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Energy Procedia 37 (2013) 7741 – 7746

Energy Procedia

GHGT-11

Interaction of CO_2 with subsurface resources

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Abstract

Planning by policy makers, and industry and regulatory agencies for underground CO_2 storage requires an assessment of the interaction of CO_2 storage operations with other subsurface resources, so that the economics, impacts and risks associated with the geological storage of CO_2 can be properly assessed. We provide guidance on the potentially beneficial and detrimental interactions of CO_2 storage operations with the production of oil, gas, coal, groundwater and saline aquifer minerals, the use of geothermal energy and the competing uses of pore space for the disposal of waste, produced water, and natural gas storage.

Keywords: Resource interaction; carbon dioxide; oil; natural gas; groundwater; geothermal; pressure fronts; interference; enhanced recovery; energy resources; mineral resources

1. Introduction

Planning by policy makers, industry and regulatory agencies for underground carbon storage requires an assessment of the interaction of CO_2 storage operations with other subsurface resources, so that the economics, impacts and risks associated with the geological storage of CO_2 can be properly assessed. The analysis of likely interactions may help to balance potential conflict of resource use prior to allocation of

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1876-6102
doi:10.1016/j.egypro.2013.06.720

tenure licences and permitting by regulatory agencies, and reduces the risk of resource sterilization, conflicts and later litigation. Our study [1], funded by the IEA Greenhouse Gas R&D Programme (IEAGHG), provides guidance on potential interactions of CO_2 storage operations with the production of oil, gas, coal, groundwater and saline aquifer minerals, the use of geothermal energy and the competing use of pore space for the disposal of produced water or natural gas storage. It reviews the necessary technical basis for developers of policy to make informed decisions on the interaction of CO_2 storage operations with the production and/or use of other subsurface resources. We provide case study examples and a checklist to assist this process. Resource uses tend to occur over characteristic depth ranges (Figure 1), and in some cases overlapping uses may be feasible in a given geographic area at different stratigraphic levels, particularly if they are separated by intervening rocks that seal and isolate each use.

