Peer Review Report

Review Report on Evaluating the Economic Potential for Geological Hydrogen Storage in Australia

Original Research, Earth Sci. Syst. Soc.

Reviewer: Alex Bump
Submitted on: 18 Apr 2023
Article DOI: 10.3389/esss.2023.10074

EVALUATION

Q 1 **Please summarize the main findings of the study.**

This paper looks at the potential for geological hydrogen storage in Australia, using a combination of geologic availability and economic considerations to create a map that shows potential for hydrogen hubs. The result is the identification of "high potential" regions for development of future hydrogen hubs.

Q 2 **Please highlight the limitations and strengths.**

Strengths: This paper addresses a timely question that should be of interest to a range of investors, regulators and policy makers, in Australia and potentially beyond. It is well written and employs purpose-built software for the analysis.

Limitations:
1) It doesn't describe the storage needs for a hydrogen hub, nor does it describe what makes a good storage site, which makes it hard to evaluate the authors' judgment of 'good' sites. How much capacity is needed? Are there temperature or pressure constraints? Filling/emptying rate requirements? The section on depleted fields mentions contamination, which is interesting. Are there other constraints?
2) It differentiates potential salt storage sites based only on the depositional thickness of the salt. Similarly, it treats all depleted fields as similar. Neither of these implicit assumptions is true and I suspect it could make a significant difference to the results.

With regard to salt, halite is a good start but to be amenable to solution mining, it may need to be all halite, without interbedded anhydrite, gypsum or shale. If salt is bedded, the thickness requirements may be much less than if it is not. Please check and clarify.

As for depleted fields, there is resource depletion and pressure depletion. Resource-depleted is an economic determination that will vary between fields, leaving differing residual gas saturation and therefore differing potential for contamination (or at least differing degrees of contamination). Pressure depletion may occur as well, which would be a serious asset for gas storage (more void space, less pressure required and also less aquifer support, so potentially higher recovery/less loss). Again however, there are differing degrees of pressure depletion. Numbers would be helpful. Last, the porosity, permeability and capacity of depleted reservoirs all vary by at least an order of magnitude. These would have direct impact on filling/emptying rate and storage capacity. Please add these to the analysis or say why they are irrelevant.

Q 3 **Please comment on the methods, results and data interpretation. If there are any objective errors, or if the conclusions are not supported, you should detail your concerns.**

The inputs for the model are well described but the modelling methods are only referenced in a separate paper. I agree with the authors' decision not to recreate that paper here but it would help the reader if they provided a brief synopsis and/or a flow chart to describe the modeling process.

Results are given as a series of maps. They are beautiful and intriguing but would benefit from additional description. What produces the hard edges? What produces the gradational transitions and the dendritic

patterns? Are they significiant? Adding description to the text could address these. Without it and with the limitations noted above, it's hard to assess the credibility of the results.

Q 4 Check List

Is the English language of sufficient quality?
Yes.

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

Does the reference list cover the relevant literature adequately and in an unbiased manner?
Yes.

Are the statistical methods valid and correctly applied? (e.g. sample size, choice of test)
Not Applicable.

If relevant, are the methods sufficiently documented to allow replication studies?
No.

Are the data underlying the study available in either the article, supplement, or deposited in a repository? (Sequence/expression data, protein/molecule characterizations, annotations, and taxonomy data are required to be deposited in public repositories prior to publication)
Yes.

Does the study adhere to ethical standards including ethics committee approval and consent procedure?
Yes.

If relevant, have standard biosecurity and institutional safety procedures been adhered to?
Not Applicable.

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

Line 49: please define 'hub'--does it also necessarily include production of H2? Sources of natural gas or water from which to produce H2? Is there a scale component to the definition?

L 57: What does “large-scale” mean? Please define. What is the requirement for storage? How much do you need? For how long? How often does it need to cycle? Could you produce hydrogen on demand? Also not that “large-scale” appears in various places as “large scale” and “largescale.” I think hyphenated is correct but please check and be consistent.

L79: Is H2 the storage medium or the commodity needing storage? It sounds like potentially both but please clarify

L83: What does it mean to “balance the frequency of shipping schedules?” Please explain

L89: What does “small capacity” mean? Even if it’s just an order of magnitude, specifying it will keep readers on the same page

L91: Why does H2 have to be “low volumetric density?” Is the cost of compression uneconomic or is there another constraint?

