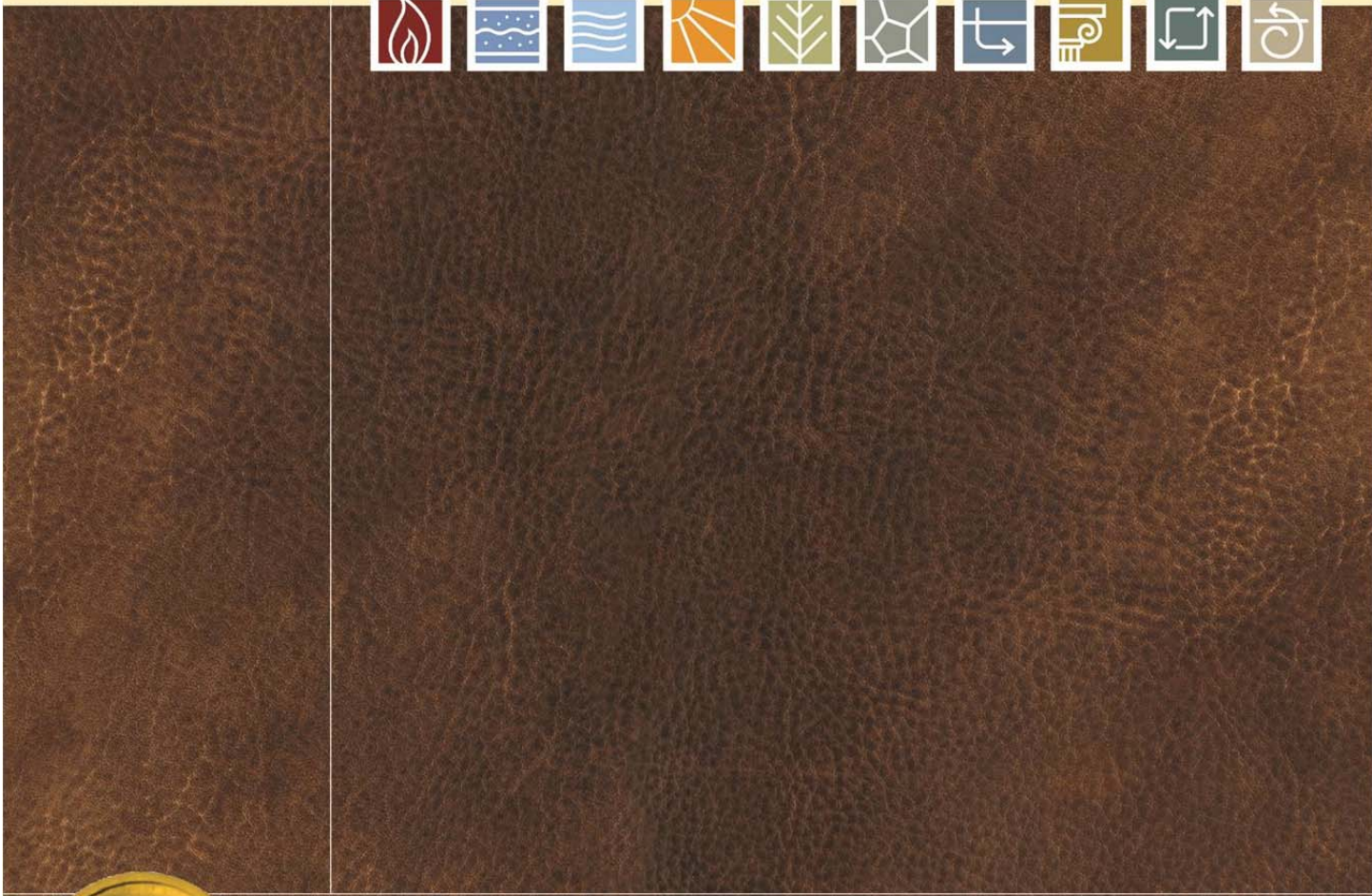


SCHOOL OF ENERGY RESOURCES

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

November 29, 2010



UNIVERSITY OF WYOMING

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This report of the Clean Coal Task Force (CCTF) supplements their annual report submitted to the Joint Minerals, Business, and Economic Development Interim Committee in Jackson, WY and dated October 1, 2010. That report informed the committee (page 9) that the CCTF issued a Request for Proposals (RFP) in July 2010 with a submission deadline of September 20, 2010. A total of \$14 million was available in the Clean Coal Research Account to fund projects.

