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# Testimony for the CA Assembly Legislature Utilities and Commerce Committee

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**Testimony for the CA Assembly Legislature Utilities and Commerce Committee, April 3rd, 2006**

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Let me begin by thanking the Committee and the Assembly for inviting me to speak and present information on the topic of carbon capture and storage (sometimes called carbon sequestration or geosequestration). I am a research scientist at the Lawrence Livermore National Laboratory (LLNL) leading the Carbon Management Program. Our Laboratory is administered by the University of California for the Department of Energy's National Nuclear Security Administration. Lawrence Livermore is a multi-program laboratory with special responsibilities in national security and state-of-the-art experimental and computational capabilities that are also applied to meet other pressing national needs. In particular, LLNL pursues a broad portfolio of innovative research and development programs in energy and environmental sciences, including carbon capture and storage. It is an honor, and I believe the time is good to discuss this very promising technology pathway for greenhouse gas emissions reduction. Here I will describe the current state of knowledge and practice for carbon capture and storage, and highlight specific opportunities for benefit by deployment in California.

## Background

Fossil fuels currently satisfy over 85% of the world's commercial energy demands and can be expected to remain an important source of energy for the world for most, if not all, of this century. Fossil fuels are also the major source of greenhouse gas emissions. Indeed, with the fast growing economies of India and China relying heavily on coal, energy related $CO_2$ emissions are projected to grow significantly. In the face of this dual reality, reducing the impact of fossil fuel consumption on global climate change may very well become the biggest challenge for energy research in the 21st century. This is no less true for California, which emits 42 million tons of $CO_2$ every year from large stationary point sources like power plants, refineries, and cement plants. Importantly, much of the state's base-load electricity is generated by coal-fired plants in Nevada, Utah and Arizona, which means the state's emissions footprint is substantially larger.

A key technology approach that can reconcile our dependence on fossil fuels with the urgent need to reduce greenhouse gas emissions is termed $CO_2$ Capture and Storage (CCS). This technology separates and captures $CO_2$ out of industrial flue streams and then injects the $CO_2$ underground for long-term storage and isolation. These technologies exist today because they were developed for other purposes; their cost for deployment is competitive with other approaches to large-scale emissions reduction. However, if optimized for the purpose of CCS, the costs could be greatly reduced. Successful CCS at a large scale requires assessment, technology development, and a framework for implementation that satisfies the many stakeholders involved.

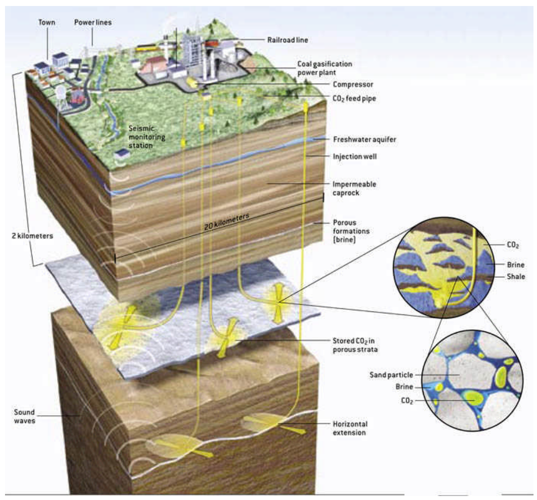
## Current Knowledge and Activities

CCS is a relatively young technology. The first paper on the topic was written in 1977, and substantial research efforts and actions began roughly 10 years ago. However, the promise of CCS has resulted in much recently study and documentation. These include a major review document by the Intergovernmental Panel on Climate Change, a white paper by the Western Governors Association, and substantial research programs in most industrialized countries. In the US, the U.S. Department of Energy (DOE) has made CCS a centerpiece of its greenhouse gas management strategy, and has formed seven regional partnerships to help develop the infrastructure for effective local deployment. The European Union, Australia, Norway, and

Canada all have large and aggressive programs in CCS, including large-scale pilot demonstrations and efforts at developing new regulatory and legal frameworks. Importantly, industry has shown tremendous leadership and has embraced CCS as a technology. Most notable among them is BP, who has created a decarbonized fuel business unit and announced a large project in Carson, CA to demonstrate the technology and verify its cost and performance.

