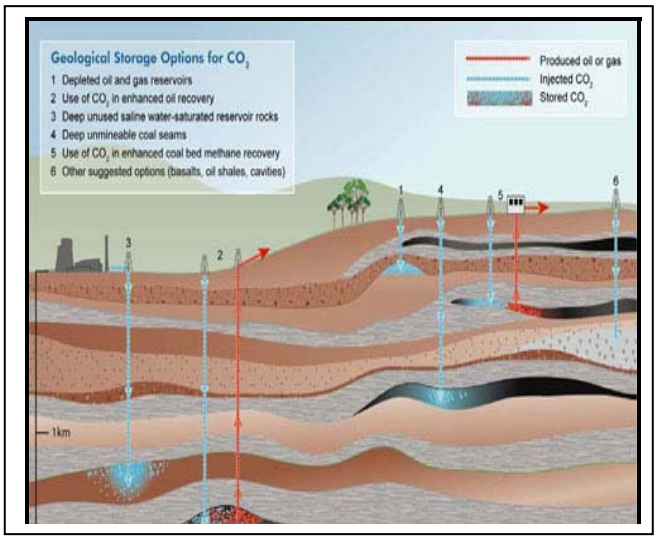
BACKGROUND INFORMATION ON CARBON CAPTURE AND STORAGE



California Carbon Capture And Storage Review Panel

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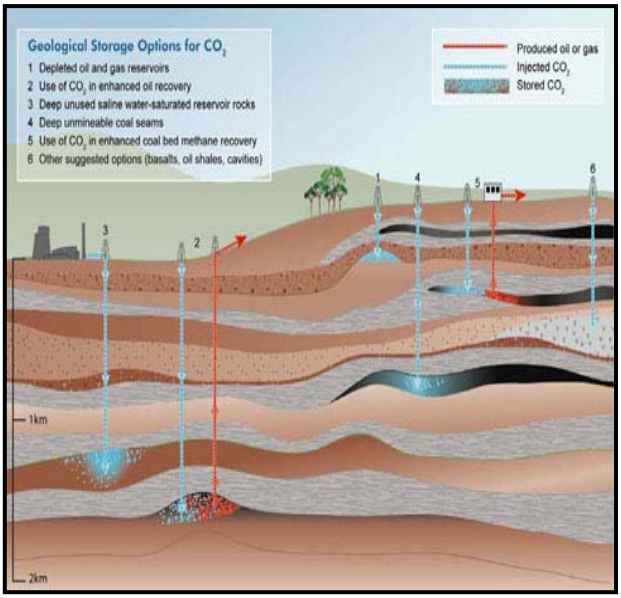
Introduction

Carbon capture and storage or "sequestration" (CCS) refers to the "capture" of CO_2 by modifying industrial plants to remove CO_2 from process or exhaust gases and to the long-term storage of that CO_2 away from the atmosphere. This usually means compressing and injecting the CO_2 deep underground into secure geologic formations, where it will remain for centuries or millennia.

Governor Arnold Schwarzenegger and the California Legislature have recognized the importance of reducing CO_2 and other greenhouse gas (GHG) emissions to the atmosphere to combat climate change. On June 1, 2005, the Governor signed Executive Order S 3-05, which established three target reduction levels for GHG emissions in California: 2000 levels by 2010; 1990 levels by 2020; and 80 percent below 1990 levels by 2050. Upon passage of Assembly Bill 32, the Global Warming Solutions Act of 2006 (Núñez, Chapter 488, Statutes of 2006), California, under the leadership of the Air Resources Board (ARB), began to identify ways to meet the second target of reducing GHG emissions to 1990 levels by 2020, culminating in the publication of the AB 32 Scoping Plan. Senate Bill 1368 (Perata, Chapter 598, Statutes of 2006), followed with a mandate, established by the California Public Utilities Commission (CPUC) and the Energy Commission, in consultation with ARB, for new or renewed long-term contracts to purchase electricity from baseload facilities owned by, or under long-term contract to publicly owned utilities, to meet the GHG emission performance standard of 1,100 lbs CO_2 per megawatt-hour (MWh). SB 1368 states that geologically stored CO_2 shall not count as an emission of a power plant for determination of GHG emission performance standard compliance.



