

CHANGE REQUEST for FY 08-09 BUDGET REQUEST CYCLE

Department:	Natural Resources
Priority Number:	12 of 18
Change Request Title:	Carbon Sequestration for Cleaner Air

SELECT ONE (click on box):

- Decision Item FY 08-09
- Base Reduction Item FY 08-09
- Supplemental Request FY 07-08
- Budget Request Amendment FY 08-09

SELECT ONE (click on box):

Supplemental or Budget Request Amendment Criterion:

- Not a Supplemental or Budget Request Amendment
- An emergency
- A technical error which has a substantial effect on the operation of the program
- New data resulting in substantial changes in funding needs
- Unforeseen contingency such as a significant workload change

Short Summary of Request:

The Colorado Geological Survey (CGS) requests an increase of \$72,392 cash funds in its base revenue from the Operational Account of the Severance Tax Trust Fund and one additional full-time equivalent (FTE) to investigate and develop data regarding Colorado's potential for carbon sequestration in the Canon City Embayment and in northwestern Colorado.

Background and Appropriation History:

Carbon sequestration is the process of trying to mitigate climate change by storing captured carbon dioxide (CO₂) from point sources, such as power plants, in geologic features instead of releasing it into the atmosphere. In order to do this effectively it is necessary to identify areas where captured carbon could be stored, and participate in or initiate pilot storage projects to assess the costs and effectiveness of storage. Since 2003, CGS has taken the lead in identifying the largest sources of carbon dioxide emissions throughout Colorado as well as the geological environments in the state that may provide potential long-term carbon storage (sinks). CGS is the only state agency that has documented their findings for public access in a report entitled *CO₂ Sequestration*

*Potential of Colorado*¹. CGS has also participated in recent Department of Energy (DOE) studies on carbon sequestration. CGS's work since 2003 in the DOE-sponsored Southwest Regional Partnership on CO₂ sequestration has been largely funded by federal grants.

Some key highlights on the ongoing work by the Colorado Geological Survey in the CO₂ sequestration arena include the following:

Sources

CO₂ emissions in 1999 were more than 86 million tons in Colorado and are projected to increase by 1.5 percent per year reaching 127 million tons in 2025. Power generation in the state primarily relies on coal and, as a result, 36 million tons of CO₂ or 42 percent of the total emissions for Colorado are emitted from power plants in the utility sector. If Colorado were ranked among the countries of the world by its estimated 2003 carbon dioxide emissions, Colorado would rank as the 35th highest carbon dioxide producer².

Sinks

Geologic storage options for CO₂ in Colorado include deep saline aquifers, depleted and marginal oil fields, natural gas and CO₂ fields, deep unmineable coal beds, and advanced mineralization engineering. CO₂ sequestration capacity for deep saline aquifers is estimated to range from 167 billion tons to more than 668 billion tons based on a one to four percent efficiency factor in the storage process, respectively. This represents a 3- to 12-fold increase over the combined storage estimates for oil, gas, coal, and mineralization options. Further, deep saline aquifers may provide several centuries' worth of carbon storage potential if the process is only one percent efficient. The storage potential is widely distributed throughout the state with eastern Colorado providing 44 percent, northwestern Colorado 42 percent, and southwestern Colorado the remaining 14 percent. Synergetic opportunities may exist for carbon sequestration demonstrations via enhanced recovery projects (oil, gas, and coalbed methane), where CO₂ is injected into fields with declining production to increase resource recovery. This may be particularly

¹ Young, G. B.C. and others, 2007, CO₂ Sequestration Potential of Colorado, Colorado Geological Survey Resource Series 45

² http://www.nationmaster.com/graph/env_co2_emi-environment-co2-emissions

viable where economic sources of anthropogenic CO₂ (human generated as opposed to naturally occurring) exist nearby mature producing fields amenable to miscible flooding. Such projects may serve as the required catalyst to promote longer-term carbon storage programs due in part to their potential for offsetting costs with revenue-generating capability as well as revitalizing some of the state's oil producing provinces. Further study is required to evaluate potential storage opportunities in eastern and southwestern Colorado.

Costs

The combustion of fossil fuel produces a contaminated flue gas that is approximately 80 percent nitrogen and only 20 percent carbon dioxide by volume. Purification of flue gas via carbon capture and storage (CCS) can be accomplished with either Integrated Gasification Combined Cycle (IGCC) or Pulverized Coal (PC) power generation technology. CCS costs add approximately 40 to 50 percent to the cost of electricity for IGCC and 70 to 90 percent for PC with bituminous coals. Although there is considerable variability in cost data with location and type of coal, the average cost of CCS is approximately \$55/metric ton of avoided CO₂ for both technologies.

