



SCHOOL OF ENERGY RESOURCES

Annual Report of the Clean Coal Task Force to
The Joint Minerals, Business, and Economic Development Interim Committee
September 30, 2012



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**Annual Report of the Clean Coal Technologies Task Force to the
Joint Minerals, Business, and Economic Development Interim Committee
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(W.S. 21-17-121c)**

This report summarizes the activities of the Clean Coal Technologies Task Force for Fiscal Year 2012 (July 1, 2011 – June 30, 2012) along with important updates on some key projects through August 31, 2012. In accordance with original Senate File 15/Senate Enrolled Act 3 (SF15/SEA3) enacted by the Sixty-first Legislature of the State of Wyoming, the Clean Coal Task Force and the Clean Coal Technologies Research Account were renamed the Advanced Conversion Technologies Task Force and the Advanced Conversion Technologies Research Account, respectively. In addition, SF15/SEA3 broadened the scope of the research program to include advanced conversion of other mineral resources along with clean coal technologies and extended the sunset date of the Task Force from June 30, 2013 to June 30, 2017. The effective date of this legislation was July 1, 2012. For the purposes of this report, the Clean Coal Task Force/Advanced Conversion Technologies Task Force will hereafter be referred to as the Task Force and the Clean Coal Technologies Research Account/Advanced Conversion Technologies Research Account will be referred to as the Account.

Creation and Appropriations Background

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

The Account was created to stimulate research and development in the area of low-emissions and advanced coal technologies. The objectives of the program are to:

- Enable and accelerate demonstration and early commercial deployment of clean coal technologies that have the potential to enhance and improve the use of sub-bituminous coal at high altitudes, specifically in Wyoming.
- Generate and test new ideas for significant improvement and cost reductions in next-generation, low-emissions, and advanced coal technologies.
- Support collaborative research and development (R&D) in accomplishing the above objectives.

The Account supports proposals addressing the following:

- Research and development of new technologies that reduce emissions from coal
- Pilot-scale demonstration of emerging technologies
- Engineering scale-up of demonstrated technologies
- Integration and operation of carbon capture technologies

Chapter 57 of the Legislature of the State of Wyoming’s 2009 General Session Law extended the sunset date for the Task Force from June 30, 2010 to June 30, 2013. Section 5 (a) provides that the 2007 general fund appropriation of \$2.5 million into the Account will not revert and can continue to be used for clean coal research. Since 2007, four additional appropriations of funds, each with a reversion date, have been made to the Account (Table 1).

Table 1: Funds Appropriated for Clean Coal Research

| Appropriation | Amount | Reversion Date |
|----------------------|---------------------|-----------------------|
| 2007 Appropriation | \$2,500,000 | No reversion date |
| 2008 Appropriation | \$3,800,000 | June 30, 2012 |
| 2009 Appropriation | \$10,613,047 | June 30, 2012 |
| 2010 Appropriation | \$14,000,000 | June 30, 2014 |
| 2012 Appropriation | \$10,000,000 | June 30, 2016 |
| Total | \$40,913,047 | --- |

FY 2012 Task Force Activities and Developments

Abandoned Mine Land (AML) Funds - Redirected

In the 2012 budget session HB121/HEA25 provided for the submittal of grant applications by the Wyoming Department of Environmental Quality (DEQ) to the Federal Office of Surface Mining for future funds and redirection of prior Abandoned Mine Land (AML) fund authorizations.

Redirected funds derive from several sources (Table 2) including the Account and the Wyoming Carbon Underground Storage Project (WYCUSP). The redirection of unallocated funds from the 2008 and 2010 appropriations leaves no excess funds in these accounts for the program; however, a combined total of \$318,326 of unallocated funds still remain from the 2007 and 2009 appropriations to be used toward funding additional research (Table 4).

Table 2: Origin of Redirected Funds

| Source | Amount |
|---|------------------------|
| Termination of Ciris Energy Research Project (2009) | \$4,250,139.64 |
| Unallocated from 2008 Clean Coal Appropriation | \$100,014.36 |
| Unallocated from 2010 Clean Coal Appropriation | \$900,000.00 |
| WYCUSP – Unallocated from 2012 Appropriation | \$40,000,000.00 |
| Total Redirected Funds | \$45,250,154.00 |

The redirected AML funds were appropriated to various programs and agencies of the State of Wyoming. A portion of these funds was appropriated to the University of Wyoming’s School of Energy Resources (SER) to fund research projects under the recommendation of the Task Force (Table 3). Each of these programs is discussed in more detail below.