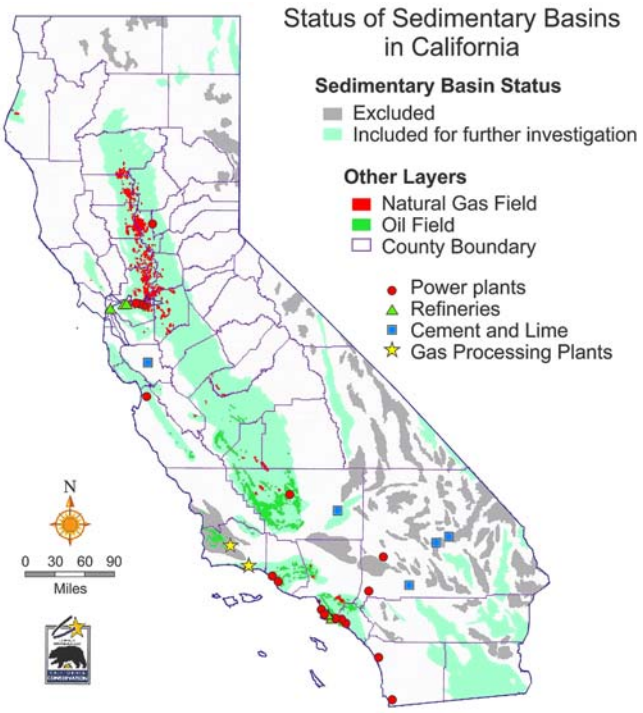
CCS could play a significant role in achieving California's greenhouse gas (GHG) reduction goals for 2020 and a major role for 2050. While the technical barriers to deployment of CCS are relatively low, there are significant statutory and regulatory ambiguities or uncertainties that stand in the way of CCS, and the economics, without a price for carbon, remain unfavorable. If the potential of CCS is to be realized, the state must establish a consistent policy framework. Such a framework must establish the authorities and roles of various state agencies, facilitate development of favorable business cases for adoption of the technology at a commercial scale, and also serve the public's interest in assuring climate change mitigation goals are met while protecting the environment and human health and safety.

How CCS would be treated as a GHG reductions technology is not explicitly dealt with in state legislation AB 32, SB 1368, or other statutes. CCS is discussed in the AB 32 Scoping Plan's "Vision for the Future" section. However CCS is not given in the Scoping Plan as an explicit measure to meet 2020 GHG emission targets. Meeting the 2020 goals without CCS could be difficult and costly. CCS could be included as one of the measures in the AB 32 Scoping Plan if proper accounting, measurement, and verification protocols are in place. Current accounting

protocols are either not comprehensive in scope or are too general for regulatory purposes. There are efforts to develop more robust protocols. Several early CCS projects are moving forward into the permitting phase now and, if approved and constructed, their emissions reductions will contribute to 2020 goals provided proper accounting and verification protocols are in place.

Background

Proper implementation of CCS requires geology suitable for sequestering carbon dioxide. In most cases, CCS targets thick sequences of sedimentary rocks within which there are permeable rocks such as sandstones, which serve as storage reservoirs, and overlying low permeability rocks, such as shales, which serve as seals to block upward migration of the CO_2. Nature has been storing gases and liquids underground for millions of years in these types of rock sequences, although leakage through faults, fractures, and other conduits does occur naturally from some reservoirs, underscoring the need for proper site selection. Types of reservoirs that may be suitable include 1) saline formations, which contain brine that is not suitable for drinking water, and 2) oil and gas reservoirs. As is shown in this map of sequestration resources, California has an abundance of both saline formations and oil and gas reservoirs that have the potential to be carbon storage sites. Many of the large industrial sources, power plants, refineries and cement plants, in the state are in close proximity to such sites.



