto, Bulgaria is responsible to reduce emissions of greenhouse gases with 8 % in comparison to year 1988, approved as a basic year. The level of emissions for the basic year is recorded as 100.28 MT/year emissions, transformed into equivalent of CO_2. Reduced with 8 % emissions for the period of years 2008-2012 should not exceed 92.261 MT/year CO_2 equivalent, which is the limit of responsibilities, accepted by the country.

The Ministry of Environment and Waters as well as the Ministry of Energy and Energy Resources, with the aim of monitoring and control of emissions, developed structural models with a number of scenarios, which predict the level of emissions not only for the monitored period of time but even after it (table 2). In general, results obtained for the period of time, considered within Bulgarian responsibilities, show that economic media in the coutry is still below the critical values, however in future periods of stricter limitations, emissions reach the critical level, which requires in time activities. If intentions of the Government take place and Bulgaria is positioned as an energy center on the Balkans and sustainable power production is achieved with the cease of energy blocks of the "Kozloduy" power plant, emissions of thermal power plants will increase significantly reaching the critical 90 MT/year. Concurently to responsibilities of the Kyoto mitutes, Bulgaria is expecting to become a part in a number of Directives of the European Union and in particular the 2001/ 80/EC Directive for large combustion installations, where requirements are rather high. In that sense discussing and managing the emissions is an issue of strategic planning.

PRINCIPLES FOR SEQUESTRATION OF CO_2

Activities in two directions are possible:

- reducing the emissions of greenhouse gases in the atmosphere;

- increasing the options for absorption of emission (refers to absorption by aqueous masses, absorption by biosphere etc).

Subject of the present study is the options for reducing of emissions of greenhouse gases in the atmosphere, in particular, opportunities for reduction of CO_2.

Principle directions for reducing CO_2 emissions in the atmosphere

Approximately one third (35%) of CO_2 emissions come from power plants on fossil fuel and nearly the same quantity (39%) is emitted by numerous industrial installations (refineries, cement plants, steel industry). Share of transportation sector is estimated as 21 % and insignificant share (5 %) is occupied by other sources (fig. 1). Power production and some other industries are referred as industries with controllable and effective reduction of emissions. However, transportation sector and households are not believed to experience noticeable results in emission reduction for well-known reasons. In that aspect, three major principles for reduction of emission from the two large groups of emitters may be defined:

- pure technological decisions;

- reduction of emissions by capturing and deposition of CO_2 in purposefully constructed containers for short-time storage and subsequent technological processing, on the principle of technological deciisons of the reaction of Fischer-Tropsch, commonly applied by the "Sasol" in the Republic of South Africa.

- reduction of emissions by capturing and deposition of CO_2 in natural hosting medium with a large capacity and long-term reliability against migration of deposited gas.

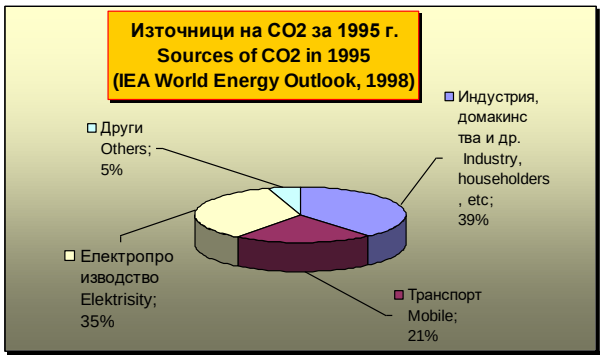

Figure 1. Sources of CO_2

There are numerous approaches for pure technological reduction of CO_2 from both major sources, for example improving the technological parameters of combusting installations, transformation from one fuel to another one etc. Estimations show that those measures do not correspond to a large potential for reduction needed to comply the requirements of the Kyoto minutes. Similar is the estimation for container storage. For that reason, other decisions are needed, one of them being the capturing and long-term deposition of CO2 into appropriate natural hosting medium. Recently acquired practical results showed that the above method is extremely prosperous. .Furthermore, that approach does not require radical changes in the infrastructure of delivery of energy sources.