Table 3: AML Funds Reallocated to SER and the Task Force (From HB121/HEA25)

| Program Name | Entity Funded | Appropriation |
|--|----------------------|----------------------|
| Clean Coal Research | SER | \$10,000,000 |
| Minerals to Value-Added Products Feasibility Study | SER | \$500,000 |
| Commercial-Scale Minerals to Value-Added Products Facility | Governor's Office | \$9,000,000 |
| Natural Resources to Manufacture Glass and Glass Products in Wyoming | SER | \$100,000 |

Clean Coal Research (includes updated information through August 31, 2012)

On behalf of the Task Force, SER issued a Request for Proposals (RFP) on June 1, 2012 to deploy the newly appropriated \$10 million for clean coal research. Proposals were solicited from academic institutions, private industry and government agencies. Proposals are evaluated competitively by two independent reviewers and judged on the ability to deliver maximum benefit to the State of Wyoming through improved use of and expanded markets for Wyoming's coal resource. To be eligible for funding, the RFP requires researchers to secure and verify a dollar-for-dollar match for the funds requested from the Account. The RFP specified a proposal submittal date of July 13, 2012. Independent reviews were completed for consideration by the Task Force for their August 24, 2012 meeting. At that meeting, the Task Force committed all the remaining Account funds (\$11,050,309) to ten new research projects (Table 4 and Table 11).

Since the beginning of the clean coal research program in 2007, the Task Force has committed funding to 49 projects. The status of these is:

- 9 projects have completed the research, have met all the final reporting requirements and the final invoices have been paid; 5 of these projects have obtained a patent or have a patent pending for their technology
- 7 additional projects were completed by June 30, 2012 and still need to submit the final reports and final invoice
- 2 project contracts were terminated before project completion; both for inability to complete the projects
- 3 projects had awards withdrawn by the Task Force due to the inability to meet the matching requirements or to negotiate a contract
- 21 projects are in progress
- 10 projects are in the process of initiating contracts

Table 4. Account Balance

| Appropriation | Amount |
|--|-----------------------|
| 2007 Appropriation | \$2,500,000 |
| 2008 Appropriation | \$3,800,000 |
| 2009 Appropriation | \$10,613,047 |
| 2010 Appropriation | \$14,000,000 |
| 2012 Appropriation | \$10,000,000 |
| Subtotal | \$40,913,047 |
| 2007 Awards | (\$2,498,222) |
| 2008 Awards | (\$3,699,986) |
| 2009 & 2010 Awards (From 2009 Appropriation) | (\$6,046,360) |
| 2011 Awards (From 2010 Appropriation) | (\$12,368,016) |
| 2012 Awards | (\$11,050,309) |
| Redirected Funds (From 2008-2011) | (\$5,250,154) |
| Subtotal | (\$40,913,047) |
| Remaining Balance | \$0.00 |

Minerals to Value-Added Products Feasibility Study (includes updated information through August 31, 2012)

During the 2012 budget session, \$500,000 of Abandoned Mine Land funds was appropriated to SER for the purpose of providing grants to conduct one or more studies to determine the feasibility of constructing a commercial-scale mineral to value-added products facility in Wyoming. The objectives of the study were to determine the economic viability of a commercial-scale minerals to value-added products facility, identify potential obstacles to the construction of such a facility, determine the availability of infrastructure and resources for the facility, and identify possible state incentives for development.

An RFP was issued by SER on behalf of the Task Force on April 20, 2012 and 14 proposals were received by the May 25, 2012 submission deadline. On June 18, 2012, the Task Force convened a special meeting to make recommendations for awards to forward to the Joint Minerals, Business and Economic Development Committee. The following two proposals were selected:

1. Western Research Institute, Dr. Vijay Sethi, Principal Investigator, “Distributed Production of Fuels and Chemicals from Stranded Natural Gas,” awarded \$162,000.
2. Arctech, Dr. Daman Walia, Principal Investigator, “Techno-Economic Analysis of MicGAS™ Coal Biorefinery Plants Deployment in Wyoming for Moving Wyoming Coal Up the Value Chain,” awarded \$329,243.