In order to be successful, CCS requires a process called carbon capture, which targets large stationary sources. Some industrial processes (e.g., natural gas processing, refining, hydrogen and ammonia production) produce a concentrated stream of $CO_2$. However, power plants (primarily coal-fired) make up the largest single class of emitters, and their $CO_2$ is produced at low concentrations (<15%). Cement plant streams have ~25-35% concentration streams because $CO_2$ is liberated from limestone to form clinker. In these cases, the $CO_2$ must be separated from the flue gas (to concentrations over 95%) and compressed to a liquid-like phase to make it suitable for transport (usually via pipeline) and storage. This process is expensive: as a consequence, the DOE and many private companies have large research programs looking for ways to substantially reduce the costs of separation.

For storage, $CO_2$ can be injected into porous and permeable geological formations. The main targets for geological storage are depleted oil and gas reservoirs and deep (> 800 m) saline aquifers. Successfully storage of $CO_2$ for long periods of time (more than hundreds of years), a target reservoir requires three things:




*Schematic diagram of a large $CO_2$ injection project into two formations. A monitoring array tracks $CO_2$ behavior in the subsurface. From Socolow, 2005*

- **Injectivity**: so that large volumes can be injected at a high sustained rate. This requires permeable strata.
- **Capacity**: the formation can contain large volumes of $CO_2$ (tens of millions of tons). This requires large pore volumes.
- **Effectiveness**: the site must trap and store $CO_2$ with extremely small leakage over long times. This requires parameters such as at least one good sealing unit and good performance of plugged and abandoned wells.

Fortunately, there is well established technology to execute these tasks. Commercial carbon capture technology has operated for nearly 100 years, providing dry ice and $CO_2$ for carbonated drinks. Companies have injected and recovered large volumes of natural gas for over 100 years, and oil companies have injected $CO_2$ underground for enhanced oil recovery for over 30 years. This knowledge and experience is supported by study of natural systems, where $CO_2$ has remained trapped underground at high pressures for tens of millions of years. In other words, the key elements are understood, and the technical capabilities exist to deploy CCS at large scale today.

Importantly, all hydrogen production from fossil fuels produces a stream $H_2$ and $CO_2$ suitable for storage. As such, CCS is considered an important bridging technology for a hydrogen economy and infrastructure.

## CCS in California

California has the right mix of point sources, potential injection targets, and technical expertise to successfully execute large-scale CCS. The specific character of each of these provides the State with unique benefits opportunities, and technology needs for CCS.

- The mix of point sources is unique. It includes an emphasis on natural gas power generation, large pure point sources at refineries, a large cement industry, and a large number of biomass power plants. In contrast, many states and regions are dominated by concerns about coal power generation although a lot of imported electricity is coal base-load
- The geological targets are also somewhat unique. The complex and young geology of California has created a number of young sedimentary basins and young strata. Also, unlike many states, there are large oil and gas reserves, which have built a data and technology infrastructure well suited for $CO_2$ storage. It also creates economic opportunities in the form of enhanced oil recovery (EOR) and enhanced gas recovery (EGR) which can serve as an anchor and economic driver for deployment and infrastructure development.
- The State has an outstanding technical workforce for CCS deployment. It includes the following elements:
  - The California Energy Commission, which leads WESTCARB, one of the DOE funded regional carbon sequestration partnerships.
  - Lawrence Livermore National Laboratory and Lawrence Berkeley National Lab, which are both internationally recognized leaders in CCS science and technology.
  - The strength of the University of California system, and other very strong in-state Universities (Stanford, USC).
  - Key state agencies, such as the California Geological Survey
  - A particularly strong industrial base, including oil and gas companies (Chevron, AERA, Occidental), engineering firms (Bechtel), the Electric Power Research Institute (EPRI), CO2 capture experts (Nexant, SPA Pacific), and novel concept companies (e.g., Clean Energy Systems).

These components help support a burgeoning CCS industry, which can provide benefits in terms of technical leadership and export industry. They can also help to meet new policy positions within the California Government towards substantial emissions reductions:

- The Governor's emissions reduction goals for 2010, 2020, and 2050
- The California PUC's recommendations regarding carbon caps on all base-load, including out-of-state generation
- The President's goals of technology development for emissions reductions
- The State's interests in development of a hydrogen infrastructure and economy

Finally, this technical and programmatic leadership may have strong economic benefits.