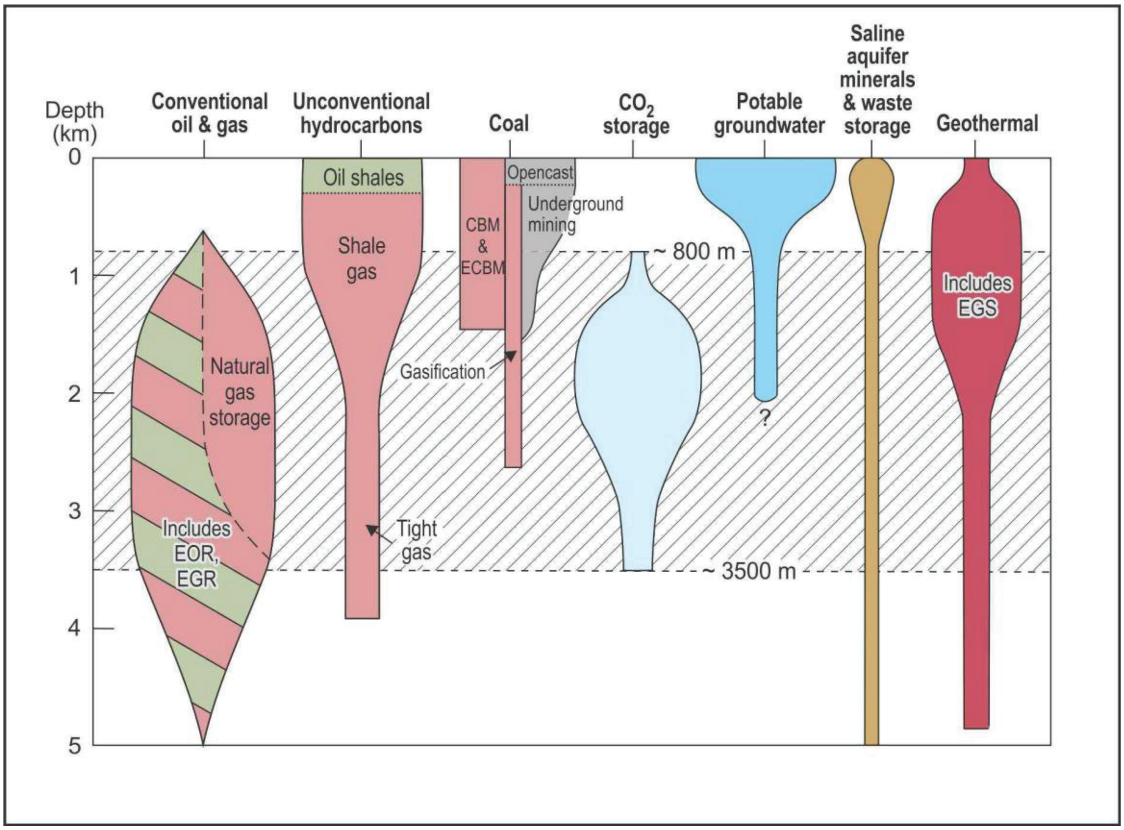

Figure 1. Schematic diagram of the typical depth ranges over which sub-surface resources occur, including the use of pore space for CO_2 storage. Variations in the widths of the polygons are conceptually in proportion to the most common depths for the activities. Note that while some uses overlap in their main depth ranges, several activities can occur at different levels at the same location provided adequate seal rocks are present between them, and that there are no detrimental effects from pressure fronts. EOR: Enhanced oil recovery; EGR: Enhanced gas recovery; CBM: Coal bed methane; ECBM: Enhanced coal bed methane; EGS: Enhanced geothermal systems.

2. Beneficial interactions

Interaction between CO_2 storage operations and the use of other subsurface resources can be beneficial or undesirable. Beneficial interactions from operations that are not aimed purely at storage include the use of CO_2 for enhanced oil or gas recovery (EOR, EGR), as a thermal transfer medium in geothermal fields, to repressurise groundwater aquifers or in the production of deep water from pressure reduction wells during CO_2 injection. These beneficial interactions may help to offset the cost of associated CO_2 storage, Water produced from pressure reduction wells might be potable or potentially treatable economically and thus increase groundwater production, or contain valuable salts such as lithium or iodine [2]. The use of CO_2 as a thermal transfer medium in geothermal fields has been proposed [3] and may be more favourable than the current use of water, though this is yet to be tested at pilot and full scale.

3. Detrimental interactions

Alternatively, interaction might be undesirable, such as if injected CO_2 were to contaminate or detrimentally affect the production of oil or natural gas from a hydrocarbon field, prevent the exploitation by underground gasification of deeply-buried coal, or mix with potable groundwater [4] or saline aquifer mineral reserves. Solving one problem might lead to new problems in other areas. For example, disposal of saline water produced from pressure-reduction wells at shallow depths has the potential to affect other subsurface resources such as groundwater by the creation of new pressure fronts or mixing.

4. Timing of interactions

In some cases, previous resource use might affect planned CO_2 storage. Old petroleum wells (for example in depleted fields) are likely to have been completed using steel and cement that might be corroded by stored CO_2 dissolved in pore water and create a containment (leakage) risk, thus increasing the cost of CO_2 storage by having to mitigate this risk. Some earlier resource uses can preclude others. For example, hydraulic fracturing as part of exploration for coal seam gas, shale gas or oil production could potentially damage a thin seal caprock and reduce the site's suitability for future CO_2 storage, or CO_2 storage in unminable coal seams could preclude later underground coal gasification.

5. Key factors

Comprehensive reviews of proposals for underground CO_2 storage should consider both immediate and potential long term interactions. Consideration of many factors is desirable when assessing CO_2 storage sites and allocating licences and permitting as this will help ensure efficient use of natural resources, anticipate any beneficial or detrimental interactions and help avoid litigation between companies or between companies and regulatory agencies, thus protecting the public interest. A range of key factors should be assessed prior to licensing:

- The timing of potential resource interactions is relevant (e.g., during injection, post-injection company monitoring, or after permanent hand-over to government agencies) as this might determine who will be responsible for any detrimental interactions.

- Risks should be assessed, at even the basic level of listing the uncertainties surrounding the existence and main parameters of each potential resource. Risk analysis can become more detailed and quantitative in phases, as more data are obtained and as investment decisions progress.

- Storage capacity limits should be assessed, so that containment by the seal and trap geometry during injection or after plume migration can be assured to a reasonable level of certainty. Any leakage increases the chances of interaction with other resources. Ideally, capacity limits should be determined through dynamic reservoir modeling.

- Improved recovery of resources, such as enhanced oil, gas or geothermal heat recovery. Enhanced recovery enables more efficient use of existing, known resources as well as, potentially, CO_2 storage.

