Peer Review Report

Review Report on Role of subsurface geo-energy pilot and demonstration sites in delivering net zero

Review, Earth Sci. Syst. Soc.

Reviewer: Niels Balling
Submitted on: 09 Oct 2021
Article DOI: 10.3389/esss.2022.10045

EVALUATION

Q 1 Please summarize the main theme of the review.

The title of this paper clearly reflects the main theme:
'Role of subsurface geo-energy pilot and demonstration sites in delivering net zero'
In addition to subsurface net-zero technologies studied at laboratory scale and with models, there is a need for testing at greater-than laboratory scale and in representative conditions.

A Geological Society conference on the 'Role of subsurface research labs in delivering net zero' in February 2021 considered the value of test sites and gaps in their capability. This review summarises some of the findings from this conference.

Q 2 Please highlight the limitations and strengths.

Limitations
Main geoscience technologies with the potential of significantly reducing CO_2 emission, (mentioned in Abstract), are not sufficiently introduced in the paper itself. Section 'Geoscience and net zero' mostly continues on 'introductory aspects' of climate change and the need for decarbonisation of energy supply systems, rather than specific geoscience technologies in question. There is a general lack of references regarding those geoscience technologies and their challenges.

I miss a somewhat broader view on the many test, pilot and demonstration systems existing globally and find lack of balance against generally well-known statements and reports on the need for reduction in CO_2 emission.

To me, the various possibilities, currently in focus, of subsurface storage systems related to 'Power to Gas' systems need more emphasis.

Both shallow and deep geothermal energy, e.g. from sedimentary basins, and likely combined with heat storage (ATES), seems regionally and globally more important for the heating sector than 'mine water geothermal' (- perhaps important in the UK and in mining areas).

There is a need for a more clear structure with sections and subsections. Apparently, only one level indicated.

Strength
Several including:
Clear focus on the need for test, pilot and demonstration facilities, to bridge between laboratory testing and computer modelling and full-scale operation.

Very good section on 'key geoscience questions for test sites'.

Particular mention of challenges and need for 'test facilities to aid the design of low cost, high resolution, unobtrusive seismic and other monitoring for a seismically noisy urban environment with a sensitive human population'.

Emphasis on focus on the risk of induced seismicity and, in general that 'the success of these emergent underground technologies relies heavily on public acceptance and support...'

Examples included of test sites that have progressed technology development (Otway International Test Centre (Australia, CCS) and the Aspo Hard Rock Laboratory (Sweden, geological radioactive waste disposal).

Generally well written with very good and informative illustrations.

Q 3 Does the review include a balanced, comprehensive and critical view of the research area?

As indicated above, it has several strong elements, but to me, in particular in introductory parts, an unbalanced treatment with much emphasis on important, but generally well-known aspects of climate change and the need for decarbonisation of energy supply systems, rather than emphasis on the main geoscience technologies in question and, here, with a general lack of references.

I addition, I would like the introduction to include a somewhat broader view, mentioning various aspects of the many test, pilot and demonstration systems existing globally, including limitations and challenges as well as recent developments and trends in test sites for 'green and sustainable' energy systems.

More emphasis needed on storage specifically related to 'Power to Gas' systems, likely to be very common in near future, as well as heat from 'shallow and deep geothermal' in sedimentary environments

Q 4 Check List

Is the English language of sufficient quality?
Yes.

Is the quality of the figures and/or tables satisfactory?
Yes.

Does this manuscript refer predominantly to published research? (unpublished or original research is non-standard for a review article, and should be properly contextualised by the author)
Yes.

Does the manuscript cover the topic in an objective and analytical manner
Yes.

Does the reference list cover the relevant literature adequately and in an unbiased manner?
No.

Does the manuscript include recent developments?
No answer given.

Does the review add new insights to the scholarly literature with respect to previously published reviews?
Yes.

Q 5 Please provide your detailed review report to the editor and authors (including any comments on the Q4 Check List):

By its focus on the need for 'green and sustainable' geo-energy test, pilot and demonstration facilities, to bridge between laboratory testing and computer modelling and full-scale operation, this review is timely and cover a broad range of important issues. However, here, my emphasis is on suggestions for improvements.

It is important to introduce the topic of climate change and the need for decarbonisation of energy supply systems. However, this introduction with emphasis on general aspects starting in section 'Need for net zero' (p. 43) continues, and covers almost all of the following section 'Geoscience and net zero' (pp. 55 - 125) expected to focus on geoscience and subsurface technology and the main questions of this review. Not until the next section, 'Importance of subsurface geo-energy test sites', are such systems briefly listed:
'To achieve emissions reductions, several existing and new geo-energy technologies (Stephenson et al. 2019) will therefore be accelerated and developed including abating emissions from fossil fuel power generation including CCS, BECCS, and DACCS, energy storage for grid stabilisation in a renewable power system (ATES, CAES), and decarbonising
heat through district heat networks (geothermal heat, thermal storage)'. Abbreviations are largely introduced only in the Abstract, where some more geo-systems are mentioned as well. Introduction to, and emphasis on those geo-energy systems need be earlier - in section 'Geoscience and net zero' and with appropriate references.

In introduction, and in general, I suggest more emphasis on subsurface storage systems related to 'Power to Gas' systems. I may recommend a paper by Ma et al. (2018) with a detailed up-to-date treatment of these systems and with highly valuable references. With vast, and uneven supply of electricity, the importance of these systems is likely to increase dramatically in the very near future.

I suggest a somewhat broader introduction and review regarding the many test, pilot and demonstration systems today existing globally, including many in Germany (cf. Ma et al. Table 2 and 3). This, even if not typically designed to follow criteria as outlined in this review, which may be an issue.

Furthermore, the question arise, if there is a general trend in recent subsurface test systems developments with respect to the various sustainable geo-energy systems, as well as in testing methodology? Which systems seems to be the more important for a future significant contribution to the global reduction in CO_2 emission?

Both shallow and deep geothermal energy, in particular from sedimentary reservoirs, perhaps combined with heat storage (ATES, e.g. Major et al. 2018), has the potential, regionally and globally, to become a large component for the heating sector. Likely, significantly more important than 'mine water geothermal', specifically emphasised in this review (- perhaps important in the UK and in general in mining areas). Vast amounts of subsurface heat resources are available. However, challenges may arise with injectivity, when reinjecting the cooled water. Two of the three geothermal heating plants in Denmark are currently out of function due to injectivity problems (Mathiesen et al. 2020). Such issues, also faced in geothermal plants elsewhere, requires testing and demonstration.

In places, further explanations in main text of information illustrated by table and figures, may help the reader.

References

Ma, J., Li, Q., Kuhn, M. and Nakaten, N., 2018. Power-to-gas based subsurface energy storage: A review. Renewable and Sustainable Energy Reviews, 97, 478-496.

Major, M., Poulsen, S.E. and Balling, N., 2018. A numerical investigation of combined heat storage and extraction in deep geothermal reservoirs. Geothermal Energy, 6:1, doi.org/10.1186/s40517-018-0089-0.

Mathiesen et al., 2020. Geothermal energy use, country update for Denmark. Proceedings World Geothermal Congress, 2020, Reykjavik, Iceland, 14 pp.

QUALITY ASSESSMENT

Q 6	Quality of generalization and summary	3/5
Q 7	Significance to the field	4/5

Q 8 Interest to a general audience ■■■■□

Q 9 Quality of the writing ■■■■□

REVISION LEVEL

Q 10 What is the level of revision required based on your comments:

Moderate revisions.