Reports for each of the studies were received on August 20, 2012. At the August 24, 2012 meeting of the Task Force, the principal investigators presented summary presentations of their projects.

The Task Force declined to accept the ArcTech, Inc. report. ArcTech, Inc. was advised by the Task Force on how to revise their report in order to achieve acceptability and asked to do so as a priority. Their contract was extended to October 1, 2012. **At such time as the ArcTech, Inc. report is accepted, their findings will be summarized and a revised summary report will be amended and re-issued.**

Additional information about the projects can be found in Appendix A, which contains a summary report of these studies from the Task Force to the Joint Minerals, Business and Economic Development Committee.

Commercial-scale Minerals to Value-added Products Facility (includes updated information through August 31, 2012)

HB121/HEA25 directed a \$9 million appropriation to the Wyoming governor's office for the purpose of supporting the construction and operation of a commercial-scale facility which converts minerals to value-added products. Applications for these funds are to be received by the Task Force with awards made by the Governor upon receiving recommendations from the Joint Minerals, Business and Economic Development Committee. Projects applying for these funds must provide a dollar-for-dollar match of funds not from the State of Wyoming.

In a letter dated May 31, 2012 from the Task Force to the members of the Joint Minerals, Business and Economic Development Interim Committee and the Joint Appropriations Interim Committee, the Task Force asked for clarity regarding the legislature's intent and focus with respect to the \$9 million appropriation. The Task Force received a response from the two committees in a letter dated August 3, 2012. The response clarified that the Task Force will not ultimately award grants from this appropriation but will present its recommendations to the Joint Minerals, Business and Economic Development Interim Committee. The committee will then convey its recommendations to the Governor, who will make the ultimate decision on awards. Since the date of the response letter, Task Force Chair Ron Harper has met with Governor Mead about this appropriation. Both agreed that any spending for this effort should be undertaken carefully. Since the \$9 million does not revert until June 30, 2016, there is time for the Task Force, the joint interim committee, the Governor's office and the full legislature to work together to ensure the funds are spent judiciously.

Natural Resources to Manufacture Glass and Glass Products in Wyoming (includes updated information through August 31, 2012)

As part of HB121/HEA25, an appropriation of \$100,000 was directed to SER to provide grants to conduct one or more studies to evaluate the feasibility of using Wyoming natural resources to manufacture glass and glass products in Wyoming. Grants authorized from this appropriation are to be awarded by the Task Force and results from any studies are to be reported to the Joint Minerals, Business and Economic Development Committee by June 1, 2013.

In a letter dated May 31, 2012 from the Task Force to the members of the Joint Minerals, Business and Economic Development Interim Committee and the Joint Appropriations Interim Committee, the Task Force identified four previous studies focusing on the manufacture of glass and glass products in Wyoming. All four studies concluded that the manufacture of glass and glass products is not economically viable in Wyoming. The letter from the Task Force asked for consideration to broaden the scope of the study to the manufacture of other products as well as glass.

In a written response dated August 3, 2012, the two committees concluded that the appropriation could only be expended as stated in the legislation. The letter suggested the Task Force confer with the Governor about options to address this issue, including working with the legislature to possibly broaden the scope of the legislation. In the meantime, the Task Force has suspended any further study on glass manufacturing and will leave the full amount in the account.

Wyoming Attorney General Representation (*includes updated information through August 31, 2012*)

The Task Force is an entity of the State of Wyoming, and as such, is represented by the Wyoming Attorney General's Office. An Attorney General's representative from the contracts division was assigned to the Task Force and a memorandum of understanding (MOU) was put in place on January 4, 2012 between the University of Wyoming (UW) and the Task Force. The MOU defines the research support services provided by UW to the Task Force in the performance of the Task Force's statutory responsibilities. The MOU was amended after July 1, 2012 to reflect the change in scope and name of the Task Force and the Account as provided in SF15/SEA3. At the August 24, 2012 meeting, the revised MOU was approved for signature by the Task Force.

