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Practice-based vs performance-based standards for carbon sequestration projects

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Abstract

Interest in deployment of carbon capture and sequestration (CCS) is at odds with the lack of regulations to guide deployment. This can be resolved by a ***practice***-based regulatory framework focused on data collection, prediction, and iteration. Such a regulatory framework could require operators to undertake behaviors that would empower initial regulatory efforts and tell potential operators what to do and why, not how to do it or to what precision. The most important practices comprise prediction and validation. This approach would have several positive effects, including encouraging would-be operators to invest in site selection, planning, modeling and prediction, monitoring, and regular updating of geotechnical operation.

Keywords: Carbon sequestration; UIC; regulatory frameworks; performance standards

1. Introduction

Increased interest in management and reduction of greenhouse gas emissions has focused attention on deployment of carbon capture and sequestration (CCS). Among the barriers to deployment, many workers and companies site a lack of regulatory clarity and certainty necessary to make critical investment or planning decisions. However, there are very few CCS projects in the field and the few there are do not currently provide the full suite of information necessary to answer key regulatory questions [1,2]. Specifically, they lack provide unambiguous statutes for minimal due diligence in site characterization, minimal data collection requirements, minimal monitoring requirements before, during or after injection, steps necessary to reach site closure and decertification.

This drive to deployment has created a unique regulatory situation. Traditionally, regulations develop *ex post* in response to recognized environmental impacts. That knowledge provides a basis for specific technical thresholds of conformance and performance-based standards. In this case, the goal is to craft regulation in advance where no problems currently exist in the field and without substantial empirical data sets in the hope of avoiding potential

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future impacts. Perhaps of equal importance, clear regulations are likely to be needed to receive credit for a carbon abatement offset, validate an obligation under a carbon tax regime, or to issue a security based on carbon sequestered. Without well-studied large projects in place, it is not possible to provide a technical basis for hard operational thresholds, for standards for performance, or for securing an offset. This problem is compounded by the great variety of local geology and rock properties and the lack of regulatory homogeneity from state to state.

This conundrum can be resolved by a ***practice***-based regulatory framework. A regulatory framework could require operators to undertake behaviors that would empower the initial regulatory efforts. In short, this framework would tell potential operators what to do and why, not how to do it or to what precision. A practice based framework would be applicable across a wide range of geological, geographical, and industrial contexts, and could be readily modified as information becomes available from large projects, commercial or otherwise. Such a framework is possible because there is substantial consensus among experts as to the central ingredients of a successful project. Similarly, a great deal of practice from analog industries that can be applied without specific consensus on hard targets or performance-based criteria.

2. Key components to a practice-based regulatory framework

The central aspects of a practice-based framework are component tasks with set goals. These tasks center on behaviors which are desirable from a stakeholder perspective. The most important behaviors are *prediction* and *validation*. *Prediction* requires both understanding and forecasting. Understanding requires a substantial level site characterization to some level of accuracy sufficient to make credible forecasts, whereas forecasting requires forward simulation of hydrological, geochemical, or geomechanical consequences to injection and sequestration. In contrast, *validation* requires both monitoring and accurate comparison with prediction, and creates a yard stick to measure the quality of practice.

Within a practice-based framework, operators would be required to predict and validate their predictions in order to proceed with permitting for each life-cycle stage, i.e. drilling, operational renewal, crediting. Mismatch from prediction indicates that more work needs to be done to understand the nature of the geological system and rectify any difficulties encountered. The specific level of accuracy need not be fixed at once – rather, it can be generally determined and improved upon. Like in other proposed frameworks [3], individual states could be given flexibility in drafting statutory requirements for operational practices, yet would lie upon a minimal foundation of prediction and validation defined nationally.

3. Recommended practices

Recommend practices among experts already include variations on practices adopted in analogous industries (i.e. oil and gas production, acid gas disposal, CO_2-EOR, natural gas storage). A constant element in these ingredients is data collection, prediction, and iteration, which follows from analog industrial practice in the subsurface. The most important of these are as follows:

- ***Substantial site characterization***: Site characterization involves gathering and interpretation of geoscientific information, estimation of key parameters (e.g., injectivity, capacity) and validation through new or prior well data. This is the fundamental basis for many other practices and predictions for a commercial project [4].
- ***Flow and transport simulation of CO_2 in sequestration formations***: Following the characterization phase, simulations are used to predict the behavior and fate of sequestered CO_2. These predictions can be validated through monitoring and verification (M&V).
- ***Development of a site-specific monitoring array***: Information from the characterization allows forward modeling and simulation of geophysical and geochemical responses to injection and the resolution and likely performance of tools and approaches to monitoring. These can then be validated and updated through pilot tests and early commercial injection.