L95: note that all references to Simon et al have a typo with the accent

L107: Please expand on the rock cavern and aquifer storage. What is their potential? Are they experimental? Sub-commerical? Hypothetical? I'd also suggest moving this up to rule them out and proactively justify the focus on salt and depleted fields.

L114: Point out that salt caverns are man-made (in contrast to the rock caverns mentioned above, I believe). It would be worth a sentence or two explaining the process and the economics of solution mining.

L120: What is significant about these examples? It sort of sounds like "global" means 2 countries, which I know is not true

L124: Among the great advantages of salt is that it's completely impermeable, so your losses and contamination can be absolutely minimal. That would be worth mentioning. Also why are you limited to 12 cycles per year?

L130: why is high-pressure inherent?

L131: "in," not "of"

L137: I should think the cost of solution mining would outweigh exploration. Please address the mining cost.

L138: "Caverns require pipeline networks…" Yes, but so do depleted fields. Are you only considering new caverns?

L140: 1% per year? Salt creep rates vary significantly, depending on composition, temperature and pressure. What's the range? Is this a reliable figure across the board?

L145-156: "…, is still at a low technological maturity and is not yet commercially viable, with only two projects in operation globally (BNEF, 2020a). The feasibility and cost of large-scale hydrogen storage in depleted gas fields, therefore, is yet to be proven." This seems contradictory. Are the 2 projects experimental? Small-scale? How do they leave the tech unproven and non-viable? Please clarify

L158: Do you mean that the reservoirs are well-understood in general or that depleted fields are likely to have reservoir performance data on specific reservoirs of interest?

L161: The key question with infrastructure is not only whether it's in place but whether it can be reused. In my experience, the answer is often no. Factors such as remaining service life, pressure rating, capacity, metallurgy and regulatory requirements for s different fluid often do not favor re-use. I highly recommend taking a close look at this and explaining the logic.

L176: it's not the porous nature of the reservoir but the fact that you're dealing with fluid flow in porous media. Porosity and permeability need to be considered here. The performance of a 1D reservoir will be very different from one with 10mD, but this appears to lump them all together.

L178: How much storage do you need? For a hub? For a fully-scaled H2 industry in Australia? How big si the challenge?

L192-200: Do you consider proximity to gas or water source (feedstock)? Or cost of transporting feedstock?

Table 1: Why the dashed lines in place of values? Please explain

L233-242: What is the impact of storage volume on capex? There seems to be a hidden assumption here. I see that you include monthly and biannual costs but how do you allocate the capex?

L248: "porous nature"—sandstone reservoirs are porous by definition. I think this should be "slower flow" but please clarify

L267: What does “favorable geology” mean? Location of storage is central to this paper so it seems worth elaborating on this. What is it, where does it occur. A map would be useful.

L274: Differences in minimum thickness might depend on whether or not the salt is bedded (which would affect an operators ability to control solution mining).

L276: do you need “halite-bearing” or halite? Halite-bearing might include anhydrite or gypsum, which would be far less amendable to solution mining and might give you very different economics

L312: How do you define “depleted?” It’s usually an economic determination, based on resource recovery rates, which means that the residual gas saturation and pressure (the properties you care about here) are highly variable. Additionally, it may or may not include pressure depletion, which would also be an important control on H2 storage performance.

L335: Adding a modelling flow chart and/or a brief description of how the modelling works would help the reader follow your logic and would support your conclusions

Figure 3: These are intriguing maps--please explain them! What gives rise to the hard edges in B? The dendritic patterns and gradational transitions in A? Adding a couple paragraphs to the text would help greatly.

L362: What does “renewable” mean? Is the plant renewable?

Results and conclusions—given the over-simplification of potential storage sites (e.g., no consideration of depleted field permeability, an apparent assumption that all infrastructure is reusable, etc), I’m not sure I believe them and without description of the modelling process, I can’t follow the authors’ logic well enough to know whether my concerns are well-founded or irrelevant. That is a serious problem that undermines the potential impact of the paper.

QUALITY ASSESSMENT

Q 6	Originality	■■■■□
Q 7	Rigor	■■■□□
Q 8	Significance to the field	■■■■□
Q 9	Interest to a general audience	■■■■□
Q 10	Quality of the writing	■■■■□
Q 11	Overall quality of the study	■■■□□