Pilot Projects

The Colorado Geological Survey is a participating member of the Southwest Regional Partnership (SWP) on CO₂ Sequestration, one of seven partnerships created by the U.S. Department of Energy (U.S. DOE) in 2003. The SWP is currently conducting three geologic pilots, one each in the San Juan Basin Fruitland coal, Greater Aneth field in the Paradox Basin, and at SACROC in the Permian Basin. CGS is taking a key role in the design, implementation, and analysis of the San Juan Basin pilot because of the division's particular expertise in coalbed methane development. In addition, CGS is co-lead for the Site Characterization technical team for all three pilot projects, as well as the point-of-contact for the Site Characterization, Reservoir Modeling, and Data Archiving technical teams.

Larger-Scale Deployment

The U.S. DOE plans to establish multiple CCS demonstrations on the scale of one million metric tonnes CO₂ sequestered per year. Site characterization for larger-scale

deployment projects will be initiated in late 2007 with injection to be initiated mid-2008, and monitoring to extend through 2017. The SWP selected the Raton Basin of Colorado as its large-scale demonstration project. The SWP has submitted a proposal to DOE to establish a large-scale demonstration project in the Raton Basin of Colorado. Plans are to inject anthropogenic CO₂ into the Entrada Formation which is an extensive saline aquifer in the basin.

The Mineral Resources and Mapping Long Bill Line Item appropriation has not increased (other than the Option 8 calculation) until figure setting for FY07. At that time the federal funds were decreased with a corresponding decrease of 2.0 FTE (from 11.5 to 9.5). Last year, Change Request #7, "*Address Current and Emerging Geologic Issues*," increased the severance tax funds for this long bill line item by \$77,817 and one FTE (from 9.5 to 10.5).

General Description of Request:

CGS currently does not have a sufficient allocation of FTE to address carbon sequestration research, data acquisition, and communication with the industry on a consistent basis in areas other than the Raton Basin project. Currently, CGS can only address CO₂ sequestration for the SWP with part of an existing position. The current workload has this FTE fully occupied. Funding for current work in the Raton Basin has been received through a federal grant from the U.S. DOE via the New Mexico Institute of Mining and Technology. However, this funding is to be used for projects for the SWP and is not to be used for research into developing CO₂ sequestration in other areas of Colorado. The technology derived in the Partnership's projects and the knowledge gained by CGS scientists is extremely important in reducing carbon dioxide emissions in the State. Colorado should take advantage of these technologies and knowledge statewide. The requested FTE would perform additional CO₂ sequestration studies for Colorado in areas not being addressed by the Partnership, which is most of Colorado. The position will also seek outside funding (federal and other) to increase the number of applied CO₂ sequestration projects and studies in Colorado. An FTE fully devoted to sequestration is needed to study opportunities to apply CO₂ sequestration technology in other areas of the state.

Consequences if Not Funded:

Without a defined FTE who can devote a significant effort to carbon sequestration in Canon City and northwestern Colorado, Colorado will not be able to take advantage of this technology and reduce its CO₂ emissions to ensure cleaner air for its citizens.

Calculations for Request:

Summary of Request FY 08-09	Total Funds	General Fund	Cash Funds	Cash Funds Exempt	Federal Funds	FTE
Total Request			\$72,392			1.0
Salary			\$59,664			
PERA			\$6,056			
FICA			\$865			
Amortization Equalization Disbursement (AED)			\$955			
Supplemental Amortization Equalization Disbursement (SAED)			\$447			
Operating Expenses			\$4,405			

Summary of Request FY 09-10	Total Funds	General Fund	Cash Funds	Cash Funds Exempt	Federal Funds	FTE
Total Request			\$69,235			1.0
Salary			\$59,664			
PERA			\$6,056			
FICA			\$865			
Prior Year SAED			\$447			

Summary of Request FY 09-10	Total Funds	General Fund	Cash Funds	Cash Funds Exempt	Federal Funds	FTE
Amortization Equalization Disbursement (AED)			\$955			
Supplemental Amortization Equalization Disbursement (SAED)			\$298			
Operating Expenses			\$950			

Assumptions for Calculations:

Salary calculation is based on \$4,972 per month for a Physical Science Researcher/Scientist II position (range minimum).

In accordance with calculation instructions from OSPB, PERA is calculated at 10.15% and FICA is calculated at 1.45% of base pay. Operating expenses for the first year consist of:

Supplies	\$	500
Computer (desk top)	\$	900
Office Suite Software	\$	330
Office Equipment	\$	2,225
Telephone Base	\$	450
Total Operating Expenses, Year 1	\$	4,405

For year 2 (FY09-10), Operating expenses consist of Supplies at \$500 and annual telephone base at \$450. Salary base, PERA, FICA, and AED remain the same. Prior year Supplemental Amortization Equalization Disbursement (SAED) is added to the personal services base.

Impact on Other Government Agencies:

Not applicable.

Cost Benefit Analysis:

The overall environmental benefits of CO₂ sequestration are significant in terms of reducing greenhouse gas emissions and the adverse health effects of air pollution. Yet, it is difficult to assign specific, verifiable monetary values to these benefits for Colorado,

especially since the benefits are worldwide in scope. The State of Colorado can benefit in two specific and quantifiable ways from CO₂ sequestration that benefit the natural resources industry as well as the environment. These are:

- 1) **Enhanced Oil and Gas Recovery** – Enhancing oil and gas recovery from older producing fields increases economic activity in Colorado and enhances severance tax and royalty revenues to the state.
- 2) **Enhanced CO₂ Commodity Sales** – Carbon dioxide has intrinsic value as a commodity and can be sold for beneficial uses such as enhanced oil and gas recovery and other uses.

Enhanced Oil and Gas Recovery

Enhanced oil recovery (EOR) refers to techniques that allow increased recovery of oil in depleted or high viscosity oil fields. One method of EOR, carbon dioxide flooding (CO₂-EOR), has the potential to not only increase the yield of depleted or high viscosity fields, but also to sequester carbon dioxide that would normally be released to the atmosphere. In general terms, carbon dioxide is flooded into an oilfield through a number of injection wells drilled around a producing well. Injected at a pressure equal to or above the minimum miscibility pressure (MMP), the CO₂ and oil mix and form a lower viscosity liquid that more easily flows to the production well. Recovery can also be enhanced by injecting CO₂ at a pressure below the MMP, swelling the oil and reducing its viscosity.

A recent study titled “Basin Oriented Strategies for CO₂ Enhanced Oil Recovery: Rocky Mountain Region”³ is helpful in quantifying the benefits of enhanced oil and gas recovery in Colorado. The following table summarizes the economic potential of CO₂ enhanced oil and gas recovery in Colorado.

³ Advanced Resources International; "[Basin Oriented Strategies for CO2 Enhanced Oil Recovery: Rocky Mountain Region](#)", prepared for U.S. Department of Energy, Office of Fossil Energy - Office of Oil and Natural Gas, February, 2006.

	(a) No. of Reservoirs Studied	(b) Original Oil In- Place	(c) Technical Potential	Economic Potential		
CO ₂ -EOR Technology ⁴		(million barrels)	(million barrels)	(d) No. of Reservoirs	(e) (million barrels)	
Traditional Practices	12	2,956	330	2	30	*
State of the Art	12	2,956	740	5	510	*
More Favorable Financial Conditions (higher per barrel price of oil)						
Risk Mitigation Incentives	12	2,956	740	6	510	**
Low Cost CO ₂ Supplies	12	2,956	740	8	580	***
* Oil price of \$30 per barrel; CO ₂ costs of \$1.50/Mcf.						
** Oil price of \$40 per barrel adjusted for gravity and location differentials; CO ₂ supply costs of \$2.00/Mcf.						
*** Oil price of \$40 per barrel adjusted for gravity and location differentials; CO ₂ supply costs of \$0.80/Mcf.						

Legend:

- (a) Number of oil reservoirs in Colorado studied.
- (b) Original Oil In-Place – Number of barrels in millions originally identified as extractable without additional efforts.
- (c) Technical Potential – Number of additional barrels in millions that can be feasibly extracted using Enhanced Oil Recovery technology.
- (d) Economic Potential, number of reservoirs – The number of reservoirs that contain “stranded in place oil”, which is that oil that cannot be extracted without additional effort, such as using CO₂ flooding technology.

⁴ Ibid. Table 16 and Table 17.

- (e) Economic Potential, number of barrels – number of barrels in millions that were stranded and may be extracted from existing reservoirs using enhanced oil recovery practices.

In this table, “Traditional Practices” means the technology level used in CO₂ enhanced oil recovery is the same that has been applied in the past in the Rocky Mountain Region. “State of the Art” assumes that improved CO₂ processes that have been achieved in other areas over the past ten years are successfully applied to the oil reservoirs of the Rocky Mountain region. This is a reasonable assumption. If more favorable financial conditions prevail, the economic potential of enhanced oil and gas recovery improves.

The 20-year cost of an FTE is \$1,400,000 (rounded). Even with “Traditional Practices” the economic impact of CO₂ enhanced oil and gas recovery of 30 million additional barrels is, conservatively, \$645,000,000⁵ Part of this economic impact is direct revenue to the state from severance taxes and royalty payments.

Enhanced CO₂ Commodity Sales

Carbon dioxide has been produced from a naturally occurring CO₂ field, called Sheep Mountain, in Huerfano County for many years. Unfortunately production has declined in this field since 1999. The county has lost considerable income from declining production. The field produced 45 billion cubic feet (Bcf) in 1999 down to 16.2 Bcf in 2006. The contract price for CO₂ was \$0.65/Mcf in 2006. That translates to a loss of over \$18 million in sales since 1999. If an FTE could be involved in efforts to replace that natural CO₂ with anthropogenic CO₂, it would more than offset the 20-year cost of an FTE.