- New energy supply and revenue from enhanced oil and gas recovery.
- New revenue and service industries trading emissions credits.
- New technology industries in California, including monitoring technology, $CO_2$ simulation, and $CO_2$ capture devices

## Important considerations

Because of California's unique industrial, environmental, and stakeholder interests, it is important to consider what kind of CCS program would be most relevant to the state. A successful program that would both show national leadership and serve the state's energy and environmental needs should have these component elements:

1. *To identify and characterize the key basins and geological formations appropriate for potential long-term storage*. The DOE-funded Westcarb regional partnership and the California Geological Survey have begun this process. However, detailed information of the distribution of porous, permeable, and secure units is required to both site injection projects and to understand the extent of the state's resource. Models for this effort include Australia's GEODISC

program or the Alberta Research Councils assessment of the Alberta Basin in Canada.

2. *To identify characterize, compare, and evaluate the economics and performance of various techniques to capture, transport, and store $CO_2$*. Given the nature of California stationary sources, it is worth examining what technologies might serve $CO_2$ capture efforts best. This might serve as a basis for technology development program at some later date.

3. *To identify and develop technologies for deployment of carbon capture and storage that are particularly appropriate for CA energy and industrial systems*. Current efforts to improve or enhance existing technologies should be assessed. There may be technologies that are close to deployment or extremely promising in general which could benefit from additional support. This could involve the University of California system, agencies such as the CEC, advanced technology development programs, and matching funds for DOE proposals. Models for this kind of program include Australia's CO2CRC and the $CO_2$ Capture Project.

4. *To identify the necessary components of a stable regulatory framework that would foster and facilitate carbon sequestration technologies*. This would likely involve many agencies and stakeholders to assemble the information relevant to non-technical considerations of deployment. Such a framework would itself have several key components:

    a. Site selection protocols that could serve as a basis for certification process. The protocols would almost certainly involve some characterization of injectivity, capacity, and effectiveness and would be informed by current technical knowledge and best practices.

    b. Development of standards for site performance, including integrity, monitoring, storage duration, and acceptable risk. This information has a technical basis, and would provide stability and sureness to financiers, operators, insurers, and regulators.

    c. Protocols or rubrics to manage failure or leakage from a site. This could take many forms and mechanism; just beginning this discussion would show leadership and provide clarity to stakeholders.

    d. An identification of the key stakeholders in CA and development of a process for their involvement. This component could include outreach and education, public hearings, or some other means of exchanging information.

    This task could be well informed by the formation of a state task force comprising experts in geological storage, $CO_2$ capture and separation, California industry and land use, and other appropriate disciplines. These individuals could make technical recommendations to decision makers and stakeholders and serve as an additional resource.

Thank you, Mr. Chairman for your commitment to enhance California's future by considering the potential to facilitate and provide incentives for cost effective strategies to contain, sequester and recycle carbon dioxide that is created during the generation of electricity. The scientific community appreciates the Committee's leadership in this area.

## Useful References and Resources

Intergovernmental Panel on Climate Change, IPCC Special Report on Carbon dioxide Capture and Storage, 2005, Interlachen, http://www.ipcc.ch/activity/srccs/index.htm.

Summary for Policy Makers: http://www.ipcc.ch/activity/ccsspm.pdf
Geological Storage (S. Benson & P. Cook): http://www.ipcc.ch/activity/srccs/SRCCS_Chapter5.pdf
Capture of CO2 (Thambimuthu et al)): http://www.ipcc.ch/activity/srccs/SRCCS_Chapter3.pdf
Cost & Economic Potential (Herzog & Smekens): http://www.ipcc.ch/activity/srccs/SRCCS_Chapter8.pdf

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Bradshaw J, Allison G, Bradshaw BE, Nguyen V, Rigg AJ, Spencer L, Wilson, P., Australia's $CO_2$ Geological storage potential and matching of emission sources to potential sinks. In: Greenhouse gas control technologies: Proceedings of the 6th International Conference on Greenhouse Gas Control Technologies, 1–4 October 2002, Kyoto, 2003

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## Useful Resources

West Coast Regional Carbon Sequestration Partnership (WESTCARB): http://www.westcarb.org/index.htm

International Energy Agency (IEA) Greenhouse R&D Programme, $CO_2$ Capture and Storage: http://www.ieagreen.org.uk/ccs.html

$CO_2$ Capture Project: http://www.co2captureproject.org/index.htm

Carbon Sequestration Homepage, LLNL: http://eed.llnl.gov/co2/

GEODISC, Australian National CO2 Storage Assessment: http://www.apcrc.com.au/Programs/geodisc_res.html

CO2CRC, Australian Cooperative Research Center: http://www.co2crc.com.au/