



UNIVERSITY OF WYOMING
SCHOOL OF ENERGY RESOURCES

2009 REPORT OF THE CLEAN COAL TASK FORCE

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Presented to the Joint Minerals, Business and Economic Development Interim Committee

Report of the Clean Coal Task Force
To The
Joint Minerals, Business, and Economic Development Interim Committee
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Background

2007 House Bill 301 created the Clean Coal Task Force (CCTF) consisting of the members of the current University of Wyoming Energy Resources Council. That legislation appropriated \$2.5 million to an account that could only be expended upon appropriation by the Legislature. The legislation also directed the CCTF to solicit proposals for research in clean coal technologies and required that the appropriation could not be disbursed unless there was a dollar for dollar match for the research from non-state funds.

In September 2007, the CCTF recommended funding of four proposals (Table 1). The recommendation was endorsed by the Joint Minerals, Business, and Economic Development interim Committee, and money was appropriated by the Legislature to fund those projects. The total amount appropriated in the first round was \$1,822,481, leaving \$677,519 unspent.

Section 320 of the Legislature of the State of Wyoming's 2008 Budget Bill authorizes the Wyoming Department of Environmental Quality (DEQ) to submit a grant application to the federal government for Abandoned Mine Lands (AML) funds for specified purposes. One project secured and additional \$3.8 million for clean coal research to be expended pursuant to Section 2(f) of Original House Bill No. 301, Enrolled Act No. 121, to be added to the Clean Coal Research Account. Section 325 of the 2008 budget bill actually creates Section 2(f) by amending the 2007 legislation. Unlike the \$2.5 million appropriation in 2007, the CCTF is authorized to expend the \$3.8 million once the recommended projects are submitted to the Joint Minerals, Business and Economic Development Interim Committee for review.

The 2008 legislation also provides for funding additional research projects from the remainder of the original \$2.5 million that was not committed in the first round. The \$677,519 is now subject to the same process as the \$3.8 million, i.e., the CCTF has the authority to expend the funds. The 2008 legislation extended the deadline for expenditure for all of the funds to June 30, 2010. In September 2008, the CCTF approved funding for five of the eight submitted proposals (Table 2). Funding for the successful proposals totaled \$2,672,120, leaving \$1,127,880 for allocation to future projects.

Chapter 57 of the Legislature of the State of Wyoming's 2009 General Session Law extends the sunset date for the Clean Coal Task Force (CCTF) from June 30, 2010, to June 30, 2013 (section 2). Section 5 (a) provides that the 2007 general fund appropriation to the clean coal research account will not revert on June 30, 2010, but can continue to be used for clean coal research until the reversion date of June 30, 2012, which now applies to all of the funds.

Table 1. 2007 Clean Coal Technology Fund Endorsed Projects.

Proposal Title	Submitted By	Funding Requested	Outside Match	Outside Match Organization	Project Total Funds	Technology Areas
(2007-1) Pre-Gasification Treatment of PRB Coals for Improved Advanced Clean Coal Gasifier Design	Western Research Institute	\$399,981	\$399,981	DOE National Energy Technology Lab	\$799,962	Pre-combustion/ pre-gasification technologies
(2007-2) Capture & Mineralization of Carbon Dioxide from Coal Combustion Flue Gas Emissions: Pilot Scale Studies	Dept. of Renewable Resources, UW	\$485,000	\$487,115	Jim Bridger Power Plant	\$972,115	Carbon capture technologies
(2007-3) Carbon Capture from Coal Flue Gas on Carbonaceous Sorbents	Supercritical Fluids, Inc. Laramie, WY.	\$375,000	\$375,000	PacifiCorp EPRI Supercritical Fluids, Inc.	\$750,000	Carbon capture technologies
(2007-4) Novel Fixed-Bed Gasifier for Wyoming Coals	Emery Energy Company, Salt Lake City, UT.	\$562,500	\$562,549	Emery Energy Co. WRI	\$1,125,000	Combustion and gasification design technologies

Totals \$1,822,481 \$1,824,596 \$3,647,077

Table 2. 2008 Clean Coal Technology Fund Endorsed Projects.