- The maximum rate at which CO_2 can be injected into the reservoir must be estimated as this affects the economic viability of any storage project, the risk of loss of seal integrity during injection, and hence leakage into other resources, and the transmission of pressure fronts which might affect other resources. Seal integrity is essential to avoiding unexpected interactions with other subsurface resources, as well as to retaining carbon credits, gaining a social licence to store CO_2, and preserving the reputation of the nascent CCS industry.

- Pressure fronts can cause injection of CO_2 or of produced water from pressure relief wells to affect other subsurface resources such as hydrocarbons and groundwater. Modeling indicates the main effects will be local but that smaller effects can occur many kilometres away from an injection site [4].

- The composition of the gas being injected might be important, as any toxic compounds from flue gas contaminants (e.g., SO_x, NO_x, H_2S) could affect other subsurface resources adversely if they were to mix.

- Mobilization of minerals and other substances by pore water acidified by injected CO_2 could mean any leakage might not comprise just CO_2 but also dissolved minerals that could affect, say, groundwater quality.

- Monitoring and verification methods will vary depending on the storage site selected, particularly between onshore and offshore sites. Techniques for onshore sites have been developed and tested but not so much for offshore sites. Monitoring plume movements and pressure changes are an essential part of detecting potential resource interactions and assuring regulatory agencies and the public about the safety and neutral effect on other resources of CCS operations.

- The potential for regulatory conflict or overlap should be assessed, to lessen the chance of litigation, for example, by operators against regulating agencies or between operators, and to enable clearly defined pathways for public submissions on CCS projects.

- Future use of resources should be considered, such as the potential for CO_2 storage to sterilize deep coal reserves, or whether the development of a virgin natural gas field with the potential for CO_2 storage as its reserves become depleted should have wells completed using CO_2-resistant materials.

6. Conclusions

The interaction of CO_2 storage with other resource uses can be positive or negative and depends on the geology, existing resources, economic potentials and the regulatory environment. Storage operations may be feasible adjacent to other resource uses, or at different levels at the same locality, particularly if there is no detrimental pressure connection between sites. On the other hand, if pressures associated with CO_2

storage are not confined then resource uses many kilometres away from a storage site might be affected (beneficially or detrimentally). Resource use interactions can occur contemporaneously or sequentially. In particular, existing permits might preclude CO_2 storage, and CO_2 storage might preclude future use of other resources.

Regulatory agencies should consider the following stages when evaluating resource development in relation to CO_2 storage:

- Identification of all the resources within the basin or region of interest, including "vacant" pore space, mapping of their distribution and assessment of their quality. It is important to do this, even using subjective criteria or estimates if there are few hard data. This will allow an assessment of the resources likely to be affected and the range of likely interactions. The Gippsland Basin study by the Victoria State Government is a good example of this type of assessment [5].
- Establishment of the priority of use or production between the various resources and CO_2 storage.
- Assessment of the proposed CO_2 storage project, its site characterization, monitoring and verification plans, contingency and mitigation planning (e.g., how to mitigate and/or remediate possible leakage, fault reactivation, loss of well integrity). The Gorgon Project has addressed these issues [6,7,8], and general approaches to mitigation have been formulated (e.g., [4]).
- Review of the injection plans and the likelihood that they will be achievable, and assessment whether they might lead to cases of resource conflict (by seal rupture, pressure-front propagation or CO_2 plume migration into regions other than predicted or licensed to the storage operation).
- Review of the abandonment plans and long term monitoring and verification planning, and liability transfer arrangements.

Delays in establishing CO_2 storage regulations could not only slow CO_2 storage project development, they could lead to future, detrimental resource interactions, delay in CCS deployment and costly litigation. Nevertheless, time is needed to ensure regulations are clear and take into account potential resource prioritization and interaction, as these issues are essential to the planning, costing, safety and surety of CO_2 storage projects. Assessments of potential resource uses in a region, and of possible usage interactions, should enable effective prioritizing of opportunities in a region and efficient allocation and use of known or anticipated resources. This may produce follow-on effects for estimates of CO_2 storage capacity and injection scenarios.

Acknowledgements

The authors thank Matt Gerstenberger and Mark Lawrence as referees of this paper, as well as Malcolm Arnot and Karen Higgs (GNS), and anonymous reviewers of the report on which this paper is based. The project was prepared under contract to CO2CRC Technologies Pty Ltd and funded by IEAGHG under IEA/CON/11/198.

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