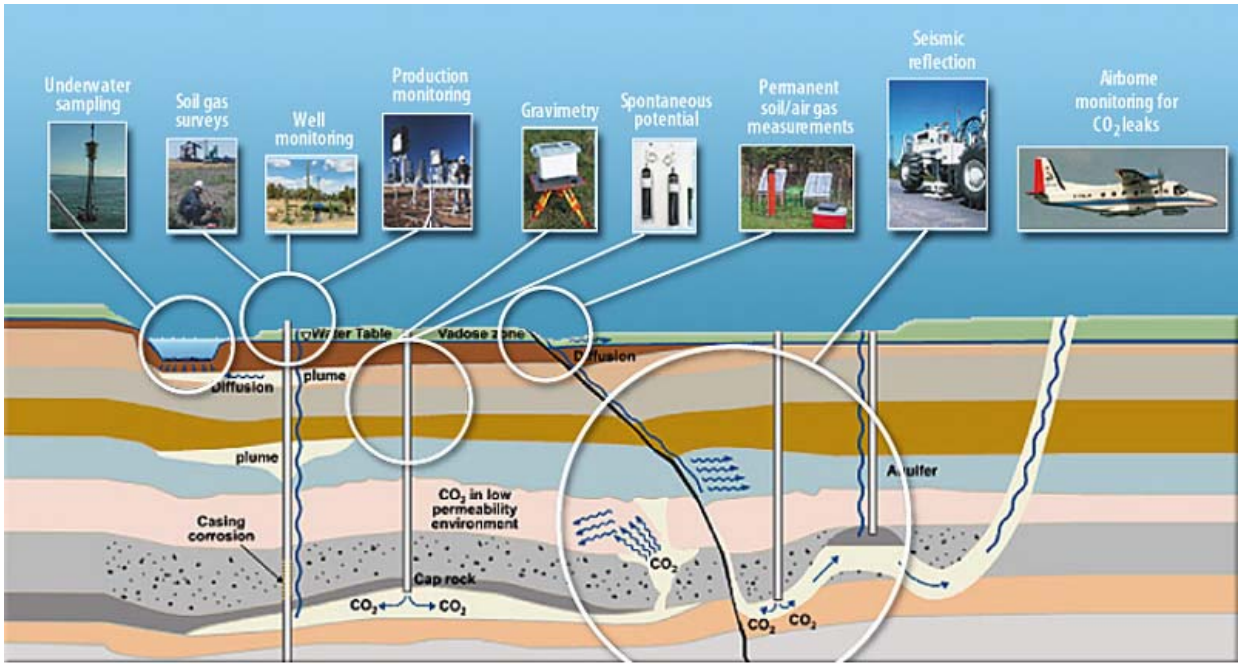
Currently, undergound injection permitting authority is split according to use, with oil and gas production activities under the jurisdiction of the Division of Oil and Gas and Geothermal Resources (DOGGR), and other activities, including CO_2 injection into saline fomations, under the federal EPA (Region 9). Regulatory authority over industrial CO_2 sources also involves multiple agencies. In spite of these differing regulatory authorities, the same goals and objectives should apply to all CCS projects regardless of source or reservoir type. Developing a consistent regulatory structure will be an important challenge for regulatory agencies and policy makers.

Pore space ownership and mineral and water rights are potentiallydifficult issues. A commercial-scale CCS project will result in a CO_2 plume with a “radius” on the order of miles and an even greater zone of pressure influence, which will likely span across multiple surface and mineral estates.

Economic considerations also are an important constraint on adoption of CCS. Enhanced oil recovery (EOR) improves CCS economics by providing additional revenue from increased oil production. Some technologies (e.g. ethanol plants), and processes (e.g. syngas/hydrogen production from gasified coal or petroleum coke) produce an essentially pure CO2 stream

thereby avoiding separation costs. With close-to-favorable business cases, these kinds of sites are likely to be among the earliest projects. Many mature hydrocarbon fields in the state are good candidates for CO_2-EOR if supplies of CO_2 could be delivered economically. CO_2-EOR has the potential to recover up to 5 billion barrels of additional oil and to store up to 1 billion tons of CO_2. About 80% of the state's large industrial CO_2 emissions point sources are within 50 km of a potential EOR site; however, the siting and development of the pipeline infrastructure to facilitate this development will be challenging without government leadership.

