§KEM Research Question (max. 4 pages + annex)

TITLE ***Risk assessment for Underground Hydrogen Storage (UHS) in Salt Caverns and Interaction with other Underground Storage Locations in The Netherlands***

Objective

Hydrogen is expected to become essential in the future Dutch energy system as a clean energy carrier by assisting the integration of renewable energies and decarbonizing specific applications in hard to abate sectors, such as industry, mobility and the residential sector. For large- scale energy storage in the order of TWh, underground hydrogen storage (UHS) in salt caverns and porous reservoirs will be needed. Up to now there are no UHS sites in The Netherlands, but the first tests with cyclic hydrogen injection in a salt cavern are being executed. TNO has recently made an inventory of risks associated with UHS and compared the risks with those of underground storage of natural gas. Possible risks of UHS that can impact the safety of the surrounding area are among others leakage, blow-out, geochemical and microbial processes (that lead to e.g. formation of H_2S), and ground motion (subsidence). Further research is needed to a) assess the long-term durability of rocks and well materials when subjected to hydrogen under an alternating pressure regime that causes mechanical and thermal stresses, and to b) understand if this behaviour can interfere with nearby underground storage and/or production locations, such as producing gas fields, conglomerates of large numbers of salt caverns for hydrogen storage, salt caverns for compressed air energy storage (CAES) and gas fields used for CO_2 storage. It is thus crucial to assess the specific risks associated with UHS in salt caverns and to develop strategies for how to manage and mitigate them, as well as better understand interference with other means of underground storage and/or production sites in the Netherlands that can be expected. The analysis should take into account the typical situational characteristics found in the Netherlands, such as type of formation, depth, pressure, temperature, rock and fluid compositions, etc. Additionally specific research questions should be answered focused on the use of underground hydrogen storage in salt caverns as part of the Dutch energy transition.

State of the art, background

There is extensive and ongoing research into hydrogen risks, primarily focused on the transport via pipelines [1-2], reusing natural gas pipelines for hydrogen transport [3], blending of hydrogen in natural gas [4], distribution of hydrogen [5], hydrogen in confined spaces, such as tunnels [6], production facilities, such as electrolysers [7] and maritime applications [8]. For UHS, there are several recent studies that provide a good insight into the techno-economic possibilities and challenges of UHS [9-12]. A recent study looking into the energy storage needs of The Netherlands towards 2050 has established that large scale hydrogen storage will require large amounts of underground space. In 2030 the storage demand will be relatively small and could be accommodated in 1-4 salt caverns. But between 2030 and 2050 this storage need will increase drastically and could require up to 60 salt caverns and/or storage in several gas fields. For its application and scale-up, and the selection of technical suitable geological formations as a UHS location, basic safety criteria regarding the geological conditions should be established for regulation, monitoring and supervision. Knowledge of underground geochemical and microbial processes of hydrogen and the geological conditions of the caverns, including geomechanical behaviour during storage and pressure and temperature is needed to assess the risks and establish their relation to safety. The adequate choice of exploitation parameters, taking into account characteristics of the specific salt formations in The Netherlands with high potential for underground storage, its surroundings and possible interaction, as well as individual characteristics of the caverns and the choice of injection and withdrawal pressures are of key importance [11] Current knowledge about the likelihood of occurrence of ground motion (subsidence and induced seismicity), possible effects and mitigation strategies for construction, operation and abandonment of a large number of salt caverns for UHS is limited.