August 25, 2011 Clean Coal Technologies Fund Research Symposium (*includes updated information through August 31, 2012*)

On August 25, 2011, the first Clean Coal Technologies Research Symposium was held in Laramie, WY to showcase completed clean coal research projects. The day-long symposium showcased 11 projects that were completed by December 31, 2011.

A second Clean Coal Technologies Research Symposium was held August 23, 2012 in Laramie. Approximately 70 people were in attendance to hear from 9 researchers who presented the final results of their projects. The symposium also featured a keynote presentation from Fred Moore, Senior Consultant with Dow Chemical Company. All the presentations were videotaped and are available for public viewing on the SER website at: <http://www.uwyo.edu/ser/conferences/conferences-past/cctf-research-symposium.html>

Historical Allocation of Funds for Clean Coal Research

Since 2007, nearly \$41 million has been awarded to 49 research projects (Tables 5-11). The Task Force has focused on funding projects that clearly meet the mandate of benefiting Wyoming's coal resources through the following technology areas specified in the RFP:

1. Pre-combustion and pre-gasification technologies
2. Combustion and gasification design technologies

3. Post-combustion, post-gasification and 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-natural gas and coal-to-hydrogen technologies
9. Economic analysis

Table 5. 2007 Funded Projects

| Proposal Title | Submitted By | Funding Requested | Outside Match | Outside Match Organization | Project Total Funds | Technology Areas | Project Status |
|---|---------------------------------|-------------------|---------------|--|---------------------|---|--|
| Capture & Mineralization of Carbon Dioxide from Coal Combustion Flue Gas Emissions: Pilot-Scale Studies | UW Dept. of Renewable Resources | \$485,000 | \$487,115 | Jim Bridger Power Plant | \$972,115 | Carbon Capture & Storage | Complete Patent obtained or pending |
| Carbon Capture from Coal Flue Gas on Carbonaceous Sorbents | Supercritical Fluids, Inc. | \$375,000 | \$375,000 | PacifiCorp, EPRI, Supercritical Fluids, Inc. | \$750,000 | Carbon Capture & Storage | Complete Patent obtained or pending |
| Novel Fixed-Bed Gasifier for Wyoming Coals | Emery Energy Company | \$847,500 | \$847,549 | Emery Energy Co., WRI | \$1,695,049 | Combustion & Gasification Design | Complete |
| Pre-Gasification Treatment of PRB Coals for Improved Advanced Clean Coal Gasifier Design | Western Research Institute | \$398,204 | \$399,981 | DOE, National Energy Technology Lab | \$798,184 | Pre-Combustion/Pre-Gasification Treatment | Complete Patent obtained or pending |

Table 6. 2008 Funded Projects

| Proposal Title | Submitted By | Funding Requested | Outside Match | Outside Match Organization | Project Total Funds | Technology Areas | Project Status |
|---|-------------------------------------|-------------------|---------------|------------------------------------|---------------------|---|-------------------------------------|
| Development of a New Solid Sorbent for CO ₂ Separation | UW Chemical & Petroleum Engineering | \$250,267 | \$253,394 | EnviroTech | \$503,661 | Carbon Capture & Storage | Complete Patent obtained or pending |
| 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 University | \$499,572 | \$500,000 | UW Research, Penn State University | \$999,572 | Carbon Capture & Storage | Complete |
| 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 & Gasification Design Post-combustion Gas Clean-up; | In Progress |
| Feasibility of Hydrothermal Dewatering for the Potential to Reduce CO ₂ Emissions and Upgrade Low Rank Coals | EERC/Pavlish | \$59,881 | \$59,881 | DOE | \$119,762 | Pre-combustion Treatment | Complete |
| 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 | Complete |
| <i>Expenditure correction for estimation error. The difference was made up by SER.</i> | | -\$91,911 | | | | | |