There are monitoring, verification and accounting distinctions between EOR and CCS. EOR operations recycle CO_2 when oil is produced and historically leave somewhere between 30 and 60% of injected volumes underground. While operators typically keep careful accounting of CO_2



injected, driven by their desire to minimize the expense of CO_2 injection while maximizing incremental oil production, their accounting systems may not meet the needs of CO_2 suppliers to verify storage to meet GHG emissions caps and/or the needs of regulators seeking to verify that CCS projects meet climate change mitigation goals. For example, there are fugitive CO_2 losses throughout the recovery and recycling processes as well as energy use for recompression and re-injection of the recycled CO_2.

Seismic risk is another important issue for a CCS policy framework to address, particularly in earthquake-prone California. Specifically, it is important to assure that CCS projects do not induce seismic activity, exacerbate natural seismic risks, or bear spurious liability for naturally occurring seismic events. These issues will have to be considered in the context of lessons learned from relevant underground injection projects including monitoring efforts at the the US Department of Energy's regional carbon sequestration partnership's large volume injection projects. Consideration should also be given to studies that attempt to better establish the relationship between the size of an induced event and the risk of surface or well bore damage. Additionally, the potential for seismic activity to impact containment is an issue for California.

Public perception issues also are important considerations in developing CCS policy. The issues surrounding seismicity, as well as the potential for catastrophic leakage, are highly sensitive ones for the public when it considers CCS technology. In this context, it is important

that regulations are sufficient to maintain the public trust and to encourage project developers to engage and educate the public on the nature and importance of CCS.

Some lessons learned and templates for California policy frameworks may be developed by examining analogous operations involving CO_2 transport, injections, subsurface storages, monitoring and policies adopted specifically for CCS by other states. Several studies are available highlighting how analogs may or may not be appropriate for CCS. Such analogs include depleted gas reservoirs used for temporary storage of natural gas, CO_2 pipelines that extend over 3,500 miles in the U.S. that have delivered over 10 trillion cubic feet of gas for CO_2-EOR purposes, experience in underground injection of other fluids, and oil industry experience in CO_2 injection for EOR. There is also extensive experience in technologies to track the fate and transport of materials in the subsurface and to monitor for leakage developed by the oil industry, hazardous waste disposal industry, and others. These have been reviewed extensively in the CCS literature. The progress of various states also has been reviewed in the literature and is summarized in the companion document, "CCS Regulatory and Statutory Approaches in Other States" found in this packet (Tab 6). A limitation of examining analogs as a model for CCS is that most analogs do not operate under as high volumes and pressures as CCS.

Statutory Issues

- ***In order to establish a process by which CCS project developers may transfer/lease the necessary subsurface pore space property rights, ambiguities must be resolved regarding pore space ownership and the relation between the surface and mineral estate.***

Property ownership issues are traditionally in the domain of state, not federal, law. California should determine how it will legislate subsurface pore space property rights with respect to whether they are tied to the surface owner, the relation (dominance) between the surface and the mineral estate and mechanisms for acquiring the property rights necessary for a CCS project.

To date, the approaches of other states have not been consistent (see Tab 6 companion document, "CCS Regulatory and Statutory Approaches in Other States" for further discussion). CCS projects pose some unique challenges because of their size. The surface footprint for a plume with a radius of a few miles could easily encompass scores of individual land parcels, even in unincorporated areas. Costs and delays may be prohibitive if it is necessary to execute independent subsurface access agreements with every one of scores of landowners. However, landowners will be assuming some risk, and some states have required a vast majority (>80%) of potentially impacted landowners to agree to the project. Adding to the challenges arising from plume size is the uncertainty in knowing how far the plume or its pressure effects will spread over the long time periods relevant to CCS. Some criteria should be developed to delineate the rights of project developers and adjacent landowners/mineral rights owners in this context.

In the area of property rights, industries such as natural gas storage are an imperfect analog for CCS. The conservative approach of acquiring both surface and mineral property rights for natural gas projects may be considered. However, unlike natural gas storage, for CCS, decisions on the assignment of pore space ownership may preclude the possibility of subsequent recovery of mineral resources. Pore space ownership issues become particularly complex in oil fields, and even more so in situations where CO_2-EOR is or has been done prior to or in conjunction with CCS. In oil fields, there is always residual OOIP (original oil in place) that belongs to the mineral rights owner. In EOR, the CO_2 both occupies pore space and is

dissolved/stored in the oil. The potential change in regulatory authority for wells depending upon if it is used for EOR or CCS is a related issue, discussed below.

- **The long-term ownership of and liability for the stored CO_2 are potential barriers for CCS development which may be addressed by transferring liability to the state or by federal or private indemnification schemes.**

For CCS to be effective as a climate change mitigation technology, the CO_2 must remain underground for time periods of hundreds to thousands of years, well beyond the historic life-span of most companies and many governments. This presents an issue with regard to assuring that there is long term stewardship of these sites to protect the public. In addition, a major barrier for industry to undertake CCS projects is the open-ended liability for the site without a transfer process.

Although operational risks associated with the transportation, injection and presence of CO_2 in the subsurface in EOR operations have been successfully managed for many years, the long-term liabiity for CCS sites post-closure is unique to CCS. It is important to note that the entity accepting the liabiity also would likely be responsible for the expense of continuing monitoring, verification and accounting activities, any mitigation or remediation required, and compensation for any damages if leakage occurs.

One option is that government agencies take on the long-term responsibilty for CCS sites. Some states have adopted legislation to accept limited liability but there has been little consistency in the time frames or agreement as to where the liability should ultimately reside. In some cases the risk and performance of the CCS site is linked to liability transfer (see the companion document, “CCS Regulatory and Statutory Approaches in Other States” for further discussion).

Another options is create an industry fund. At the federal level, bills have been introduced that would establish a carbon storage stewardship trust fund financed by fees from operators to ensure compensation for potential damages. At least one private insurer is making short term insurance policies available.

In addition, long term liability schemes have been adopted for other industries, including bond provisions by the Underground Injection Control (UIC) program, trust accounts funded through fees to operators that are administered by state or industry organizations such as the Acute Orphan Well Account, the Price-Anderson indemnity program that pools risk for the nuclear industry, or the National Flood Insurance Program that is federally funded.

Regulatory Issues

- ***Defining agency roles and responsibilities in regulating CCS will remove ambiguities and reduce uncertainties for project developers***

Permits required include those for surface facilities, pipelines, and underground injection wells and associated facilities. Regulators are involved at the federal, state, and local levels. Considerations include meeting health, environmental and safety requirements as well as assuring climate change mitigation goals, such as those mandated by AB 32, are met.

In California, CCS projects currently involve permitting of the subsurface injection wells through the underground injection control (UIC) program, of pipelines through federal and state requirements, and of other surface facilities as required by the applicable Air Quality Management District, all of which must comply with CEQA and satisfy any requirements for performance standards such as the SB 1368 GHG emissions limit of 1,100 lbs CO_2 per MWh

generated. Pending action following the US EPA proposed rules for GHG, CCS will likely require regulation under the Clean Air Act or relevant state rules. As of 2008, at least 21 states and the US EPA have taken or proposed some type of legislative and/or regulatory action with regard to CCS.

Regulating CO_2 Producers/Surface Facilities

Issues concerning facilities permitting include several raised by the Hydrogen Energy California (HECA) Application for Certification (AFC), currently under consideration at the Energy Commission, as well as those raised by new and proposed US EPA rules. The proposed HECA project involves the construction of a gasification combined-cycle power plant with pre-combustion CO_2 capture and sequestration through sale to Occidental Petroleum Corporation (OXY) of the captured CO_2 for EOR. The power plant must satisfy the emissions performance standard established under SB1368 for CO_2 emissions.