Thirty-three proposals requesting a total of \$48,390,354 were submitted by the deadline and each proposal was reviewed by two independent outside reviewers. The CCTF met on November 19th, 2010 to consider awarding funds to selected projects, based on those reviews, fit with the research program and benefits Wyoming coal.

Allocation of Funds for Clean Coal Research

The CCTF determined in 2007 that a comprehensive clean coal research program should have projects distributed across a range of technology areas that contribute to low emission use of Wyoming coal for energy generation. The following technology areas have been specified in each RFP:

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

In September 2007, the CCTF recommended funding four proposals. 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 (see Table 2). The total amount appropriated in the first round was \$1,822,481, leaving \$677,519 unspent.

In September 2008, the CCTF approved funding for 5 of the 8 submitted proposals. Funding for the successful proposals totaled \$2,671,725, leaving \$1,128,275 for allocation to future submittals (see Table 3).

In September 2009, the CCTF approved funding for 8 of the 21 qualified proposals. Funding for the successful proposals totaled \$5,952,766, leaving \$6,466,065 for allocation to future submittals (see Table 4). Furthermore, the CCTF informed the Joint Minerals, Business and Economic Development Interim Committee of its intent to issue a revised Request for Proposals RFP) in order to deploy remaining funds in a timely manner. A revised RFP was issued in October 2009.

In January 2010, the CCTF approved funding for 4 of the 10 proposals submitted see (Table 5). Funding for the successful proposals totaled \$6,466,065, allocating all funds that remained for submittals prior to the most recent appropriation of \$14,000,000, referenced above.

Philosophically, the CCTF has elected to fund only projects that clearly meet the mandate of benefiting Wyoming's coal resources and consequently has not expended all available funding in each RFP. Remaining funds have been rolled over to subsequent RFPs (Table 1).

Table 1. Record of funds appropriated for clean coal research.

Appropriation	Amount
2007 Appropriation	\$2,500,000
2008 Appropriation	\$3,800,000
2009 Appropriation	\$10,613,047
2010 Appropriation	\$14,000,000
Subtotal	\$30,913,047
2007 Commitments	(\$1,822,481)
2008 Commitments	(\$2,671,725)
2009 Commitments	(\$12,418,841)
2010 Commitments	(\$6,992,300)
Remaining Balance	\$ 7,007,700

The CCTF authorized distribution of a fifth, thoroughly revised RFP in July 2010. Areas of research eligible for consideration remained the same as in previous RFPs, but language in the request emphasized several new elements. The latest RFP:

- Encourages international collaboration and accepts foreign funds as cost share; no Wyoming funds can be spent outside the US

- Expands categories of proposals to include engineering scale-up and integration of carbon capture technologies
- Allows for greater range of funding (\$250 thousand - \$7 million)
- Limits “in-kind” contribution (non-cash) to 50% of cost share
- Manages risk of projects greater than \$500 thousand through stage-gating process
- Includes statement that funding decisions will be positively influenced by full description of business plan for commercialization

Table 2. 2007 Clean Coal Technology Fund Endorsed Projects.

Proposal Title	Submitted By	Funding Requested	Outside Match	Outside Match Organization	Project Total Funds	Technology Areas
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	Precombustion/ pregasification technologies
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 and sequestration technologies
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 and sequestration technologies
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 3. 2008 Clean Coal Technology Fund Approved Projects.

Proposal Title	Submitted By	Funding Requested	Outside Match	Outside Match Organization	Project Total Funds	Technology Areas
Development of a New Solid Sorbent for CO ₂ Separation	UW Chemical & Petroleum Engineering	\$250,267	\$253,394	EnviroTech	\$503,661	Carbon capture technologies
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	\$499,605	\$500,000	UW Research Penn State	\$999,605	Sequestration technologies
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;
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.
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		\$2,671,725	\$2,675,278		\$5,347,003	

Table 4. 2009 Clean Coal Technology Fund – First Round – Approved 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 (AML) BYU	\$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 (AML)	\$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		\$5,952,776	\$6,253,175		\$12,205,951	

Table 5. 2009 Clean Coal Technology Fund – Second Round – Approved Projects.