Research Question

What is the likelihood and effect of risks associated to underground hydrogen storage in conglomerates of salt caverns developed specifically for hydrogen storage in the Netherlands and what is the recommended strategy for risk management and mitigation?
This part of the research aims at quantifying and ranking the risks based on different failure scenarios, taking into account the likelihood of occurrence and the effects, and identifying measures to mitigate those risks. To have a better understanding of the risks, these should be put into perspective in comparison to natural gas storage in salt caverns, which is a well-known and established form of underground energy storage.
Specific research questions:

- What are the incremental effects of having conglomerates of salt caverns for UHS in the Northern and North-eastern Netherlands on the current levels of induced seismicity and subsidence, and how do they affect the stability of the existing and new to construct salt cavern field(s)? Here considerations must be taken into account on how the brine can be processed in a safe way in case that there will be no market for such large amounts of salt.
- What are the interactions expected between the stored hydrogen with the salt cavern itself and with the well infrastructure? Here considerations must be taken into account with possible permeation, effects van temperature and pressure differences in the cyclic operation of the storage location and the long term effects on the installations.
- What are the possible interactions with other nearby underground storage and/or production locations, such as producing gas fields, other salt caverns for hydrogen storage, salt caverns for compressed air energy storage (CAES) and gas fields used for CO_2 storage?
- What are recommendations for risk management and mitigation? (regarding how to design new caverns, distance between caverns, surface installation considerations, interaction with other possible underground storage techniques such as CAES and CO_2-storage, brine processing, dimensions and shape of the storage caverns, etc.)

Deliverables expected

This research will deliver a report answering the research questions stated above:

- A literature study on hazard and risks for UHS in conglomerates of salt caverns in the Northern and North-eastern Netherlands (focusing on the Zechstein salt layer). This should contain a literature and accident database review of all occurred risks in the construction and operation of conglomerates of salt caverns for gas storage, identifying the causes and consequences and an analysis of the likelihood of occurrence. This review should include insights from other projects around the world (for example the salt caverns in Rudersdorf and Etzel in Germany).
- A geomechanical study on the stability of the cavern field, seismicity and induced seismicity assuming a conglomerate of salt caverns are used for storage of hydrogen and other underground storages (CAES, natural gas, CO_2) or salt cavern production.
- A quantitative, where possible, qualitative, where not possible, risk analysis, in terms of health, safety and environment, related to UHS in conglomerates of salt caverns in the Zechstein salt of the Northern Netherlands will be delivered.
- A recommended strategy for risk management and mitigation of conglomerates of UHS in salt caverns onshore, including criteria for spatial planning and locations of salt caverns.
- Recommendations for further study in order to better asses the risks of UHS storage in conglomerates of salt caverns

Timeline

The research will be split in two phases, the first phase is the literature review which should shape the rest of the project. The first phase will take at maximum 3 months, the second phase will take 9 months, making the total project duration 12 months. After 3 months a go/no go decision will be made based on the results so far. Monthly technical progress report meetings will be planned with at least the technical team and a member of the KEM scientific panel. Additionally, KEM has two annual meetings where progress on the research will be presented.

Expected use

This project will contribute to the development of new knowledge on risk assessment for possible underground (conglomerate) hydrogen storage caverns in the Netherlands. This information, together with other studies being developed, will be used by the Dutch government to make a strategy on energy storage for the future energy system and for risk policy making for underground hydrogen storage. It is expected that this project will participate in the UHS research task under development at the IEA Hydrogen Technology Collaboration Programme (HTCP), which is at the Project Definition Phase (PDP) and aims to start its activities beginning of 2022. The Netherlands has started this initiative and has assigned TNO as the coordinating agent. This project will be embedded in the UHs research task, making use of the network to access international data. The project will serve as national funding contribution of the Netherlands to the research activities within the UHS HTCP task. The deliverables/reports of this research will be open-access and publication of project results is encouraged.

Expertise and tools preferred for the team

- Knowledge about the Dutch subsurface and underground storage in general.
- Knowledge on salt behaviour, hydrogen storage, induced seismicity, subsidence and cavern stability
- Experience with geomechanic modelling of (multi) cavern stability and integrity as well as wellbore stability/integrity
- Experience with risk analysis
- Project management
- High proficiency in communicating (writing/speaking) in English

Quality assurance, Organisational and communication requirements

A representative of the KEM panel will be involved in the monthly 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 meetings. The results of the project should be reviewed by independent researchers, organized by the project team.

Remarks and Suggestions

References

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