Table 2. Some important projects for capturing and deposition of CO_2 in projects all over the world

Continent	Geographic affiliation	Brief information about the project
North America	Oklahoma Shady Point Power Plant;	Reduction of CO_2 by absorption in liquid medium
	Weyburn Oilfield	Depositing in low productive oil-bearing layers, volume of deposited mass - > 5000 MT/day
	New Mexico Can Juan Basin	In deeply occurring non-economical coal seams
	Salt Lake Sity	Experimental project of formation of fractures and subsequent injection of CO_2
	Utah, Ohio	Aquifers with a high level of total dissolved solids.
	Alabama	Deposition in coal seams
	New York	Deposition in basalt massif
Africa	Algeria, Salah project	Deposition in exhausted gas reservoirs
Middle East	Abu Dabi Deposits Mubarras, Umm Al-Anbar, Neewat Al-Glahann	Injecting significant quantity of gas mixture, where the CO_2 is prevailing
Europe	Project Sleipner Field Gas field	CO_2 from a system of heating installations is deposited in the aquifers
	Norway Snohvit	Depositing the gas from a plant for production of LNG by means of 160 км ducts
	The Netherlands	Depositing in aquifers
	United Kingdom	Depositing in oil-bearing reservoirs
Asia	Japan	Depositing in aquifers of known reservoir properties
	China Liaohe Oilfield	Injection of CO_2 for intensifying the oil liberation
Australia	Australian Petroleum Research Centre	Depositing of CO2 in aquifers from convection of natural gas into LNG; Depositing in exhausted gas reservoirs

PRINCIPLES OPTIONS FOR REDUCING THE EMISSIONS BY DEPOSITION IN NATURAL HOSTING MEDIUM

Experience of compulsory introduction of CO_2 in the oil deposits and results from the efforts of the International Energy Agency (IEA), as well as efforts of private energy companies, forced to invest in reduction of greenhouse emissions revealed that principle efforts in that direction need to be focussed as follows:

- options for deposition in the deep sea of the world ocean;

- options for deposition in natural reservoirs of the geological medium (fig. 2);

Deep waters of the oceans are estimated as very prosperous for deposition mainly due to the expected lower levels of investments and lower exploitation cost. Large potential of World Ocean is also an important advantage. Furthermore, it is well known that within the World Ocean there is a continuous and equalized process of CO_2 absorption by the atmosphere without certain knowledge about the thermal-barometric and physical-chemical behavior of deep-sea ocean waters in case of compulsory injection of CO2. That means that initial obstacles before the practical application of that opportunity are still not overcome.

As it is well-known, CO2 was injected into oil-deposits for increase of oil liberation. Recently, number of experiments was carried out and interesting results were obtained for the deposition of CO_2 in reservoir rocks, saturated with mineral waters. That gave an additional advance and today a number of projects on other modifications of geological reservoir deposition are developed and financed. In that case processes of interaction and behavior of the rock-fluid system are described with higher reliability. In practice, the following main directions are considered for deposition of CO2 in geological hosting medium (fig. 2):

- mined out coal deposits;
- mined out or exhausted oil deposits;
- deeply occurring aquifers;
- non-economical gas localizations;
- water-bearing trap structures;
- oil-saturated layers of slight permeability;

- etc. .

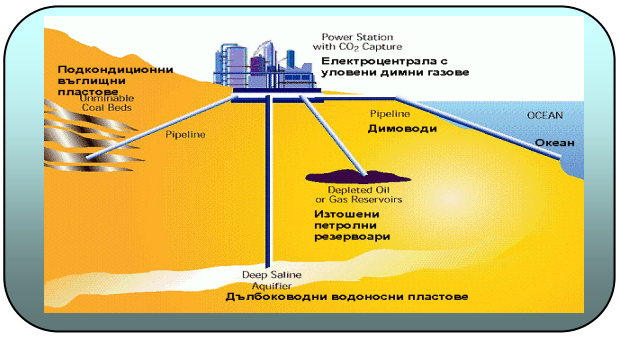

Figure 2. Storage Options for CO2

Information about important projects from the international practice for deposition of CO_2 in the geological hosting medium is shown in table 3 to support the author's opinion. Worldwide distribution of that activity and positive consideration of energy companies give a reason that underground deposition has its own future, including its future in Bulgarian economy.

