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ENERGY
COMMISSION

GEOLOGIC CARBON SEQUESTRATION STRATEGIES FOR CALIFORNIA

REPORT TO THE LEGISLATURE

FINAL STAFF REPORT

November 2007
CEC-500-2007-100-SF

STATE OF CALIFORNIA
ENERGY COMMISSION

Arnold Schwarzenegger, *Governor*

PREFACE

This report was prepared in response to legislation passed last year, Assembly Bill 1925 (Blakeslee, Chapter 471, Statutes of 2006), which states,

> On or before November 1, 2007, the State Energy Resources Conservation and Development Commission, in coordination with the Division of Oil, Gas, and Geothermal Resources of the Department of Conservation and the California Geological Survey, shall submit a report to the Legislature containing recommendations for how the state can develop parameters to accelerate the adoption of cost-effective geologic sequestration strategies for the long-term management of industrial carbon dioxide. In formulating recommendations, the commission shall meet with representatives from industry, environmental groups, academic experts, and other government officials, with expertise in indemnification, subsurface geology, fossil fuel electric generation facilities, advanced carbon separation and transport technologies, and greenhouse gas management.
>
> The study for the report shall be conducted using existing resources and shall include, but is not limited to, all of the following:
>
> - Key components of site certification protocol, including seal characterization, reservoir capacity and fluid and gas dynamics, testing standards, and monitoring strategies.
> - Integrity and longevity standards for sequestration sites.
> - Mitigation, remediation, and indemnification strategies to manage long-term risks.
>
> The commission shall include the report prepared pursuant to this section in its 2007 integrated energy policy report required by Section 25302 of the Public Resources Code.

The California Energy Commission is currently funding studies on the feasibility of geologic carbon sequestration. This research is co-sponsored by the U.S. Department of Energy through a research program known as WESTCARB. In addition, the Energy Commission is funding the development of improved methods to estimate greenhouse gas emissions and studying options to reduce these emissions. The WESTCARB project will provide the necessary foundational data and analysis to ensure an appropriate regulatory framework for geologic carbon sequestration, including the development of site certification protocols; integrity and longevity standards; and mitigation, remediation, and indemnification strategies. The second phase of the WESTCARB project is scheduled for completion in 2010. A significant amount of data, which would be valuable for formulation of recommendations required by AB 1925, will not be available until then.

Therefore, the Energy Commission has prepared this first of two reports in response to AB 1925. This report establishes the parameters for the second report to be submitted in November 2010 after the results of the WESTCARB project can be thoroughly evaluated.

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List of Acronyms

AB 32	California Assembly Bill 32 (Núñez) Chapter 488, Statutes of 2006
AB 1925	California Assembly Bill 1925 (Blakeslee) Chapter 471, Statutes of 2006
ARB	California Air Resources Board
CCS	carbon capture and sequestration
CGS	California Geological Survey
CO_2	carbon dioxide
CPUC	California Public Utilities Commission
DOGGR	Division of Oil, Gas and Geothermal Resources (California Department of Conservation)
EGR	enhanced gas recovery
EOR	enhanced oil recovery
GHG	greenhouse gases
IOGCC	Interstate Oil and Gas Compact Commission
IPCC	Intergovernmental Panel on Climate Change
MMT	million metric tons
SB 1368	California Senate Bill 1368 (Perata) Chapter 598, Statutes of 2006
U.S. EPA	United States Environmental Protection Agency
WECC	Western Electricity Coordinating Council
WESTCARB	West Coast Regional Carbon Sequestration Partnership

ABSTRACT

Assembly Bill 1925 (Blakeslee, Chapter 471, Statues of 2006), passed unanimously by the California Legislature in 2006, requires the California Energy Commission and the Department of Conservation to prepare a report recommending how the state could facilitate adoption of geologic carbon sequestration. This legislation is part of the state's efforts to assess methods for reducing greenhouse gas emissions within California's overall strategy to mitigate anthropogenic climate change.

The relevant scientific and engineering topic areas covered by this report are: the potential to store carbon dioxide in the state's deep geologic formations, the technologies needed to capture carbon dioxide emitted from power plants and other large industrial sources in the state, and issues surrounding sequestration reservoir management (including site characterization, monitoring approaches, risks and their management, and remediation and mitigation measures should leakage occur). In addition, the report examines the economics of geologic carbon sequestration and discusses issues and options for developing the necessary statutory and regulatory frameworks for carbon capture and sequestration.