Proposal Title	Submitted By	Funding Requested	Outside Match	Outside Match Organization	Total Funds	Technology Areas
(2009-25) WRI's Pre-Gasification Treatment of Low Rank Coals for Improved Advanced Clean Coal Gasifier Design: Phase I: Pilot-Scale Demonstrations	Western Research Institute	\$ 977,617	\$ 979,405	Industrial Commission of ND; Montana-Dakota Utilities; EERC; FuelCell Energy	\$ 1,957,022	Pre-combustion/pre-gasification coal technology
(2009-27) Innovative Catalytic Gasification Technology to Maximize the Value of Wyoming's Coal Resources	GreatPoint Energy, Inc.	\$ 463,050	\$ 463,050	GreatPoint Energy, Inc.	\$ 926,100	Combustion and gasification design
(2009-28) Reactive Transport of Acidic Brine Resulting from CO ₂ Sequestration in the Rock Springs Uplift (SW Wyoming): Variation of Porosity and Permeability	University of Wyoming	\$ 188,500	\$ 270,000	University of Wyoming	\$ 458,500	Carbon Sequestration
(2009-31) Proposal for Clean Coal Technology Research	Ciris Energy, Inc.	\$ 4,836,898	\$4,999,167	Ciris Energy, Inc.	\$ 9,836,065	Combustion and gasification design
Totals		\$6,466,065	\$6,711,622		\$13,177,687	

Proposals for Research

The CCTF submits the following recommendation to fund twelve new proposals and one supplemental request for funds from a project funded in 2007 (“Novel Fix-bed Gasifier for Wyoming Coals”; Table 2). Funding these projects will utilize \$6,992,300 from the Clean Coal Research Account. It should be noted that some of these proposals contain proprietary information so that only summary information can be shared openly. CCTF 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 6.

1. “The Engineering Scale-Up of Hydrogen Separation Facilities”, submitted by the Western Research Institute, Principal Investigator (PI)– Thomas Barton. This project will build and test a 2 lb/day metallic membrane-based hydrogen separation device to operate on simulated and coal-derived synthesis gas, and evaluate performance criteria of the device for flux, membrane cost, overall efficiency and resistance to sulfur contamination. The PI will also begin developing and testing the technology in preparation for the potential Phase II \$5 million DOE award to build a 100 lb/day device.
2. "Testing of an Advanced Dry Cooling Technology for Power Plants in Arid Climates", submitted by the Energy and Environmental Research Center, Principal Investigator – Dr. Christopher Martin. This project will evaluate the feasibility of using dry cooling technology to meet the cooling needs of power plants located in arid environments. The investigators will fabricate and test a prototype cooling system at EERC, then perform a detailed economic assessment of the technology.
3. “Evaluation of Novel Technologies for CO₂ Capture: Neustream-C System”, submitted by the Energy and Environmental Research Center, Principal Investigator – Dr. Brandon Pavlish. This project will design, fabricate, demonstrate and evaluate an advanced contacting device that utilizes solvents (the NeuStream-C system) for capturing CO₂. The investigators will perform system optimization testing with multiple solvents from other technology suppliers and perform economic analysis of the system at different points in the optimization to determine feasibility.
4. “Pilot-Scale Testing Evaluations of the Effects of Bromine Addition on Continuous Mercury Monitors at Low Mercury Concentrations”, submitted by the Energy and Environmental Research Center, Principal Investigator – Dennis L. Laudal. This project seeks to determine if bromine compounds and/or brominated carbons interfere with Continuous Mercury Monitor results. The investigators will conduct a pilot-scale study evaluating low-level mercury variability of CMMs when bromine and bromine-treated carbons are used, and

determine the accuracy and variability of CMM measurements while burning PRB coal with mercury control level <1.0 micrograms/m³.