1) Which Agency has Statutory Authority: In a recent memorandum on the HECA AFC, Commission staff noted that DOGGR staff "indicated that they do not currently believe they have statutory authority to permit oil field activities that have the goal of permanently sequestering carbon and that such activities could conflict with their duty to ensure the continued availability of petroleum resources." (Docket 08-AFC-8, December 31, 2009). The Energy Commission and DOGGR have since met with and received information and materials from HECA and OXY demonstrating that DOGGR does have the authority to permit the CO_2-EOR activities and those activities needed to demonstrate sequestration. A small-scale project proposed by Shell and WESTCARB illustrates a different regulatory path. The project involves injection of CO2 from a refinery or other industrial source into a saline formation. In this case, there is no apparent permitting role for DOGGR or the Commission; instead, US EPA Region 9 will permit the injection wells, and the county will permit the land use for facilities, which triggers CEQA documentation requirements. It is important to note that the different UIC well classes have different requirements, particularly for monitoring. These differences may result in inconsistencies among projects in their abilities to verify GHG reductions.

2) Emissions Verification: The HECA AFC noted that CO_2 may be vented up to 504 hours per year, and the Commission staff requested further clarification in Data Requests as to how this number was derived and whether the applicant has guarantees in place for carbon sequestration. The HECA Data Responses explained that the 504 hours stated in the AFC represented potential CO_2 venting during Early Operations (approximately first three years of operation, or between 65 percent and 85 percent hydrogen-rich fuel availability), and that during Mature Operations (after approximately the third year of operation, or at 85 percent hydrogen-rich fuel availability) the project expected zero venting of CO_2 except in the case of upset conditions where an estimated 120 hours of venting was expected. Also, Commission staff asked for more information about how much of the injected CO_2 would stay sequestered permanently and how much may be emitted with extracted petroleum. Such questions arise in the context of establishing how the project will meet GHG emissions reductions goals, for example, qualifying under SB 1368 caps. Accounting for fugitive emissions also may be a concern.

3) Emissions Accounting: Protocols for accounting should be consistent with the intent of promoting CCS adoption while still assuring accurate accounting of net GHG reductions achieved by projects. Some of the new and proposed US EPA rules

illustrate the difficulties of finding this balance. For example, a new rule adopted Sept 22, 2009, the "Mandatory Greenhouse Gas Reporting Rule" requires reporting by suppliers of the mass of CO_2 captured, extracted, imported or exported and requires that information to include end use, if known. This may prove particularly difficult for suppliers sharing CO2 pipelines that feed multiple end users. In another instance, the US EPA has proposed a rule, the PSD and Title V Greenhouse Gas Tailoring Rule, in an effort to decrease the number of sources subject to major source permitting for GHGs under the Clean Air Act (CAA). The Energy Commission has expressed concern that the "current tailoring proposal is far too modest", and will likely result in the same gridlock in the federal PSD permit process that the proposed rule is intended to avoid. Decisions on accounting protocols must be made in consideration of what may be required by federal rules, to meet requirements under state laws such as AB32 and SB 1368, and in consideration of lessons learned by other entities on how various protocol structures have impacted CCS adoption.

Regulating Pipelines

Pipelines for CCS will be regulated by local authorities, the California State Fire Marshal, and the US Dept of Transportation with regard to the traditional requirements for mechanical integrity, health, safety and environmental protection. CCS, however, raises additional issues beyond those considered previously by these agencies, specifically how CARB or another agency might assign and keep track of carbon credits, given that custody and perhaps even "ownership" of the CO_2, governed by contract, may change from the plant to the injection site. While this may be relatively straightforward during early stages when pipelines connect one supplier with one end user or sequestration site, accounting becomes considerably more complex when a pipeline infrastructure has developed that may contain CO_2 from multiple sources delivered to multiple end users and/or sequestration sites.