The report concludes that, although technical challenges remain, the primary barriers to progressing with initial geologic sequestration projects concern economic viability and statutory and regulatory issues. The exceptions to this may be projects that combine sequestration with enhanced hydrocarbon recovery or take advantage of industrial process with relatively pure CO_2 emissions streams. Further studies, including demonstration projects, are needed to integrate or adapt existing knowledge and the technology of geologic carbon sequestration and to guide development of regulations and statutes. These efforts should provide public education on carbon capture and sequestration, opportunities to engage stakeholders, and better understanding of the economic factors and business case considerations that affect commercial adoption.

KEYWORDS

Carbon capture and sequestration, CCS, coal, climate change mitigation, electricity, power plant emissions, carbon emissions, greenhouse gas emissions reductions, geologic sequestration, carbon dioxide emissions

Executive Summary

Assembly Bill 1925 (Blakeslee, Chapter 471, Statutes of 2006), passed unanimously by the California Legislature, directs the California Energy Commission, in coordination with the Department of Conservation, to prepare a report for the Legislature containing:

> ...recommendations for how the state can develop parameters to accelerate the adoption of cost-effective geologic sequestration strategies for long-term management of industrial carbon dioxide.[1]

Carbon capture and sequestration options include any process that "captures" carbon dioxide (CO_2) and stores, or sequesters, it away from the atmosphere to mitigate anthropogenic climate change caused by atmospheric CO_2 buildup. Three major approaches can capture and sequester carbon: terrestrial, geologic, and oceanic. Of these, the first and second can be used in California. Terrestrial carbon sequestration involves changing the management of forests, rangelands, agricultural lands, and wetlands so that these ecosystems naturally capture and store more CO_2 and/or emit less. Geologic sequestration, the focus of AB 1925, involves using gas separation technologies to capture CO_2 from large point sources, such as power plants, cement factories, or refineries, then injecting it deep underground.

Achieving commercial-scale application of geologic carbon sequestration requires not only technological readiness and economic viability, but also appropriate regulatory and statutory frameworks. Geologic sequestration poses particular challenges because it potentially cuts across the jurisdictions of several state and federal agencies and sequestration of CO_2 should extend potentially for well over a hundred years to be effective at mitigating CO_2 buildup in the atmosphere.

As identified by the AB 1925 legislation and technical experts, several topics are relevant to assessing the state's readiness for commercial-scale geologic sequestration:

- Geologic potential for sequestration in the state
- Capture technologies
- Site characterization
- Monitoring and verification
- Risks and risk management
- Remediation and mitigation
- Economic considerations
- Regulatory and statutory issues

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[1] Legislative Counsel, "Assembly Bill 1925," *Official California Legislative Information*, n.d., <http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_1901-1950/ab_1925_bill_20060926_chaptered.pdf>.

To develop this report, the Energy Commission engaged subject matter experts who contributed white papers that serve as a technical foundation for each chapter. The Energy Commission is publishing the white papers in a separate document through its Public Interest Energy Research Program. Developing this report also included holding two public workshops and attending technical and community meetings to engage other state agencies, additional experts in various aspects of geologic sequestration, a range of stakeholders, and the public.

This report is a preliminary effort to capture the issues associated with a rapidly emerging new technology. Given the pace of development of carbon capture and sequestration technology worldwide and the range of activities planned over the next three years in California, a follow-up report is planned for 2010. Specifically, the Energy Commission is funding studies on the feasibility of geologic carbon sequestration, co-sponsored by the U.S. Department of Energy though a research program known as the West Coast Regional Carbon Sequestration Partnership. In addition, the Energy Commission is funding the development of improved methods to estimate greenhouse gas emissions and studying options to reduce these emissions. These efforts are necessary to provide the foundational data and analysis to support developing an appropriate regulatory framework for geologic carbon sequestration, including site certification protocols; integrity and longevity standards; and mitigation, remediation, and indemnification strategies. Thus, a significant amount of data that will be critical to formulating the recommendations required by AB 1925 will not be available until nearly 2010.

This report focuses on identifying the parameters pertinent to adoption in California of commercial geologic sequestration that need further study or analysis of their implications for the state. The 2010 report will summarize the results of these studies and analyses and make recommendations in accordance with the legislation.

