

KEM Research Question (max. 4 pages + annex)

TITLE *Geomechanical and geochemical factors determining fault criticality during pressure (non) cycling of underground CO₂, H₂, N₂ storage.*

Objective

The objective of the proposed study is to re-assess the causes of seismicity, specific risk factors including chemical processes in the reservoir, and safe operational bandwidths for reservoir storage conditions during pressure (non) cycling of underground storage of CO₂, H₂, and N₂ in depleted gas fields. To which extent does geochemical dissolution effects cause mechanical weakening of the reservoir or faults in the caprock? How is the formation pressure affected differently for the different types of storage fluid (fluid viscosity, density, compressibility)? This study is a follow-up of the KEM-01 study, where storage of natural gas was studied, and it focuses on the specific issues related to the storage of other gases. Storage of CO₂, H₂, N₂ in depleted gas fields may be a necessary measure in the energy transition. CO₂ storage is currently being pursued offshore (Porthos) in the Netherlands. Research on hydrogen storage is currently focused on storage in salt caverns (UHS) but also storage in abandoned gas fields will be considered in the future. Nitrogen is currently being stored in a salt cavern near Heiligerlee. The nitrogen is being used to convert high-calorific gas to low-calorific gas to be used in the Dutch households for heating and cooking. During the cyclic or more permanent storage of CO₂, H₂, and N₂, seismicity could occur depending on the geological and operational parameters and chemical reactions in the reservoir. In this study, the factors controlling the reactivation of faults during storage of gasses is assessed for insights into the risks of energy storage. Buoyance effects or mixing effects with residual gases are not specifically taken into account for this study. This study will provide first insights in the difference between (cyclic) storage of other than natural gases on the probability of seismicity.

State of the art, background

Natural gas in the Netherlands is stored in underground gas storage (UGS) facilities to manage gas demand and supply on a seasonal and daily basis. This study focusses on the geomechanical and geochemical factors that may cause fault slippage and seismicity on faults in and around the reservoirs that are used for storage. Gas storage in salt caverns is not part of this project. Currently there are four such UGS facilities operational in the Netherlands: Bergermeer, PGI Alkmaar, Norg and Grijpskerk. Three of these reservoirs have experienced multiple seismic events during gas extraction. The reservoirs were subject to geomechanical studies before receiving storage licenses and validated storage plans. These studies (see references) examined the geomechanical conditions of fault reactivation causing the observed seismicity during the depletion and re-injection phases, based on which monitoring and risk management programs were installed. The KEM-01 project has looked at the safe operational bandwidth for storage of natural gas. This project will focus on other types of gasses (CO₂, H₂, N₂) and the difference with respect to the KEM-01 study.

Research Question

Which main factors control the reactivation of faults and seismicity under permanent or cyclic storage conditions of CO₂, H₂, N₂?

- **Provide an overview of induced events related to CO₂, N₂, H₂ storage facilities globally, focussing on both the injection and production phases (in case of cyclic storage).**
- **Relate the induced events to possible physical mechanisms that explain their occurrence during both phases. Are the physical mechanisms similar to the mechanisms for natural gas storage?**
- **To which extent do geochemical dissolution effects cause mechanical weakening of the reservoir or faults in the caprock?**
- **To which extent is the formation pressure affected differently for the different types of storage fluid (affected by fluid viscosity, density, compressibility)?**
- **Relate to the existing conclusions of KEM-01. Which conclusions still stand for gasses other than natural gas (CO₂, H₂, N₂)? Which conclusions change?**
- **Identify, if possible, generic guidelines for a safe operational bandwidth (e.g. pressure range/rates) of CO₂ (permanent and cyclic), N₂ (cyclic), H₂ (cyclic) storages.**

Deliverables expected

- a) Inventory of the factors causing unforeseen seismicity from global CO₂, H₂, N₂ storage operations (i.e., lessons learned elsewhere).
- b) Description of the changes with respect to the KEM-01 study, underpinned with geomechanical or geochemical models where needed.
- c) A report containing conceptual model results, interpretations, and underpinning deliverable a & b.
- d) A recommendation toward a recipe (formulation of a ranking system) for determining safe operational bandwidth, regarding seismicity, including the main factors and their weight for the cyclic storage of H₂, and the storage of CO₂ and N₂.

Timeline

Four months, with the following milestones:

- Project kick-off meeting (M1)
- Project process meeting (M2)
- Report on deliverables a, b, c and d (M4)
- Final project presentation (M4)

Expected use

The results will be used for:

1. Insight in different risks for other than natural gas storages. This insight can be used by storage operators, the competent authority and supervisory bodies.
2. Communication to the public. The deliverables/reports will be open-access; publication of project results is encouraged.

Expertise and tools preferred for the team

Similar to KEM-01 expertise, extended with geochemical expertise.

Quality assurance, Organisational and communication requirements

A representative of the KEM panel as well as a member of EZK will be involved in the progress meetings from the onset of the project ensuring continuity and reporting to the KEM panel. The project will be presented at the bi-annual KEM meeting.

Remarks and Suggestions

References

1. Safe operational bandwidth of gas storage reservoirs reports, Teatini et al., 2019 (KEM-01)
2. Embry, J.M., Guises, M, 2015, Dynamic geomechanical modeling of the Bergermeer Underground Gas Storage - the effect of the 150 bar scenario on fault-slip behaviour, Baker Hughes for TAQA Energy.
3. Muntendam, A.G., Wassing, B.B.T., Geel, C., Louh, M. and van Thienen-Visser, K. 2008, TAQA Bergermeer seismicity, TNO.
4. CATO and CATO-2 program ([CO2 - CATO - CATO Programme](#))
5. Ondergrondse Gasopslag Norg seismisch risicobeheersysteem – NAM report EP201703226547
6. Unraveling the causes of the seismicity induced by underground gas storage at Castor, Spain, Geophys. Res. Lett. 48, Doi 10.1029/2020GL092038
7. Heinemann et al. (2021), Enabling large-scale hydrogen storage in porous media – the scientific challenges, Energy Environ. Sci. 2021, 14, 853, <https://pubs.rsc.org/en/content/articlepdf/2021/ee/d0ee03536j>