POTENTIAL OF BULGARIA FOR UNDERGROUND SEQUESTRATION OF CO_2

Matters of regions and dimensioning of noxious emissions from industrial enterprises in Bulgaria are an object of precise investigations that may be found in specialized bibliography. At that preliminary stage we will discuss only some important zones from a point of view of CO_2 emissions. Those are:

- coal mining and power production plants "Maritsa-East" and "Bobov dol";
- industrial area near Devnya, including the "Varna" power plant";
- industrial areas of Sofia and, firstly, district heating plants;
- metallurgical plant of "Kremikovtsi";
- industrial area near Rouse and, firstly, "Rouse" power plant;
- cement-producing plants;
- others.

Perspectives for the major emitters in North Bulgaria may be outlined as referred to the following:

- regional, zonal- and local natural reservoirs, affiliated to established and comparatively well studied Paleozoic, Mesozoic and Neozoic aquifers;

- the numerous trap structures, outlines by seismic and borehole exploration, but considered for a certain reason as non-economical and therefore not-involved into development;

- mined out and exhausted oil-bearing and gaseous areas, the further exploitation of which is estimated as economically non-effective;

- larger structures, formed as a result of salt excavation.

One may consider that due to broad experience from exploration of reservoir properties of the Mesozoic and Neozoic section in North Bulgaria, professionals from the petrophysical sector of applied geology are able to provide acceptable and economically reasoned decisions for both significant emitters of Bulgarian industry and trans-boundary exchange, as well.

As It is well-known, geological cross-section in South Bulgaria has not been explored to a satisfactorily extent from a point of view of natural reservoirs. That makes the formulation of a strategy for sequestration of CO_2 from the main emitter in the country – the power production site of "Maritsa-East" with its four power plants, where local, low quality lignite coal are burned, extremely difficult. Limited number of boreholes and their low depth do not reveal the perspectives for sustainable control of noxious emissions from power production in that region. For periods of later future, if directives of the EU introduce much more strict restrictions, the author believes that there are reasoned opportunities for investing in exploraion within the perimeter of the Eastern Rhodopes depression. Preliminary data for that region show that at a depth below 800 m significant quantities of noxious emissions may be deposited in a sustainable way.

BRIEF INFORMATION ON FINANCIAL ASPECTS OF PROJECTS FOR SEQUESTRATION OF CO_2

For reasons of different kind there are no unified cost models for estimating the projects for deposition of CO_2 in the geological hosting medium. Only, general information is available, which reveals that cost of kWh will become higher with 1.5 cents. Additionally, the efficiency of technological process will be reduced with at least 10 %. The integral estimations show that sequestration of emissions will cost within 40-60 US dollars for ton of CO_2.

NEXT STEPS

The following matters are considered as the main priorities in development of technologies for sequestration of CO_2 :

- more complete investigation of the mechanism of dissolving of gases in the layer fluids of different physical-chemical characteristic;
- development of simulation models and systems for monitoring the migration of deposited gaseous material into the hosting geological medium;
- development of information and reliable cost models with the aim of developing cost-efficient projects;
- reasoning a strategy, which will stimulate the crediting of projects for sequestration of greenhouse gases;
- assistance in the development of regulating norms that will generate sustainable interest within financial institutions and energy companies, which invest in activities of climate protection.

CONCLUSION

The option for capturing and depositing of CO2 in natural reservoirs of the geological medium is estimated as extremely prosperous and beneficial. The high rate of exploration of the geologic section in North Bulgaria is a precondition in favor of development of activities not only for depositing emissions from Bulgarian industry but also for trans-boundary exchange. That is expected to be normal practice, at least for the

countries of the EU, similarly to the opportunity for guaranteeing obligatory reserves of oil and oil products.

It is evident that each financial loading will be critically accepted by energy companies, however severe consequences of climate change are the moving force for reduction of greenhouse gas emissions.

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