Potential for Commercial Capture and Sequestration

Capture and geologic sequestration involve three major components: modifying large industrial plants, such as power plants, oil refineries, and cement plants, to capture CO_2 from process or exhaust gases; delivering the CO_2 to a sequestration site, generally by pipeline; and injecting the CO_2 deep underground into rock formations that will prevent it from re-entering the atmosphere for a hundred years or longer.

Achieving widespread adoption of commercial sequestration depends on finding a size correspondence between emissions sources and capacities of safe, accessible sequestration sites and an economic correspondence between the costs of capture and sequestration and the value placed on the CO_2. Source and site correspondence includes factors such as source emissions volumes relative to underground sequestration capacity and the distance between the source and the sequestration site. Costs of capture vary widely with the type and size of the emissions source. The value for CO_2 may be set by policy in accordance with climate change mitigation objectives or realized by sale of the captured CO_2 for industrial purposes, such as enhanced oil recovery.

From a theoretical standpoint, the amount of CO_2 emissions that can be sequestered annually by geologic sequestration is limited by the number and size of point sources that can be captured. For example, power plant emissions, based on the greenhouse gas emissions inventory, totaling about 108 million tons CO_2 per year (61 out-of-state and 47 in-state), could all theoretically be geologically sequestered.

In practical terms, assuming that a business case or policy develops that favors carbon capture and sequestration deployment, the rate of deployment may still be limited by insufficient understanding of the sequestration resource potential, the pace of transport and other infrastructure development, and other factors. Practicality and economics also limit carbon capture and sequestration to that part of the emissions inventory associated with large single point sources, such as smokestacks on factories or power plants. In California, about 30 facilities emit more than 1 million tons of CO_2 per year. Most are natural gas-fired power plants, along with several oil refineries and cement kilns. The few coal- and petroleum coke-fired power plants in California are relatively small non-utility generators built as cogeneration qualified facilities. The largest CO_2 point sources within the state's inventory of emissions are related to California's imported electricity. Several of the coal-fired utility power plants in Arizona, New Mexico, and Utah that supply electricity to California produce emissions in the range of 4 to 10 million tons of CO_2 per year.

Capture also would be impractical, for example, for transportation fuel emissions, which come from millions of small mobile sources and constitute California's largest sector source at about 190 million tons of CO_2 per year. Plans for CO_2 emissions reduction in the transportation sector typically focus on using lower net carbon fuels, such as ethanol. However, bioethanol plants have highly concentrated CO_2 emissions, which make them potentially good opportunities for low-cost capture. While emissions today total less than 1 million tons per year from a few ethanol plants, the number of plants in the state should rise significantly, presuming sustained favorable biofuels policies and financing. These plants offer the potential for using geologic sequestration to create "net negative" CO_2 emissions because biomass derived fuels are already nearly carbon neutral (see Chapter 4).[2]

California has many rock formations that potentially are suitable sites for geologic sequestration. Sequestration targets commonly are rock layers within deep sedimentary basins, places where sand and mud have accumulated to thousands of feet of thickness over many millions of years and lithified into rock. These types of layered rocks are potentially good sequestration sites because they have the capacity to hold or trap large amounts of CO_2 in the pore spaces of sand layers, while overlying impermeable mud rock layers form good seals to prevent the gas from escaping upward. Preliminary estimates of CO_2 sequestration capacity for

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[2] "Net-negative" emissions are possible from sequestering emissions from energy derived from biomass. Because plants withdraw CO_2 from the atmosphere, when biomass is burned, the CO_2 simply returns to the atmosphere—a carbon-neutral situation. However, if the emissions from burning biomass are sequestered, a net transfer of that carbon occurs from the atmosphere to underground storage, which can be booked in the emissions inventory as a subtraction from gross emissions.

formations within the 10 largest sedimentary basins lie between 75 and 300 metric gigatons of CO_2. Capacity estimates are better constrained for a small, but important, subset of target formations that contain oil and natural gas. Sequestration estimates are 3.5 metric gigatons of CO_2 for oil and 1.7 metric gigatons for natural gas reservoirs.