- ***Assessment of risks and hazards***: This task follows from interpretations of the site characterization effort. Hazards are identified, and their failure modes estimated. That prediction is also validated by operational monitoring.
- ***Post-injection monitoring***: It is widely believed that some continued monitoring is desirable after project ceases injection and until the site is deemed safe and closed. The practice and tasks derives from the need to validate predictions of models or events.

This practice-based approach centered on prediction and validation automatically provides some guidance to potential operators and regulators. For example, the guidance around monitoring would not concern specific tools, timing, or metrics, but rather is the monitoring array sufficient to validate predictions. More specifically, the regulatory need for a microseismic array is only based on its utility in validation of prediction with respect to forecasts, simulations, or hazard failure. The duration of post-injection monitoring would depend on the need to validate key predictions regarding pressure, CO_2 distribution, or rate of migration.

4. Examples and antecedents

In considering possible regulatory analogs or examples of practice-based approaches, it is necessary to consider regulation in rapidly evolving fields. One of these is in hazardous waste handling. Regulation of this practice is difficult because new materials are constantly created that may be deemed hazardous wastes. For this reason, regulation is needed even in the absence of a clear understanding of toxicity levels, exposure threats, or performance standards for handling, disposal, or destruction. This approach has been adopted in British Columbia [5], under components of Title 40 in the Code of Federal Regulations (CFR) Chapter I subchapter i, and as amended by the state of Florida [6,7]. In the case of British Columbia, practices are required or forbidden at many stages, including required drafting and submitting a management plan, required security activities and plans, or forbidden construction on a flood plain. In the case of Title 40 CFR, practices required of owners, generators, operators, and disposers of hazardous waster were augmented and modified within EPA Region 4 by the state to suit their specific needs by making requiring additional practices that were more stringent than the CFR.

In considering its draft rulemaking [3], the EPA has proposed some practice-based regulation. These include the section of "phased corrective action" around GS wells, and the Area of Review re-evaluation. These encourage practices such as modeling, monitoring, comparison, and iteration that are likely to improve overall compliance and performance. In other portions of the draft rulemaking, the EPA considers hard numbers or performance standards without a clear technical basis. These include the 50 year default duration for post-injection monitoring or the use of down-hole shut-off valves. In contrast, practices around the prediction and validation of models through monitoring could provide operators with greater flexibility in achieving high performance and a metric to demonstrate compliance without specific time or task mandates.

5. Discussion

Regulatory approaches for CCS are likely to be with us for a long time. A project sited today will begin injection in 5-10 years, operate for 30-60 years, and continue operation post-injection for some years afterwards. This means that early projects (a) will have a substantial body of knowledge before injection and before closure much greater than our current knowledge of CCS today, and (b) will benefit from the learning-by-doing of other commercial CCS projects. As such, a certain humility is warranted. It is difficult to imagine a regulator in the 1950's or 1970's crafting regulation for a modern practice, given the pace of innovation and technological change.

In that context, part of the attraction of a practice based framework is that it is inherently iterative. It could require operators to learn by doing and to match expectations and performance. A regulatory framework could require operators to undertake behaviors that would empower the initial regulatory efforts, such as data collection and mandatory reporting. This approach would have several positive effects:

- Encourage would-be operators to consider the data density and quality of a site regarding its possible accuracy
- Provide early warning where there are substantial mismatches between prediction and observation.
- Create a metric to demonstrate operational improvement or degradation.
- Provide incentives to select proper sites and operate with high technical acumen.
- Require regular check-ups between regulators and operators without threatening the likely continuation of capital-intensive project.
- Lay out terms for activity which can be met to demonstrate compliance
- Give industry clear guidance regarding the most important actions for permitting and operating injection
- Help to develop formal practices to be applied or compared between regions or states

Although a practice-based approach could have substantial benefits, there are several problems and difficulties up front in considering this framework. To begin, it is still possible to craft requirements that are either too lax or unduly burdensome. To avoid this problem, early projects will need either mandates or incentives to gather interpret, and integrate results to tune requirements early on. It is possible to craft that sensibility into the early approach, such that the extent or duration of required or forbidden practices is re-evaluated in the first 10 years. In addition, there specific metric for validation of prediction could prove troublesome. IN the absence of an explicitly designed regulation, there is a reasonable concern that one party may find a prediction accurate while another may not. A technical basis for determinations of accuracy would still be helpful in avoiding sustained implementation problems.

6. Conclusions

There is both a need for clear regulatory frameworks for CCS and a great challenge in providing that framework in such a way as to enable CCS while protecting vital public interests. A practice-based framework can provide a basis for operational and regulatory decision making rooted in prediction, validation, and matching of accuracy. The strength of this approach is in encouraging good behavior of operators, great early flexibility, and a basis in process that helps identifies potential problems or concerns. This approach has analogs that can be further considered for applicability.

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