Proposal Title	Submitted By	Funding Requested	Outside Match	Outside Match Organization	Project Total Funds	Technology Areas
(2008-1) Development of a New Solid Sorbent for CO ₂ Separation	UW Chemical & Petroleum Engineering	\$250,267	\$253,394	EnviroTech	\$503,661	Carbon capture technologies
(2008-2) Geologic Sequestration of CO ₂ in the Rock Springs Uplift(Southwest Wyoming): Experimentation and Modeling of CO ₂ /Brine Relative Permeability, Hysteresis, Permanent Capillary Trapping and Salt Precipitation	UW & Penn State	\$500,000	\$500,000	UW Research Penn State	\$1,000,000	Sequestration technologies
(2008-3) A Novel Integrated Oxy-Combustion Flue Gas Purification Technology - A Near Zero Emissions Pathway	Western Research Institute (WRI)	\$1,454,552	\$1,454,552	DOE Southern Co.	\$2,909,104	Combustion and gasification design technologies; post-combustion gas clean-up
(2008-4) Feasibility of Hydrothermal Dewatering for the Potential to Reduces CO ₂ Emissions and Upgrade Low Rank Coals	EERC/Pavlish	\$70,000	\$70,000	DOE	\$140,000	Pre-combustion coal technologies
(2008-5) Coal Electrolysis for the Production of Hydrogen and Liquid Fuels	Ohio University	\$397,301	\$397,332	Ohio University	\$794,633	Coal-to-liquids/coal-to-hydrogen technologies

Totals \$2,672,120 \$2,675,278 \$5,347,398

Finally, Chapter 159, Section 339 of the Legislature of the State of Wyoming's 2009 General Session Law authorizes the DEQ to submit grant application for an additional \$10,613,047 to be added to the Clean Coal Research Account.

To summarize, three separate appropriations of funds have been made to the Clean Coal Research Account:

Appropriation	Amount
2007 Appropriation	\$2,500,000
2008 Appropriation	\$3,800,000
2009 Appropriation	\$10,613,047
Subtotal	\$16,913,047
2007 Commitments	(\$1,822,481)
2008 Commitments	(\$2,672,120)
Remaining Balance	\$12,418,466

In total, nine projects have been funded and the Clean Coal Research Account currently holds \$12,418,446 to fund new research.

Proposals for Research

The CCTF authorized the distribution of a third request for proposals on April 7, 2009 (http://www.uwyo.edu/sersupport/Clean_Coal/Clean_Coal_RFP/Wyoming_Clean_Coal_RFP_2009.pdf) with a submission deadline of August 3, 2009. Areas of research eligible for consideration remained the same as in the previous RFP, but language in the request emphasized that the CCTF seeks to fund technology demonstration projects as well as technology development research. In all, 22 proposals were submitted and a total of \$15,663,827 was requested.

Each proposal was reviewed initially for compliance with the proposal guidelines, especially verification of the outside match. Then, each proposal was submitted to two qualified external reviewers with relevant technical expertise. The proposals were evaluated against the criteria described in the RFP. These reviews were taken into consideration fully by the CCTF.

The Task Force met on August 28, 2008 to review and evaluate 21 proposals (one failed to comply and was withdrawn). In accordance with the 2008 legislation referenced above, the CCTF submits the following recommendation to fund eight proposals. Funding these projects will utilize \$5,952,766 from the Clean Coal Account. The Task Force endorses funding these proposals in light of their being the best methods for achieving sustained research for clean coal technologies in Wyoming. It should be noted that some of these proposals contain proprietary information so that only summary information can be shared openly. Task Force members and reviewers executed non-disclosure agreements with each submitting organization to protect their confidentiality as a condition of their being made available for review.

Projects endorsed by the CCTF for funding are as follows, and information concerning project finance and matching funds for each project is contained in Table 3.