Geologic sequestration in the subset of target formations that have produced oil and natural gas for long periods has several advantages. Because these formations are oil- and gas-bearing, they have demonstrated, over geologic time, their ability to retain buoyant fluids like CO_2. In addition, through exploration and production activities, the subsurface geology in theses areas usually is very well-characterized. Oil and gas operations have the appropriate infrastructure and require expertise similar to that needed for CO_2 injection. Furthermore, a project may use the injected CO_2 to extract additional oil and gas from the formation in a process known as CO_2-enhanced oil recovery, thereby creating a value for the CO_2.

However, there are additional considerations when the target is a formation where hydrocarbons are present, including statutory issues related to protection of mineral rights and ambiguities under existing frameworks as to how the project may be regulated (see Chapter 10). Although it is not clear to what degree enhanced oil recovery using CO_2 might supplant existing approaches, CO_2 capture for sequestration creates a potentially economic supply of CO_2 within the state for this purpose. The high cost of acquiring CO_2 has been a barrier to adoption of CO_2-enhanced oil recovery because there are no low-cost sources of CO_2 in California. Economic studies should establish the relationship between cost and demand for use of captured CO_2 in enhanced oil recovery in the state. Existing regulatory and statutory frameworks for enhanced oil recovery must be examined carefully to see if they are appropriate and sufficient for sequestration and, conversely, if inclusion of sequestration would disrupt existing practices.

Many proposed early carbon capture and sequestration projects in California will likely include consideration of selling captured CO_2 for enhanced oil recovery. For example, two proposed power plant projects, the BP-Rio Tinto-Edison Mission Energy petroleum coke gasification project in Carson (Los Angeles County) and the Clean Energy Systems oxy-combustion plant in Kimberlina (Kern County), include carbon capture and sequestration in conjunction with CO_2 sales for enhanced oil recovery.

Large point sources in California generally are favorably located within about 30 miles of suitable sites for geologic sequestration, including many close to oil and gas formations with enhanced hydrocarbon recovery potential. The Los Angeles Basin, the Bakersfield area, and the San Francisco–Sacramento area are key industrial areas that also have good sequestration sites. Where large industrial sources amenable to CO_2 capture do not overlie suitable geologic CO_2 sequestration sites, CO_2 will have to be transported, most likely via pipeline. The technical, economic, safety, and permitting aspects of CO_2 pipeline transport are relatively well understood because of the many pipelines in other states that transport large volumes of CO_2 for use in enhanced oil recovery. The costs and complexity of building CO_2 pipeline infrastructure in California will depend on the proximity of CO_2 sources to preferred sequestration sites, available rights-of-way, the surface terrain, and current surface land uses.

Capture Technologies and Economics

Current technologies to capture CO_2 out of flue gas are costly. However, the alternative of injecting the full flue gas stream into deep geologic formations would be prohibitive with respect to use of underground sequestration capacity, energy, and other costs. Three approaches are available to capture CO_2 from large power plants and other industrial CO_2 sources: post-combustion, pre-combustion, and oxy-firing combustion.

Carbon capture and sequestration costs are mainly due to the capital equipment and energy used to concentrate the CO_2 to a purer stream, compress it to high pressure, and transport it to a sequestration site. In general terms, keeping costs low favors large point sources near good geologic sequestration sites, use of low-cost fuels, and use of fuels high in carbon that generate higher concentrations of CO_2 in flue gas streams. Consequently, the costs of CO_2 capture generally are higher for smaller sources and for natural gas-fired plants relative to coal-fired plants.

Large industrial CO_2 sources, such as natural gas–fired power plants, cement plants, and oil refinery furnaces and boilers, do not generate emissions of high purity CO_2 in their combustion exhaust or process flue gas streams. Instead, the CO_2 is present in fairly dilute concentrations and has to be separated or captured from the main flue gas stream. In the case of power plants, coal-fired plants have higher concentrations of CO_2 in emissions flue gases compared to natural gas-fired plants, making them less expensive options for capture. Refineries fall between natural gas combined cycle and coal-based plants, but generally constitute a number of separate flue gas streams. Cement plants also have very high flue gas CO_2 concentrations. Fermentation processes at ethanol plants produce nearly pure CO_2 emissions.