⁵ Calculation: 30 million barrels x (\$30/barrel – \$8.50/barrel for enhanced recovery infrastructure and CO₂ costs) = \$645,000,000

Proposed Action	Estimated Benefit	Estimated Cost	Benefit – Cost Ratio
Add 1.0 FTE and associated severance tax funding	<ul style="list-style-type: none"> ▪ \$322,500,000/20-year period – From additional oil production. 15 million barrels (one reservoir) x \$21.50/barrel (\$30/barrel – \$8.50/barrel for enhanced recovery infrastructure and CO₂ costs) ▪ Offset \$9,000,000 in lost CO₂ commodity sales 	<ul style="list-style-type: none"> ▪ \$1,400,000 /20-year period for 1.0 FTE 	\$331,500,000/ \$1,400,000 or 237 to 1

Implementation Schedule:

Task	Month/Year
Write Position Description Questionnaire	May, 2008
Open the Application Window to the Public	May, 2008
Review, Interview, and Hire New Position	June, 2008
FTE Hired / New Employee Begins	July, 2008

Statutory and Federal Authority:

Section 34-1-103, C.R.S. (2006) Objectives of survey – duties of state geologist.

(1) The Colorado geological survey shall function to provide assistance to and cooperate with the general public, industries, and agencies of state government, including institutions of higher education, in pursuit of the following objectives, the priorities of which shall be determined by mutual consent of the state geologist and the executive director of the department of natural resources:

- (a) To assist, consult with, and advise existing state and local governmental agencies on geologic problems;*
- (b) To promote economic development of mineral resources;*
- (c) To conduct studies to develop geological information;*
- (d) To inventory and analyze the state's mineral resources as to quantity, chemical composition, physical properties, location, and possible use;*
- (e) To collect and preserve geologic information;*

- (f) To advise the state and act as liaison agency on transactions dealing with natural resources between state agencies and with other states and the federal government on common problems and studies;*
- (g) To evaluate the physical features of Colorado with reference to present and potential human and animal use;*
- (h) To prepare, publish, and distribute reports, maps, and bulletins when necessary to achieve the purposes of this part 1, but in accordance with section [24-1-136](#), C.R.S.;*
- (i) To determine areas of natural geologic hazards that could affect the safety of or economic loss to the citizens of Colorado;*
- (j) To advise the state engineer in the promulgation of rules and regulations pursuant to article [90.5](#) of title [37](#), C.R.S., and to provide other governmental agencies with technical assistance regarding geothermal resources as needed;*
- (k) To promote safety by reducing the impact of avalanches on recreation, industry, and transportation in the state through a program of forecasting and education conducted by the Colorado avalanche information center.*

Section 39-29-109, C.R.S. (2006) Severance tax trust fund - created - administration - use of moneys - repeal.

(1) (a) There is hereby created in the office of the state treasurer the severance tax trust fund. The fund is to be perpetual and held in trust as a replacement for depleted natural resources and for the development and conservation of the state's water resources pursuant to sections 37-60-106 (1) (j) and (1) (l), 37-60-119, and 37-60-122, C.R.S., and for the use in funding programs that promote and encourage sound natural resource planning, management, and development related to minerals, energy, geology, and water.

Performance Measures:

CGS believes that this decision item is consistent with the Department's vision statement on energy as contained in the FY08-09 Strategic Plan for the Department of Natural Resources. The energy vision statement is as follows:

Promote responsible and sustainable development of Colorado's energy and mineral resources in a manner that is consistent with environmental protection, maintenance of Colorado's quality of life, and protection of Colorado's diverse economic base. Promote

renewable energy, innovative technology, and energy efficiency as part of sustaining Colorado's long term energy supply.

<u>Performance Measure:</u>	<u>Outcome</u>	<u>FY 05-06</u> <u>Actual</u>	<u>FY 06-07</u> <u>Actual</u>	<u>FY 07-08</u> <u>Approp.</u>	<u>FY 08-09</u> <u>Request</u>
Promote the responsible economic development of mineral and energy resources (expressed as the percent of counties in the state and state departments receiving assistance in mineral and energy resources from CGS).	Benchmark	5%	5%	5%	5%
	Actual	5%	10%		
This change request will increase the number of counties in the state and state departments receiving information and technical assistance from the Colorado Geological Survey. CGS expects, as part of this decision item, to interact with the following counties: Fremont, Pueblo, El Paso, Custer, Mesa, Garfield, Rio Blanco, and Moffat. This would increase the Performance Measure Actual for FY08-09 by 7%.					