1. “Cryogenic Carbon Capture”, submitted by Sustainable Energy Solutions, Principal Investigator – Dr. Larry Baxter. This project will investigate a new design for a fully integrated bench-scale cryogenic carbon capture unit that promises to reduce cost and energy consumption for carbon capture versus standard CO₂ absorption processes.
2. “Removal of Synthesis Gas Pollutants and Liquid Fuel Synthesis”, submitted by Ceramatec, Inc. and Western Research Institute (WRI), Principal Investigators – Dr. S. Elango Elangovan and Dr. Vijay Sethi. This project seeks to develop and test a novel modular, mine-mouth deployable fixed-bed Fischer Tropsch reactor and a unique catalyst that has high conversion and selectivity in the JP5 range.
3. “Demonstration of Hydrogen Production from Wyoming Coal”, submitted by The Energy & Environmental Research Center, Principal Investigators – Joshua Stanislawski and Jason D. Laumb. This project will conduct a long-term demonstration of coal-to-hydrogen production using warm-gas cleanup techniques and H₂ separation membranes. It offers an alternative to traditional carbon capture technology, as well.
4. “Development and Evaluation of Non-Carbon Sorbents”, submitted by WRI, Amended Silicates, Inc, and NanoScale Corp., Principal Investigators – Dr. Khalid Omar, Dr. Slowomir Winecki, and Mr. James Butz. This project will develop, characterize and test sorbents for in-flight capture of pollutants in pulverized coal-derived gasses.
5. “Extended Operational Runs on Emery Hybrid Gasifier to Accelerate Commercial Adoption”, submitted by Emery Energy Company with WRI, Principal Investigators – Ben Phillips and Dr. Vijay Sethi. This project aims to conduct 2,000 hours of operational testing on its *Novus-G* hybrid gasifier, the development of which was funded under the 2007 CCTF project “Novel Fixed-Bed Gasifier for Wyoming Coals”. A successful extended run program is an important step in the quest for commercialization of this technology.
6. “Supplemental Budget for Capture & Mineralization of Carbon Dioxide from Coal Combustion Flue Gas”, submitted by the University of Wyoming and Brigham Young University, Principal Investigators – Dr. KJ Reddy and Dr. Morris Argyle. The objective is to design and build a fly ash conveying system to convert their carbon capture system – funded by 2007 CCTF project “Capture & Mineralization of Carbon Dioxide from Coal Combustion Flue Gas Emissions: Pilot Scale Studies” – from a batch to a continuous process.
7. “CO₂ Sequestration in Depleted Compartmentalized Gas Fields – the Key to Deploying Clean Coal Technology in the Powder River Basin, submitted by the Wyoming State Geologic Survey and the University of Wyoming, Principal Investigators – Dr. Ron Surdam and Dr. Carol Frost. This project seeks to determine the carbon sequestration capacity of depleted gas fields in the PRB, to determine the rate and volume of CO₂ that can be injected into the fields, and the timing of availability of the fields.

8. “Hydrogen Separation for Clean Coal Applications”, submitted by WRI, Principal Investigator – Dr. Thomas Barton. This project seeks to develop hydrogen separation technologies for coal gasification systems utilizing membrane material and ceramic based absorbents to achieve high-pressure hydrogen production.

The total research funding in these proposals is summarized as follows:

<u>Project</u>	<u>Proposed Clean Coal Funds</u>	<u>Non-State Match</u>	<u>Total</u>
1.	Cryogenic Carbon Capture \$1,405,750	\$ 2,811,494	\$1,405,744
2.	Synthesis Gas Pollutants \$ 950,393	\$ 1,900,393	\$ 950,000
3.	Demonstration, H ₂ Production \$ 600,000	\$ 900,000	\$ 300,000
4.	Non-Carbon Sorbents \$ 350,000	\$ 700,000	\$ 350,000
5.	Extended Operational Runs \$1,340,650	\$1,340,650	\$ 2,681,300
6.	Capture & Mineralization \$ 106,382	\$ 212,764	\$ 106,382
7.	CO ₂ Sequestration \$ 500,000	\$ 1,000,000	\$ 500,000
8.	Hydrogen Separation \$1,000,000	\$ 2,000,000	\$1,000,000
Totals	\$5,992,766	\$6,253,175	\$12,205,951

When these eight projects are funded, \$6,421,680 will remain in the Clean Coal Research Account. The CCTF believe that it is in the best interest of the state to put these remaining funds to work in a timely manner in order to achieve maximum benefit prior to their reversion date of June 30, 2012. They therefore requested that SER prepare a revised RFP to be posted as soon as practical and as described in the following section.

Further Development of the Wyoming Clean Coal Research Program

Implicit in the legislation that established the Clean Coal Research Account and the CCTF is an understanding that the funds are an investment by the state of Wyoming to motivate and provide for a broad research program that will benefit the production of Powder River Basin coal. The calls for proposals have specified a range of technology areas that contribute to a comprehensive

program. In addition, there is an expectation that successful research should lead to commercial technologies that will serve to keep Wyoming coal in the clean energy mix.

The CCTF requested that SER evaluate the projects funded to date to determine how well the program is developing in terms of breadth of coverage and maturity of the technologies, to identify technology areas that are under-represented in our developing program, and to prepare a new call for proposals to target specific topics to fill in existing gaps.

Table 3. 2009 Clean Coal Technology Fund Endorsed Projects.