5. “Efficient Coal-to-Hydrogen System”, submitted by TDA Research, Inc., Principal Investigator – Dr. Stephen Paglieri. This project seeks to demonstrate a process to make ultrapure hydrogen from coal using a system based on coal gasification, warm-gas desulfurization and sulfur-tolerant, high-temperature membrane reactors. The investigators will fabricate and test a system comprising an adsorbent bed for sulfur removal, and fabricate a membrane reactor based on high-temperature water-gas shift catalyst.
6. “Development of a Compact Heat Exchange Reactor for Fischer-Tropsch (FT) Synthesis”, submitted by the Western Research Institute and Chart Energy and Chemicals, Principal Investigator – Dr. Yulong Zhang. This project seeks to evaluate the heat and mass transfer properties and reaction kinetics of FT reactions in the Compact Heat Exchange Reactor (CHER). The investigators seek to scale the CHER up by 25-fold to achieve an effective reactor capacity of about one barrel per day of liquid products, to evaluate scaled-up CHER with syngas from the WRI gasifier, and to perform economic evaluation of CHER for commercialization of the reactor.
7. “Modular Fischer-Tropsch for Wyoming Coal-to-Liquids Fuels”, submitted by Ceramatec, Inc, Principal Investigators – Dr. S. Elongovan and Dr. Joseph Hartvigsen. This project seeks to demonstrate the scale-up of a novel Fischer-Tropsch unit using syngas generated by gasification of WY coal for conversion into JP5. The unit will demonstrate modular fixed-bed technology and a unique catalyst that has high conversion per pass and high selectivity in the JP5 range. The investigators will evaluate long-term performance for four different catalysts.
8. “Use of Historic Wyoming field Test Data to Validate and Calibrate a Comprehensive Underground Coal Gasification (UCG) Simulator”, submitted by Lawrence Livermore National Laboratory, Principal Investigator – Dr. David Camp. This project will recover, modernize, and consolidate much of the historic test data from UCG tests performed in WY during the 70’s and 80’s. The investigators will use the data to improve a new generation of 3-D UCG simulator being developed. They will create a compendium of all old summary and topical reports, new digital files of old archived analog data, and a consistent set of key UCG construction, operation, process results, and geophysical results for each selected historical field test. The electronic data will then be available for public use.
9. “Conceptual Design of a System for Treating Formation Waters Produced as Part of Geologic CO₂ Sequestration Operation in the State of Wyoming”, submitted by Lawrence Livermore National Laboratory, Principal Investigator – Dr. Thomas Woolery. This project will develop a conceptual custom design for treating saline formation waters that are produced to create accommodation space for CO₂ to be stored in geologic formations in WY. The investigators will focus on desalination of brines recovered from WY-CUSP Phase 1

stratigraphic test well, and other brines as appropriate, and test models on 10 liter samples, then in a 20 gpm facility for real (where available) and synthetic brine samples.

10. “Retrofit Impacts of Oxy-Coal Combustion of PRB Coal on Deposit Formation and Mercury Speciation”, submitted by the University of Utah and Reaction Engineering International, Principal Investigators – Dr. Jost Wendt and Brad Adams. This project will determine the effects of oxy-combustion of PRB coals on boiler tube deposits, and determine the effects of oxy-combustion of PRB coals on mercury speciation.
11. “SequesTech Demonstration Project: Capture and Mineralization of Coal Combustion Flue Gas CO₂, SO₂, and Hg”, submitted by the Department of Renewable Resources, University of Wyoming, Principal Investigator – Dr. K.J. Reddy. This project will conduct a 3-year test of the SequesTech process to capture post-combustion CO₂ from flue gas using fly ash particles at the Jim Bridger power plant. The investigators will enhance and optimize process parameters such as temperature, moisture and reaction time, determine the efficacy of the process in removal of flue gas CO₂, SO₂, and Hg, and evaluate cost economics of the process and derive cost benefits vs. traditional CCS. This project is a follow of two previous projects supported by the CCTF.
12. “Low Cost Route to Commercial Iron Fischer-Tropsch Catalysts for Coal-to-Liquids and Biomass-to-Liquids”, submitted by Brigham Young University, Principal Investigator – Dr. Morris Argyle. This project seeks to develop simple, low-cost, and environmentally-sound methods for preparation of high-performance Fe FT catalysts that can be scaled to commercial manufacture. The investigators will continue to develop the promising Fe/Cu/K/SiO₂ catalyst, pursue the preparation of other promising supported and unsupported Fe FT catalysts, and compare the above with catalysts prepared by conventional methods.

The Clean Coal Task Force also recommends awarding an additional \$285,000 to the 2007 project, “Novel Fix-bed Gasifier for Wyoming Coals” (Table 2) for the purpose of completing construction of the gasifier. The \$285,000 will be matched by private funds from Emery Energy. Emery Energy offered the following justification for the additional funds:

- The gasifier was built larger than originally contemplated. The gasifier is of sufficient size to allow scale-up and the offering of commercial units. This will hasten technology implementation and help advance PRB coal gasification. Doing so also resulted in larger auxiliary equipment requirements for steam, oxygen and structural supports.
- Emery took a much more active role in site construction than originally contemplated, which resulted in an increase in labor and travel budget.
- The original proposal also anticipated more existing site infrastructure (natural gas lines; water line, feedstock area; electric capacity, etc.) but virtually all infrastructure had to be installed and implemented for this project.
- The investigators have had to engage more outside sub-contractors to do construction than anticipated.