Assessing the business case for carbon capture and sequestration is very challenging, in part because no policy exists presently to establish a price for CO_2 in the marketplace. Additional complicating factors include the large run up in the last several years of costs for process equipment and piping worldwide, as well as a "first-of-a-kind" premium for carbon capture and sequestration facilities. Factoring in these parameters, preliminary estimates for CO_2 capture and compression costs, which are estimated to constitute 70 to 80 percent of a CCS project's total costs, are on the order of $50 to $100 per metric ton of CO_2 removed for a range of sources, from coal-fired plants at the low end, to oil refineries at the high end. The carbon price estimated to stabilize CO_2 concentrations at 550 parts per million by 2100, according to the Intergovernmental Panel on Climate Change, is $20 to $80 per metric ton by 2030, and $30 to $155 per ton by 2050. Technologic advances could lower these ranges by $15 per ton. The panel also estimates that a sustained or increasing real price over decades of $20 to $50 per ton would be necessary to make greenhouse gas reduction options economically attractive to the power sector by 2050. However, comparisons with the carbon capture and sequestration costs are difficult because the carbon stabilization estimates were made before the recent run up in construction and materials costs.

To be practical, carbon capture and sequestration costs also must be competitive with the costs of other CO_2 emissions reduction options such as end-use efficiency improvements, renewables, and nuclear power. The run up in materials and construction costs has affected both renewables and nuclear options. For example, the Department of Energy reports increases over the last five years of over 50 percent in the costs of construction for wind turbines.[3] Thus, comparisons must be done using contemporaneous estimates. In addition, in comparing alternatives for power generation, it is important to consider the capabilities of each alternative to meet baseload and peak demand.

While trading in efficient carbon markets may prove to be the most economic way for various sectors or locations to meet any mandated emissions reductions or caps, carbon capture and sequestration technology has the flexibility to achieve reductions in many locations and major economic sectors. Applying the technology to large out-of-state coal-fired power plants targets the least costly per unit carbon and largest point sources of carbon emissions in California's emissions inventory; nevertheless, it may be necessary to establish in-state options for sequestration to attract or retain industries faced with mandated emissions reductions or caps. In-state options also may be needed in the absence of regional carbon crediting agreements among the western states. While decreasing emissions in the transportation sector relies on shifting to bio-derived fuels, geologic sequestration of ethanol plant emissions gives this sector an additional opportunity to achieve further emissions reductions.

Geologic Sequestration Project Components

In addition to considerations of economic success, projects must be designed to assure successful technical operation and protection of the health and safety of workers, the public, and the environment. Carbon capture and sequestration projects require surface and subsurface site characterization, monitoring and verification of the stored CO_2; health, safety and environmental risk assessment and management; and remediation and mitigation planning.

For carbon capture and sequestration, risk derives primarily from the potential for releases of captured gases through all phases of operation, including capture, transportation, and subsurface sequestration. Local land uses and structures, including pre-existing subsurface structures such as mines or basements, should be identified and their associated risks considered. Topography and prevailing meteorological conditions must be characterized to understand the potential impact of any significant CO_2 leak. Monitoring and verification are essential to demonstrate that geologic sequestration is safe for the public and local communities, does not create significant adverse local environmental impacts, and is effective as a greenhouse

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[3] Wiser, R. and Bolinger, M., 2007, *Annual Report on U.S. Wind Power Installation, Cost and Performance Trends: 200,* U.S. Department of Energy, Energy Efficiency and Renewable Energy <http://www1.eere.energy.gov/windandhydro/pdfs/41435.pdf>

gas control technology. Finally, remediation and mitigation procedures must be in place to cover the possibility of CO_2 leakage, whether from the sequestration formation, during pipeline transport, or from injection activities.

A CO_2 sequestration project also must be compatible with previous, current, and future uses of the site. In particular, in oil or gas producing areas, the distribution and condition of wells affect the potential for reservoir leakage. Sequestration projects also could influence future use of water and mineral resources in the area.

The degree of site characterization should reflect the goals of the project stakeholders and be appropriate to the subsurface and surface character of the site(s) under consideration. Subsurface parameters of importance include the rate at which CO_2 can be injected into the rock formation, the capacity of the rock to store CO_2, and the geologic features that affect the security of sequestration. Surface parameters include the locations of the sequestration site and the emissions source, routes of necessary pipelines, and consideration of the societal and environmental effects of infrastructure and operations. While availability of data and cost of data acquisition may be limiting, in general, site characterization information should be sufficient to

- Identify sites with low overall risk and high chance of short- and long-term success
- Provide a technical basis for decision making for financing and insurance
- Provide data for planning, including safe and successful operations
- Design and deploy monitoring and verification tools
- Quantify and manage risk

Proper site characterization is critical to proper risk assessment. Dividing the process of carbon capture and sequestration into above-ground and below-ground components aids the assessment process. Pre-injection risk assessment is associated with releases from surface facilities and engineered systems for separating, compressing, and transporting CO_2; post-injection is focused on potential impacts of releases from wells and sequestration reservoirs. Predicting the future course of events at a carbon sequestration site is particularly challenging because the site must retain injected CO_2 for at least a hundred years to be effective at reducing greenhouse gas buildup in the atmosphere. These timescales are short compared to geologic timescales, but very long compared to the timescales of typical risk assessments and to existing datasets on geologic phenomena.

One of the most important purposes of monitoring and verification is to confirm that the project is performing as expected; monitoring also is needed to ensure that natural resources, such as groundwater and recoverable oil and gas, are protected and that natural ecosystems, local populations, and livestock are not exposed to unsafe concentrations. Various monitoring techniques can verify the amount of CO_2 stored, track the CO_2 plume underground, and check for potential leakage from the sequestration formation or to the surface. Monitoring instrumentation must be reliable, economical, and capable of detecting low-level leakage while having sufficient range to register major leaks. Currently available equipment is more than adequate to meet the needs for monitoring CO_2 injection rates, wellhead and formation pressures, and occupational safety. Determining pre-injection subsurface conditions, as well as natural background levels of CO_2, is also critical to understanding project performance. Without an adequate baseline, it may not be possible to distinguish sequestration-related changes in the environment from natural variations.

All sites, even those with optimal features, must be assessed for potential human health and safety and environmental risks during the operational and post-operational phases of a project. Safety procedures to limit these risks and leakage response procedures will be necessary. Experience with storing CO_2 in geological formations suggests that the inherent risks and potential quantities of CO_2 leakage will likely be minimal. However small the risk, CO_2 leakage can result from human error, natural hazards, or other unknown factors. Procedures should cover the possibility of CO_2 migrating out of the sequestration formation(s) or other releases that might occur during pipeline transportation or injection activities that could affect worker safety, public health, the environment, or economic interests.

Existing technology and conventional data sets can readily meet the needs of carbon sequestration projects. However, CO_2 measurement and monitoring approaches suited to the large areas and long timescales relevant to geologic sequestration need further evaluation and refinement, perhaps best done through demonstration projects. Analogous industries, such as natural gas storage and enhanced oil recovery, should be studied to rigorously evaluate the potential application of their remediation and mitigation procedures to geologic sequestration. However, further efforts should address CO_2 monitoring, leak detection, and mitigation and remediation at greater spatial and time scales than those pertaining to enhanced oil recovery operations. Priorities for continued research include procedures for identifying and addressing a failure in the reservoir seal or cap rock; materials selection; and construction procedures to achieve a cost-effective means for securely reworking or plugging wells in a CO_2 sequestration environment.

From these discussions, there is a clear need to develop consistent and integrated frameworks and protocols for carbon capture and sequestration site characterization, risk assessment, monitoring and verification requirements, and mitigation and remediation planning. Projects will be more successful operationally and gain public acceptance more readily if these components are integrally linked. Currently no consensus or standard exists to set criteria for these components that will adequately or even minimally address the potential concerns of operators, regulators, and other stakeholders. Considerable relevant experience is available from the oil and gas industry, natural gas storage, and underground injection of wastes. Flexibility to tailor carbon capture and sequestration frameworks to the specific geological and geographic attributes of a sequestration site would be beneficial. It may also be appropriate to establish a minimum set of requirements.

Statutory and Regulatory Issues

For carbon capture and sequestration, as for any new technology or industry, it is important that legal and regulatory standards be established to protect the public, the environment, and the state's resources. At the same time, standards should be designed to limit economic impacts and facilitate technical innovation and advancement. In California, carbon capture and sequestration-specific regulatory and statutory frameworks do not yet exist. There is increasing activity internationally and nationally to develop these frameworks and California can benefit from study and analysis of these efforts.