Although common in other states such as Texas, today, the amount of CO_2-EOR practiced in California is negligible, and no CO_2 pipeline infrastructure exists. Sale of captured anthropogenic CO_2 could provide an economic source to EOR operators, offset some of the cost of CCS, and boost state income from incremental oil revenue. The CO2 pipeline infrastructure that California will require in the future must be designed to take into consideration the needs of both the CO_2 producers and the purchasers of that CO_2. Without accommodating the purchasers, the opportunity to make CCS more economic is diminished; without accommodating the suppliers, their ability to meet air quality or regulatory permit caps may be compromised. In a worst case, the reliability of the transmission grid is also compromised because the unavailability of CO2 purchasers to transport and store CO_2 from the producers leads to plant interruption in order to remain within GHG emissions limits.

In this context, it is important to recognize that the drivers for CO_2-EOR and CCS are distinct. CO_2 pipeline operators for EOR accommodate needs of oilfield operators, but for CCS, drivers come from the CO_2 producer's side. If projects are to include both, then additional challenges arise. These include accommodating temporary situations where the quality of gas from the power plant may not meet contractual EOR or pipeline specifications and addressing how EOR operational upsets may result in the EOR operator being unable to accept CO_2 that the power plant needs to have sequestered in order to qualify for emissions credits, or to meet GHG emissions caps. Furthermore, the monitoring procedures and project components that require monitoring in order for the producer to receive emission credits may be different than the storage verification accounting routinely performed by CO2-EOR operators.

Regulating the Subsurface

Ambiguities remain in the authority and approach of proposed US EPA Underground Injection Control (UIC) rules and among proposed or adopted state rules. Both US EPA and state UIC programs are authorized by the Safe Drinking Water Act (SDWA) and as such are constrained in their abilities to address issues apart from contamination of underground potable water sources. These programs, therefore, do not explicitly address issues such as leakage of gas to the surface, although the requirements to assure no potential impacts to an underground source of drinking water (USDW) also may provide a great deal of assurance that there will be no leakage to the air. As was discussed above, there also are differences in implementing agencies in California, depending upon whether the CO_2 will be injected for the purpose of incremental oil or gas production, or into a saline formation. In the nine states that have proposed rules by early 2009, five assigned authority to an oil and gas regulator; four to an environmental regulator. In all cases the state must be granted primacy from the EPA in order to regulate injection wells.

The US EPA has proposed a new class, Class VI, for geologic sequestration wells. While there has been some question about whether these would apply to EOR operations, US EPA stated in its Preamble that it did not intend to alter Class II permit requirements for CO_2-EOR operations. Class II pertains to EOR wells so long as oil continues to be produced while CO_2 is injected. If CO_2 injection continues after oil production ends, the well strictly is no longer Class II. It is not clear whether wells would have to be converted from Class II to VI, and this also raises the question of whether they would have to be converted back to Class II should oil recovery operations resume due to economics or otherwise. Further discussion of these issues may be found in the Multi-stakeholder Recommendations made to the US EPA.

EOR operations also must somehow be able to do accounting of CO_2 storage to meet the needs of suppliers for storage verification. Furthermore, decisions on CO_2 injection well regulations should consider the effect of that classification on any existing EOR wells.

Regulating CCS to Assure Performance

Performance objectives and a system of emissions accounting must be established for CCS sites aimed toward protection of the environment, human health and safety and to meet GHG emissions standards set for the purposes of mitigating climate change. Regulations also must establish requirements for the time period necessary for CCS site performance and for long-term monitoring to assure environmental and human health and safety in the case of catastrophic leaks, and also to detect slow leaks which, over long periods of time, eventually can erase the GHG emissions reductions and climate change mitigation benefits gained by CCS. There are many technologies available for monitoring CO_2 sequestration reservoirs, as well as associated infrastructure, for leakage. There are also well established techniques for mitigating and remediating both catastrophic and slow leaks.

The regulatory ambiguity, discussed above, must be resolved before performance standards can be implemented to make CCS acceptable as a GHG reduction strategy. The proposed US EPA rulemaking may eventually address this issue, but some states have created performance standards by linking CCS explicitly to their GHG reduction goals or by expanding performance objectives to address concerns specific to CCS (see companion document, “CCS Regulatory and Statutory Approaches in Other States”). In addition, there are differences in definitions of the period of reservoir performance by federal and state regulators (see companion document, “CCS Regulatory and Statutory Approaches in Other States.”)