When these twelve projects and the supplemental request are funded, just over \$7 million will remain in the Clean Coal Research Account (Table 1). It is the intention of the CCTF to issue an additional targeted RFP as soon as possible in an attempt to deploy remaining funds.

Table 6. 2010 Clean Coal Technology Fund Approved Projects.

Proposal Title	Submitted By	Funding Requested	Outside Match	Outside Match Organization	Total Funds	Technology Areas
(2010-03) The Engineering Scale-Up of Hydrogen Separation Facilities	Western Research Institute	\$ 1,100,000	\$ 1,519,998	Department of Energy, Chart Energy and Chemicals, Synkera	\$ 2,619,998	Coal-to-Hydrogen
(2010-05) Testing of an Advanced Dry Cooling Technology for Power Plants in Arid Climates	Energy & Environmental Research Center	\$ 500,000	\$ 600,000	Department of Energy, Electric Power Research Institute	\$ 1,100,000	Combustion and gasification design
(2010-07) Evaluation of Novel Technologies for CO ₂ Capture: Neustream-C System	Energy & Environmental Research Center	\$ 280,156	\$ 1,697,683	Department of Energy, EERC	\$ 1,977,839	Carbon Capture
(2010-11) Pilot-Scale Testing Evaluations of the Effects of Bromine Addition on CMMs at Low Mercury Concentrations	Energy & Environmental Research Center	\$ 150,000	\$ 226,156	Department of Energy, Electric Power Research Institute	\$ 376,156	Post Combustion
(2010-12) Efficient Coal-to-Hydrogen System	TDA Research, Inc.	\$ 340,000	\$ 340,000	Pall, CSIRO, Colorado School of Mines, TDA Research, Inc	\$ 680,000	Coal-to-Hydrogen
(2010-14) Development of Compact Heat Exchange Reactor for Fischer-Tropsch Synthesis	Western Research Institute	\$ 450,000	\$ 600,200	Department of Energy, Chart Energy and Chemicals	\$ 1,050,200	Advanced Cycle Technologies
(2010-17) Modular Fischer Tropsch for Wyoming Coal-to-Liquid Fuels	Ceramatec	\$ 596,105	\$ 596,105	WRI, Ceramatec	\$ 1,192,210	Coal-to-Liquids
(2010-18) Use of Historic Wyoming Field Test Data to Validate and Calibrate a Comprehensive Underground Coal Gasification Simulator	Lawrence Livermore National Lab	\$ 500,000	\$ 1,769,701	Department of Energy	\$ 2,269,701	In-Situ Gasification
(2010-19) Conceptual Design of a System for Treating Formation Waters Produced as part of Geologic CO ₂ Sequestration Operation in the State of Wyoming	Lawrence Livermore National Lab	\$ 500,000	\$ 600,000	National Energy Technology Lab	\$ 1,100,000	CO ₂ Sequestration
(2010-23) Retrofit Impacts of Oxy-Coal Combustion of PRB Coal on Deposit Formation and Mercury Speciation	University of Utah	\$ 540,691	\$ 542,329	University of Utah, Praxair, Department of Energy	\$1,083,020	Post Combustion

Table 6 – Continued. 2010 Clean Coal Technology Fund Approved Projects.

Proposal Title	Submitted By	Funding Requested	Outside Match	Outside Match Organization	Total Funds	Technology Areas
(2010-26) SequesTech Demonstration Project: Capture and Mineralization of Coal Combustion Flue Gas CO ₂ , SO ₂ , and Hg	Department of Renewable Resource, UW	\$ 1,330,344	\$ 1,330,344	University of Wyoming, Jim Bridger Power Plant	\$ 2660,668	Carbon Capture
(2010-26) Low-Cost Route to Commercial Iron FT Catalysts for Coal-to-Liquids & Biomass-to-Liquids	Brigham Young University	\$ 420,004	\$ 420,009	Brigham Young University Consortium	\$ 840,013	Coal-to-Liquids
(2007-04) Novel Fixed-Bed Gasifier for Wyoming Coals	Emery Energy	\$ 285,000	\$285,000	Emery Energy	\$ 570,000	Combustion and gasification design
Totals		\$6,992,300	\$10,527,525		\$17,519,825	