This report provides a review of this issue to assess how current frameworks may apply to carbon capture and sequestration implementation in the state; however, it is not a formal legal analysis of the statutes and regulations relevant to carbon capture and sequestration. Given the complexities of the regulatory and statutory frameworks that have been identified as potentially applying to carbon capture and sequestration, a robust follow-up analysis before 2010 seems warranted to establish the potential impact of including carbon capture and sequestration under existing statutes and regulations and of the effect on existing frameworks of any new carbon capture and sequestration-specific regulations and statutes. To facilitate early projects may require determining, case-by-case, the best regulatory approaches to meet emissions mitigation goals, maintain protection of the public and local environment, and at the same time, retain business incentives to undertake carbon capture and sequestration.

Regulatory continuity is an important goal for the frameworks to be established for carbon capture and sequestration. It is possible, under current regulations, for authority to become split along the lines of reservoir type and along pre-injection (surface) and post-injection (subsurface) activities. Because of the potential to affect existing industries, particularly enhanced oil recovery operations, the ramifications of different regulatory options must be studied. Ideally, a single authority should regulate the injection, sequestration, and monitoring of CO_2 into all potential geologic reservoirs. Another area of complexity is the interplay among ownership interests and the public good and how these diverse interests should be accommodated for geologic CO_2 sequestration.

A key uncertainty is the issue of liability. While the operational risks associated with transportation, injection, and sequestration of CO_2 have been successfully managed for many years, there is major concern with sources of liability during the post-closure phase of carbon capture and sequestration, given that no time limitations have been established and thus making the term, in effect, unending. For industry, the concerns associated with this open-ended liability include the consequent inability to obtain insurance for the project, the potential to incur remediation costs related to CO_2 migration and/or leakage at some point in the distant future, and the disincentive that these potential costs may have on investment today in CO_2 geologic sequestration.

Education and Public Participation

Worldwide, the heightened level of activity on geologic sequestration research and applications reflects a growing consensus across a range of stakeholders that carbon capture and sequestration should be included in strategies to mitigate anthropogenic CO_2 buildup in the atmosphere.

A well-trained workforce to select and certify CO_2 sequestration sites, install carbon capture and sequestration infrastructure, manage operations, and respond to leakage events is critical to protecting public health, safety, and the environment and to ensuring the overall success of carbon capture and sequestration projects. Regulators who oversee geologic sequestration siting and permitting may need additional training.

Public outreach activities must provide accurate information to help the public weigh the benefits and risks, as well as the safety and mitigation measures that may be taken to manage risks. Public support and participation will be important to the success of early geologic sequestration projects, which should openly share information to demonstrate that sequestration of CO_2 can be accomplished safely.

As is true for other new technologies in the early stages of deployment, there is generally little public awareness and understanding of carbon capture and sequestration. Even though CO_2 capture and sequestration is a public good in contributing to global anthropogenic climate change mitigation, the perceptions, risks to, and benefits for the local public and communities should be acknowledged and addressed through efforts to openly share carbon capture and sequestration knowledge and pertinent project-specific information.

Recommendations

In that this is a preliminary report, which is to be followed by a more comprehensive analysis in 2010, its recommendations focus on information needed for the 2010 report, which will contain the recommendations requested by the AB 1925 legislation.

1. Over the next three years, any state planning and other analyses involving energy or greenhouse gas emissions reduction strategies, as appropriate, should include consideration of carbon capture and sequestration options. Better cost estimates should be developed, and policy makers at all levels of government should consider them an appropriate proxy for the long-term value of CO_2 reduction.
2. Further examination is needed of the scenarios for carbon capture and sequestration adoption identified in this report as early opportunities, based on potentially close-to-favorable business cases. These opportunities may have greater value than as niche applications and may facilitate creation of an in-state market for CO_2 by demonstrating enhanced oil and gas production.
3. Demonstration projects in the United States and around the world over the next three years will provide key data to set carbon capture and sequestration policy. They should be facilitated and carefully studied, and may provide early insight into public and property owner concerns about risks.
4. California's power imports encourage consideration of carbon capture and sequestration in a regional context. Coordinated investigations of carbon capture and sequestration for power plants should take place involving other states in

the Western Electricity Coordinating Council region. This should be done in the context of recognizing the connection between regional climate change and electricity generation objectives and involve consideration of how carbon responsibility should "flow" with electricity.

5. Regulatory and statutory ambiguities and barriers identified in this report must be addressed, potentially through efforts that cut across the agencies that will ultimately be involved in regulating carbon capture and sequestration, from surface facilities through injection to sequestration and verification of climate change mitigation. These efforts would include evaluating the need for protocols and, as applicable, drafting them. This would include protocols for site characterization, monitoring and verification, and contingency plans for remediating leakage.