Table 7. 2009 Funded Projects – First Round

| Proposal Title | Submitted By | Funding Requested | Outside Match | Outside Match Organization | Total Funds | Technology Areas | Project Status |
|---|---------------------------------|--------------------------|----------------------|---|--------------------|----------------------------------|-----------------------|
| Cryogenic Carbon Capture | Sustainable Energy Solutions | \$1,405,744 | \$1,405,750 | BYU, Illinois CCI | \$2,811,494 | Carbon Capture & Storage | Complete |
| 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 | Complete |
| Demonstration of Hydrogen Production from Wyoming Coal | EERC | \$299,986 | \$600,000 | National Center for Hydrogen Technology | \$899,986 | Hydrogen Separation | Complete |
| Development & Evaluation of Non-Carbon Sorbents | Western Research Institute | \$347,584 | \$350,000 | Nano-Scale, Amended Silicates, LLC | \$697,584 | Carbon Capture & Storage | Complete |
| 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 & Gasification Design | In Progress |
| 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 & Storage | Complete |
| CO ₂ Sequestration in Depleted Compartmentalized Gas Fields-the Key to Deploying Clean Coal Technology in the Powder River Basin, Wyoming Contract Terminated March 29, 2012 | Wyoming State Geological Survey | \$ 183,452 | \$500,000 | Wyoming Carbon Sequestration Fund (AML) | \$183,452 | Carbon Capture & Storage | Terminated |
| Hydrogen Separation for Clean Coal Applications | WRI | \$1,000,000 | \$1,000,004 | DOE, Idaho Nat'l Lab, WRI | \$2,000,004 | Hydrogen Separation | In Progress |

Table 8. 2009 Funded Projects – Second Round.

| Proposal Title | Submitted By | Funding Requested | Outside Match | Outside Match Organization | Total Funds | Technology Areas | Project Status |
|---|----------------------------|--------------------------------------|-------------------------------------|---|--|--|-------------------------------------|
| 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, Fuel Cell Energy | \$1,957,022 | Pre-Combustion, Pre-Gasification Treatment | In Progress |
| 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 & Gasification Design | Complete Patent obtained or pending |
| 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 | \$ 88,500 | \$ 88,500 | University of Wyoming | \$ 177,000 | Carbon Capture & Storage | Complete |
| Proposal for Clean Coal Technology Research Contract Terminated August 8, 2011 | Ciris Energy, Inc. | \$ 4,836,898 \$586,758 | \$4,836,898 \$586,758 | Ciris Energy, Inc. | \$ 9,673,796 \$1,173,517 | Combustion & Gasification Design | Terminated |

Table 9. 2010 Funded Projects

| Proposal Title | Submitted By | Funding Requested | Outside Match | Outside Match Organization | Total Funds | Technology Areas | Project Status |
|--|--|--------------------------------|----------------------------------|--------------------------------|----------------------------------|-----------------------------|-----------------|
| The Engineering Scale-Up of Hydrogen Separation Facilities | Western Research Institute (WRI) | \$1,100,000 | \$1,519,998 | DOE, Chart, Synkera | \$2,619,998 | Coal-to-Hydrogen | In Progress |
| Testing of an Advanced Dry Cooling Technology for Power Plants in Arid Climates | Energy & Environmental Research Center | \$500,000 | \$600,000 | DOE, EPRI | \$1,100,000 | Post-Combustion | In Progress |
| Evaluation of Novel Technologies for CO ₂ Capture; Neustream-C System | Energy & Environmental Research Center | \$280,156 | \$1,697,683 | DOE, NPPD, EERC | \$1,977,839 | Carbon Capture & Storage | In Progress |
| Pilot-Scale Testing Evaluations of the Effects of Bromine Addition on CMMs at Low Mercury Concentrations | Energy & Environmental Research Center | \$150,000 | \$226,156 | DOE, CATM, EPRI | \$376,156 | Post-Combustion | Complete |
| Efficient Coal to Hydrogen System | TDA Research | \$340,000 | \$340,000 | Pall, CSIRO, CSM, TDA Research | \$680,000 | Coal-to-Hydrogen | In Progress |
| Development of Compact Heat Exchange Reactor for F-T Synthesis | WRI | \$450,000 | \$600,200 | WRI(DOE), Chart | \$1,050,200 | Advanced Cycle Technologies | In Progress |
| Modular Fischer Tropsch for Wyoming Coal-to-Liquid Fuels | Ceramatec | \$596,105 | \$596,105 | WRI(DOE), Ceramatec | \$1,192,210 | Coal-to-Liquids | In Progress |
| Use of Historic Wyoming Field Test Data to Validate & Calibrate a Comprehensive Underground Coal Gasification Simulator Award Withdrawn – Couldn't meet match requirement | