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Review Article

ECOLOGICAL, ECONOMIC AND SOCIAL ISSUES OF IMPLEMENTING CARBON DIOXIDE SEQUESTRATION TECHNOLOGIES IN THE OIL AND GAS INDUSTRY IN RUSSIA

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ABSTRACT
The objective of this paper is to define the main approaches to the implementation of carbon dioxide sequestration technologies in the oil and gas industry in Russia, and also to identify ecological, economic and social issues of their usage. Promotion of the technology of carbon dioxide (CO_2) sequestration by means of capturing and injecting it into underground reservoirs is a promising mechanism of reducing carbon dioxide concentration. Carbon capture and storage (CCS) technologies might be used to enhance oil recovery (EOR-CO_2) and production by means of oil extraction and decreasing oil viscosity. Conceptual view of the potential of EOR-CO_2 technologies within the context of oil and gas industry sustainable development are presented. Incentives of the CCS projects implementation are identified. On the basis of the conducted research a number of scientific research and practical areas of the CCS technology development are presented.

Keywords: carbon dioxide, sequestration, carbon capture and storage, oil recovery, EOR-CO_2 technology, oil and gas, Russia.

INTRODUCTION

The key challenges of global energy sector, such as deterioration of reserves quality, the increasing importance of energy- and resource-saving technologies, environmental restrictions, the adoption of unconventional raw hydrocarbon sources, economic and technological sanctions, require undertaking interest in a new conception of sustainable development for oil and gas industry (OGI). The model of modern OGI development should reflect the change in priorities and the switch to the conception based on innovations and resources, in which resources exploitation is based upon rational usage of mineral resources, energy costs optimization and more complete extraction of the hydrocarbons.

The paradigm of modern sustainable development of Russian OGI should be grounded upon innovations, which form a high-tech, rational, ecologically-balanced system of operation of oil and gas production, transportation and refinery enterprises [Cherepovitsyn 2009].

The principles of Russian OGI operation in the modern economic conditions may and should provide for a use of sets of organizational and technical, economic solutions targeted on the adoption and implementation of environmental and nature conservation related technologies. That makes it possible to use the options of greenhouse gas reduction that are widespread in the Western countries in order to ensure energy-efficient development and rational usage of natural resources.

Promotion of the technology of carbon dioxide sequestration by means of capturing and injecting it into the underground reservoirs is a promising mechanism of reducing carbon dioxide (CO_2) concentration.

MAIN APPROACHES TO THE IMPLEMENTATION OF CARBON CAPTURE AND STORAGE TECHNOLOGIES (CCS)

By the estimates of the International Energy Agency (IEA), contribution of Carbon Capture and Sequestration (CCS) technologies to the worldwide emission reduction may reach 1.5 billion tons of CO_2 a year by 2050 [Energy technology prospects. International Energy Agency 2011, WWF – The Energy Report 2011].

The proportion of the CCS technologies in reduction of the global emission is estimated to be from 20 to 28 percent, which indicates the prospects of development and vast adoption of such technologies [Energy technology prospects. International Energy Agency 2011, IEA – Energy Technology Perspectives 2010]. CCS technologies include the following technological processes: capturing, transportation and geological storage. Geological storage is linked with the possibility of injecting CO_2 into saline formations (water-bearing strata), oil and gas fields, and coalbeds.

When injecting CO_2 into the saline formations or oil and gas fields at depths exceeding 800 meters, one should consider mining and geological properties of the rock. The reservoirs should have high porosity in order to accumulate big amounts of carbon dioxide. The rocks inside are usually permeable, so that CO_2 can penetrate into the underground reservoirs. At the same time, the storage reservoirs should be covered with impermeable overlying rocks in order to prevent surface leakages.

The coalbed storage might be implemented at shallow depths and is based on the CO_2 adsorption by the coal. The technical practicability of such a technology to the great extent depends on the coalbed permeability.

The CO_2 storage in oil and gas fields that are at the final production stage might be used to enhance oil recovery (EOR-CO_2) and production by means of oil extraction and decreasing oil viscosity [Cherepovitsyn et al. 2013].

Enhancing oil recovery by the EOR-CO_2 method may be characterized by the added value by usage of anthropogenic CO_2, captured at power plants and industrial enterprises. Studies conducted by American experts showed that the worldwide potential of the EOR-CO_2 is 340 billion barrels of technically recoverable oil resources and the capacitive potential of CO_2 storage is 120,000 million tons. Large volumes of potential carbon dioxide storage in the oil reservoirs underline the interest in the EOR-CO_2 technologies [Beecy et al. 2004].

CO_2 utilized in the underground reservoirs might be considered reduced greenhouse gas emissions. If there is a functioning carbon market, it is also possible to get some extra profits from the carbonic acid utilization.

It should be noted that the "Energy Strategy 2030" forms a number of target indicators of oil production technological advancement, such as scaling up the implementation of industrial innovational technologies, enhanced oil recovery and intensified oil production. The gas, gas-water, thermal-gas, rheo-gas-chemical and thermal EOR methods were identified as priorities [Energy strategy of Russian Federation to 2030].

Experts estimate stimulating oil formation by gas, which includes injection of carbon dioxide, associated petroleum gas (APG), petroleum gas and flue gas to be one of the most effective and rational technological processes from the point of view of energy- and resource-saving and EOR.

POSSIBILITIES OF THE EOR-CO_2 TECHNOLOGIES IN THE CONTEXT OF OIL AND GAS INDUSTRY SUSTAINABLE DEVELOPMENT

The concept of OGI sustainable development under the strategic vision of potential vast usage of the CCS technology is presented in Figure 1. In the OGI, the CCS technologies are related to injection of the anthropogenic CO_2 into the oil formation in the first place.

The main problem of the EOR-CO_2 usage is the high price of anthropogenic CO_2. The CCS technologies, as mentioned above, are a combination of three processes: capturing, transportation and geological storage. These processes (stages) differ from each other considerably in terms of technical and technological practicability and have different experience of practical application. Currently, most of the CCS projects serve the demonstration purpose, therefore, there is no definite way to evaluate the costs of CCS technology usage. The implementation costs of the CCS technology depend on particular project, technological features of capturing industrial enterprises, mining and geological conditions of fields, distance of transportation etc.

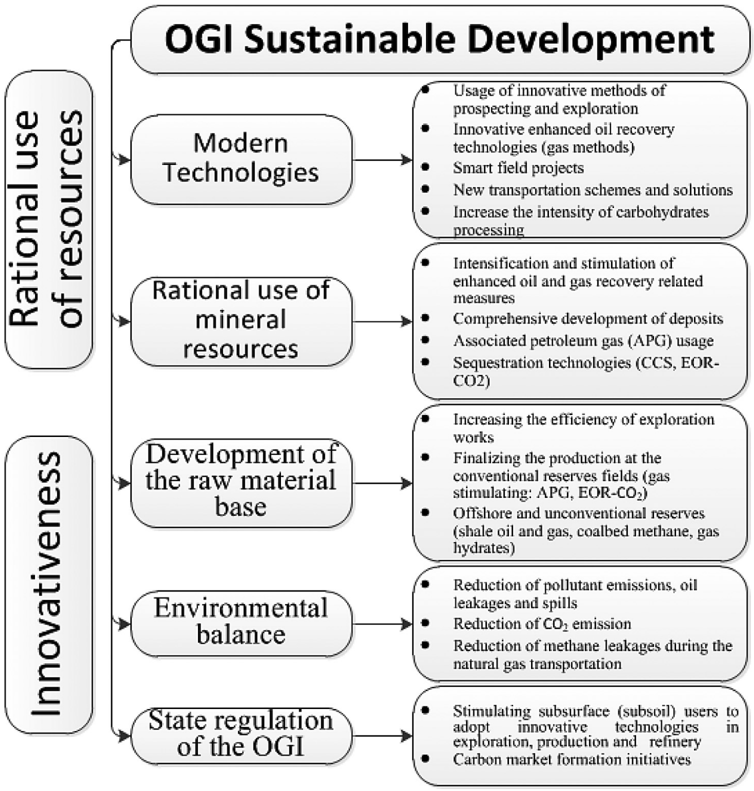

Figure 1. Conceptual view of EOR-CO_2 technologies opportunities within the context of OGI sustainable development

According to the estimates from different experts, the cost of the CCS technologies varies from 1440 to 2136 rubles per ton of CO_2. The cost of capturing is 1087–1392 rubles per ton of CO_2, the transportation cost is 179–266 rubles per ton, and the storage cost in oil and gas reservoirs is about 174–478 rubles per ton. Thus, the cost of storage on the onshore fields accounts for around 12% of the overall that of the CCS technology, whereas the offshore accounts for around 22% [Naucler et al. 2008, Toth et al. 2011].

Efficiency of the EOR-CO_2 technology usage also depends on the price of CO_2 on the carbon market.

It has to be mentioned that the CO_2 sequestration costs will differ at different stages of the technology development. Thus, at the demo stage (currently) projects are minor and focused on drawing attention of all the stakeholders to this technology in order to prove its efficiency and safety. At this stage, the cost of such projects remains rather high, especially at the CO_2 capturing stage.

In the future, when CCS technologies enter the early commercial stage, on account of the economies of scale and trainings, the costs of adoption will decrease by 35%. Later, by reaching of the commercial maturity stage the costs of CCS may decrease by extra 10–12%.

Economic constraints for the domestic oil and gas industry on the EOR-CO_2 technology usage under the possible creation of national carbon market or under the integration with the mechanisms of the European carbon credit market have to be identified. That would allow determining the price range and the critical pricing parameters of the CCS projects.

Injection of CO_2 into the oil reservoirs is a complex process, the precise prognosis of the EOR-CO_2 potential for Russian deposits may be determined by geological and economic modeling and detailed research of the potential reservoir capacity. The economic analysis of the EOR-CO_2 schemes is a research, whose implementation entails additional difficulties related to the necessity of the improvement of technical and technological approaches, including the selection and usage of oil production equipment, taking specific capital and operating costs into account, evaluation of geological and investment risks.

The majority of Russian oil and gas fields (Western Siberia) are located in the areas that are remoted from the main industrial CO_2 emission sources. The old oil and gas production areas, such as Tatarstan and Bashkiria, the North-western region (including Kaliningrad oblast) are the most suitable for the EOR-CO_2 methods usage. It is important to evaluate the geological and technical potential of the EOR-CO_2 technology, the CO_2 storage for the old oil production areas in the first place.

Reasonability of the effective and stimulating state policy for the large-scale CCS projects adoption is conditional on the demo stage and high capital intensity of such technologies, as wells as the uncertainty about the future world carbon market development. Therefore, incentives and the support of OGI companies' strategic initiatives in the resource-saving and environmental areas, one of which is the implementation of CCS projects, are necessary.

The typology of instruments of stimulating the CCS technology promotion has been developed in the paper. It is based on the principles of innovational resource-saving and resource-effective development of economic sectors in general and the OGI in particular (Figure 2) [European Commission 2013, Global CCS Institute 2009, Greenpeace 2008, IPCC – Renewable energy sources and climate change mitigation 2012, Rubin et al. 2005, Shapovalov et al. 2012, Van Egmond et al. 2012]. Besides organizational, administrative and economic incentives, it is suggested to pay great attention to the social aspects. Since the CCS technologies are innovative by themselves and are linked to the rational use of natural resources, it is instrumental to develop public awareness and image of socially responsible companies [Cherepovitsyn et al. 2011].

Furthermore, long-term storage of carbon dioxide in the geological reservoirs implies forming the mechanisms of monitoring the underground environment and evaluating the risks of potential release of CO_2 to the surface. It is necessary to understand who will be monitoring and controlling the CO_2 diffusion process in the underground formations over time.

There is also an interesting and important strategic problem of working out the mechanisms of interaction between the state, oil and gas companies, research institutes and environmental organizations to promote the CCS technologies, and EOR-CO_2 in particular.

CONCLUSIONS

Thus, the CCS technology is a promising mechanism of carbon dioxide concentration reduction and one of the methods of enhancing oil recovery (EOR-CO_2). On the basis of the conducted research a number of scientific research and practical areas of the CCS technology development are worth mentioning:

- Knowledge generation with purpose of formation of scientific problems and priorities of the CCS technology usage in Russian Federation,
- Formation of methodological approaches to evaluation and revaluation of geological reservoirs suitable for greenhouse gas conservation,

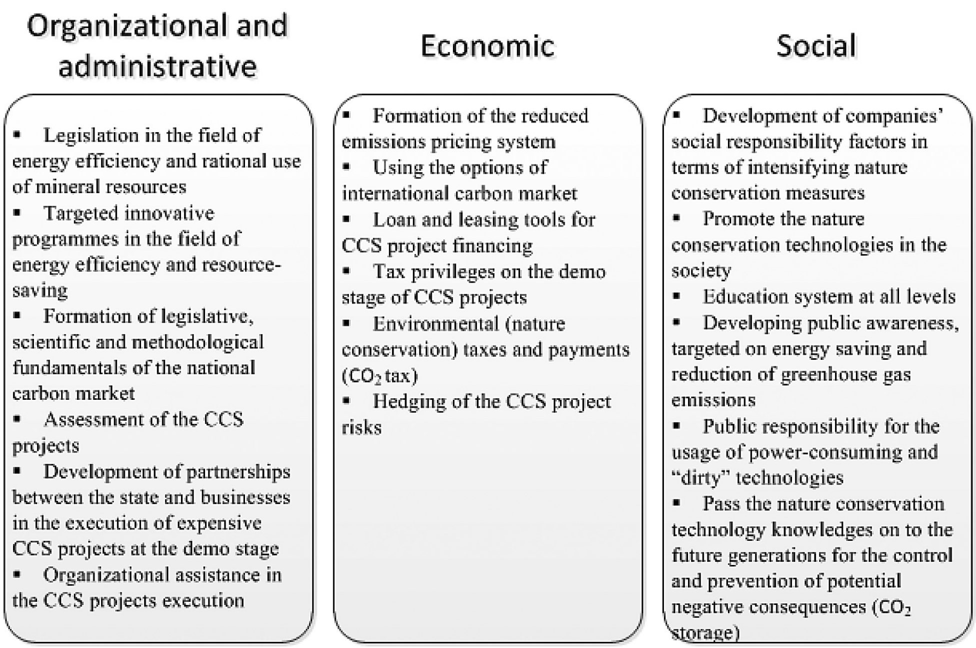

Figure 2. Incentives of the CCS projects execution

- Building a system of geological and environmental maps, showing the places and potential of CO_2 storage in geological structures, emission sources and the required infrastructure,
- Formation of conceptual framework of the national carbon market,
- Modeling marginal operating and capital costs of the CCS technology adoption, depending on the prognoses of carbon market development and technical advancement,
- Developing the mechanisms of interaction between the state and businesses in the CCS projects implementation,
- Developing the technique of geological, environmental and investment risks evaluation of the CCS projects.

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