Bill Mandatory Rpt.

BILL NUMBER: AB 1925 CHAPTERED
BILL TEXT

CHAPTER 471
FILED WITH SECRETARY OF STATE SEPTEMBER 26, 2006
APPROVED BY GOVERNOR SEPTEMBER 26, 2006
PASSED THE ASSEMBLY AUGUST 29, 2006
PASSED THE SENATE AUGUST 28, 2006
AMENDED IN SENATE AUGUST 15, 2006
AMENDED IN SENATE AUGUST 7, 2006
AMENDED IN ASSEMBLY MAY 3, 2006
AMENDED IN ASSEMBLY APRIL 17, 2006

INTRODUCED BY Assembly Member Blakeslee

FEBRUARY 1, 2006

An act relating to energy.

LEGISLATIVE COUNSEL'S DIGEST

AB 1925, Blakeslee Energy: electricity: carbon dioxide.

Existing law imposes various duties on the State Energy Resources Conservation and Development Commission, including requiring the commission to undertake a continuing assessment of trends in the consumption of electrical energy and other forms of energy and to analyze the social, economic, and environmental consequences of these trends, and to recommend to the Governor and the Legislature new and expanded energy conservation measures, as specified.

Existing law also requires the commission to adopt an integrated energy policy report that contains an overview of major energy trends and issues facing the state, including supply, demand, pricing, reliability, efficiency, and impacts on public health and safety, the economy, resources, and the environment.

This bill would require the commission, on or before November 1, 2007, and in coordination with the Division of Oil, Gas, and Geothermal Resources of the Department of Conservation and the California Geological Survey, to submit a report to the Legislature containing recommendations for how the state can develop parameters to accelerate the adoption of cost-effective geologic sequestration strategies for the long-term management of industrial carbon dioxide.

The bill would require the commission, in formulating those recommendations, to meet with specified individuals and groups. The bill would require the study for the report to be conducted using existing resources and to include specified information. The bill would require the commission to include the report in its 2007 integrated energy policy report.

The bill would require the commission to support specified research and development efforts concerning storage, capture, and sequestration of carbon dioxide.

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS:

SECTION 1. (a) (1) On or before November 1, 2007, the State Energy Resources Conservation and Development Commission, in coordination with the Division of Oil, Gas, and Geothermal Resources of the

Department of Conservation and the California Geological Survey, shall submit a report to the Legislature containing recommendations for how the state can develop parameters to accelerate the adoption of cost-effective geologic sequestration strategies for the long-term management of industrial carbon dioxide. In formulating recommendations, the commission shall meet with representatives from industry, environmental groups, academic experts, and other government officials, with expertise in indemnification, subsurface geology, fossil fuel electric generation facilities, advanced carbon separation and transport technologies, and greenhouse gas management.

(2) The study for the report shall be conducted using existing resources and shall include, but is not limited to, all of the following:

(A) Key components of site certification protocol, including seal characterization, reservoir capacity and fluid and gas dynamics, testing standards, and monitoring strategies.

(B) Integrity and longevity standards for storage sites.

(C) Mitigation, remediation, and indemnification strategies to manage long-term risks.

(3) The commission shall include the report prepared pursuant to this section in its 2007 integrated energy policy report required by Section 25302 of the Public Resources Code.

(b) The commission shall support research and development efforts to do all of the following:

(1) Identify and characterize state geological sites that potentially are appropriate for long-term storage of carbon dioxide.

(2) Evaluate the comparative economics of various technologies for capture and sequestration of carbon dioxide.

(3) Identify technical gaps in the science of sequestration of carbon dioxide, to be prioritized for further analysis.

(4) Evaluate the potential risks associated with geologic sequestration of carbon dioxide, including leakage resulting from carbonates and other dissolved minerals.

(5) Evaluate the potential risks if geologically sequestered carbon dioxide leaks into aquifers.

(6) Evaluate, and to the extent feasible quantify, the potential liability from the leakage of geologically sequestered carbon dioxide and potentially responsible parties.

(c) For purposes of this section, "commission" means the State Energy Resources Conservation and Development Commission (Chapter 3 (commencing with Section 25200) of Division 15 of the Public Resources Code).