A Technical – Economic Comparison of Deep Saline Aquifers vs. Depleted Gas Reservoirs Factoring in Risk for CCUS Projects

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Summary

In determining economically optimum CO_2 hub pathways, we need to compare Saline Aquifers (SA's) to Depleted Gas Reservoirs (DGR's). Basin-wide studies often quote that SA's have huge storage capacity vs. DGR's. That is correct, but that ignores critical factors of reservoir continuity and large-scale permeability, and timescale. For the target volumes and rates, we have we are going to need both SA's and DGR's. With DGR's the uncertainty of storage capacity, reservoir continuity and injectivity is clearly lower, giving them a net economic advantage when the cost (and risk) of exploration and appraisal are taken into account.

Background and Theory

SA's have a containment-risk advantage from a cap rock integrity standpoint as the cap rock is intersected by fewer wells, however SA's have riskier continuity and permeability probability profiles while DGR's are generally well mapped and well-understood through production and pressure history. SA's will generally operate at higher injection pressures than DGR's.

Consider for a SA injecting from 100% initial pressure to 120%, whereas for a depleted gas reservoir you may be injecting from 20% initial pressure to 80%.

This economic-technical study compares saline aquifers to depleted gas reservoirs. In order to have an "apples to apples" comparison, we must take into account the primary risks of both SA's and DGR's.

Four key interrelated variables in the analysis for SA's vs. DGR's are:

- Storage Capacity,
- Permeability/Injectivity
- Reservoir Continuity
- Faults.

For Saline Aquifers, it's important to account for continuity and permeability risks combined; Whereas, for Depleted Gas Reservoirs, it's important to do a risk analysis on potential well and cement integrity pathways for vintage wellbores as well as account for storage capacity, permeability/injectivity, reservoir continuity and faults.

Mental Models

Technical subsurface work is largely driven by our mental models of complicated processes occurring deep underground. We need to adjust our mental models when transitioning our workflows from oil and gas to carbon sequestration (and the associate jump in scale).

Shell Quest vs The Infinite-Acting Mental Model

Many references have used the assumption of deep saline aquifers are relatively infinite-acting.

However, a shift is needed when considering these porous intervals as a resource for CO_2 injection on a globally relevant scale. Typical acid gas or water disposal wells in many cases are injecting much lower reservoir volumes than the megatonne per year CO_2 Injectors needed for project economics and federal goals (100 Mtonne/year by 2030).

At these higher rates, aquifers are not infinite-acting; in fact, we can see pressure buildup in the case of Shell Quest in Alberta, Canada. Shell Quest's Basal Cambrian sands are somewhat of a "unicorn" in terms of favourable continuity, permeability, and pore volume in the Western Canadian Sedimentary Basin, but even in that case, reservoir pressure buildup (increase) is observed.

Shell Quest is a key example against infinite-acting aquifers. Even with the thick, high permeability Basal Cambrian sands, there is evidence of pressure buildup. Pressure buildup tells us that we have boundaries on engineering timescales.

In the author's opinion, working with hundreds of fields worldwide and in hundreds in Canada, I have never found it valid to model a reservoir as infinite acting for a final forecast.

Assumption: Pore Space as Capacity

Pore space is a necessary but not sufficient condition for CO_2 geological storage.

Analyzing pore volume as a first pass is a necessary first step, followed by narrowing down to connected pore volume, but this still isn't an accurate picture. Depending on the analytics/methods used, we need to be careful we're charactering connected pore volumes on a meaningful time scale (not geological time). Permeability is the critical variable in aquifer evaluation.

Many regional geological reviews seem to imply that deep saline aquifers are well connected. This may be the case on geological time scales, but not engineering timescales, and much of the data are rejected as outliers.

Because of the massive scale needed for CO_2 injection, we need to pay careful attention to injectivity and capacity on engineering timescales.

When analyzing aquifers that have had a chance to equilibrize over geological timescales, continuity may be apparent, but that continuity is time-dependent, i.e. the permeability may create compartmentalization on engineering (project) timescales.

Optimism Bias

Optimism bias is evident in over-estimated EURs during the early years of the shale boom.

Unknowns rarely contribute positively to project economics in the long term. In the case of deep saline aquifers for CO_2 injection, we have very poor understanding of:

- Continuity: compartmentalization and edges of aquifer
- Large scale permeability: core or DST knowledge isn't far-field enough to base project feasibility on
- Injectivity constraints: driving up the number of injectors required

It's easy to reason by analogy and assume that our work with acid gas injectors, water disposal, or CO_2 EOR give good insight into CO_2 project dynamics, but we need to be careful to check our optimism against unknown effects of scale.

Risking Economics based on Technicals

Properly risking our economics based on the value of known and unknown information allows better decision making. Saline Aquifers are better thought of as "Wild Cat" or exploration wells, whereas depleted gas reservoirs are often well mapped and have a plethora of dynamic data.

Results, Observations, Conclusions

In many cases, Depleted Gas Reservoirs are an attractive alternative to Saline Aquifers because we have dynamic pressure and production and rate/cumulative data. However, both storage options should be used.

Novel/Additive Information

Determining the "Value of Information" concept for CCUS projects.

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