Proposal Title	Submitted By	Funding Requested	Outside Match	Outside Match Organization	Total Funds	Technology Areas
(2009-1) Cryogenic Carbon Capture	Sustainable Energy Solutions	\$1,405,744	\$1,405,750	BYU IL CCI	\$2,811,494	Carbon Capture
(2009-2) Removal of Synthesis Gas Pollutants & Liquid Fuel Synthesis - Part 2	Ceramatec WRI	\$ 950,000	\$950,393	Office of Naval Research	\$1,900,393	Synthesis Gas Clean-up
(2009-3) Demonstration of Hydrogen Production from Wyoming Coal	EERC	\$300,000	\$600,000	National Center for Hydrogen Technology	\$900,000	Hydrogen Separation
(2009-4) Development & Evaluation of Non-Carbon Sorbents	Western Research Institute	\$350,000	\$350,000	NanoScale Amended Silicates, LLC	\$700,000	Carbon Capture
(2009-5) Extended Operational Runs on Emery Hybrid Gasifier to Accelerate Commercial Adoption	Emery Energy Company	\$1,340,650	\$1,340,650	WRI Emery Energy Co.	\$2,681,300	Combustion and gasification design
(2009-6) Supplemental Budget for "Capture & Mineralization of Carbon Dioxide from Coal Combustion Flue Gas Emissions: Pilot Scale Studies"	UW	\$106,382	\$106,382	UW	\$212,764	Carbon Capture
(2009-7) CO ₂ Sequestration in Depleted Compartmentalized Gas Fields-the Key to Deploying Clean Coal Technology in the Powder River Basin, Wyoming	Wyoming State Geological Survey	\$ 500,000	\$500,000	Wyoming Carbon Sequestration Fund	\$1,000,000	Carbon Sequestration
(2009-8) Hydrogen Separation for Clean Coal Applications	WRI/Tom Barton	\$1,000,000	\$1,000,000	DOE Idaho Nat'l Lab WRI	\$2,000,000	Hydrogen Separation

Totals \$5,992,766 \$6,253,175 \$12,205,951

The CCTF determined that a comprehensive clean coal research program should have projects distributed across the technology areas specified in the three previously-issued RFPs:

1. Pre-combustion/pre-gasification technologies
2. Combustion and gasification design technologies
3. Post-combustion/post-gasification gas clean-up technologies
4. Advanced cycle technologies
5. Air separation technologies
6. Carbon capture and sequestration technologies
7. *In situ* gasification technologies
8. Coal to liquids/coal to hydrogen technologies
9. Economic analysis

Furthermore, it is desirable for technologies in the program to exhibit a reasonable distribution across the evolutionary stages of technology development (i.e., research and development, bench-scale demonstration, pilot-scale demonstration, and commercialization).

Table 4. Matrix of Project Distribution by Topic and Maturity.

	Research & Development	Bench-Scale Demonstration	Pilot-Scale Demonstration	Commercialization
Pre-combustion/pre-gasification technologies		2007-1; 2008-4		
Combustion and gasification design technologies		2008-3;	2007-4; 2009-5	
Post-combustion/post-gasification gas clean-up technologies		2008-3	2009-2	
Advanced cycle technologies				
Air separation technologies				
Carbon capture and sequestration technologies	2007-2; 2007-3; 2008-1; 2008-2; 2009-7; 2009-4	2007-2; 2009-1; 2009-8	2009-6	
<i>In situ</i> gasification technologies				
Coal to liquids/coal to hydrogen technologies	2008-5		2009-2; 2009-3	
Economic analysis				

The 17 projects funded to date are distributed across five of the nine categories listed above, and are also distributed across all stages of technology development except commercialization. The matrix in Table 4 provides more detail about this distribution. A summary of Table 4 shows the following:

1. Pre-combustion coal cleanup: two projects at lab/bench scale totaling \$1.1million.
2. Combustion and gasification technology: three projects spanning bench to pilot scale totaling \$3.4 million.
3. Post-combustion/gasification cleanup: one project has an objective that falls in this category.
4. Advanced cycle technologies: **none**.
5. Air separation technology: **none**.
6. A. Carbon Capture: seven projects spanning the range from applied research to pilot totaling \$4 million.
B. Sequestration: two projects applied research totaling \$1 million.
7. In situ gasification: **none**.
8. Coal to liquids, gas, chemicals: three projects spanning from applied research to pilot totaling \$1.7 million.
9. Economics: **none**.

A good distribution of projects spanning the technology maturity range exists in several of the six topic areas. It is reasonable to expect, based on the stage of development for several of the projects that one or more of them will move into commercialization in the foreseeable future.

In order to build a more comprehensive clean coal program, the CCTF suggest that a new RFP be issued as soon as practical to invite proposal to specifically address the underrepresented topics, and to fill pipeline within some of the lightly-represented topics. The RFP will solicit proposals that cover technologies and studies across the maturity stages in the following topic areas:

- Advanced cycle technologies
- Air separation technologies
- *In situ* gasification technologies
- Economic analysis

In addition, projects that address early and late stage technology in combustion and gasification design, post-combustion/post-gasification clean-up, and coal to liquids will be solicited to round out the program and to attempt to improve coverage across all topics and maturities.

The CCTF envision a submittal deadline of December 1, 2009, a review period through early January 2010, and decisions on funding by late January 2010. As always, funding decisions will be highly selective and will be reviewed with the Joint Minerals, Business, and Economic Development Interim Committee.

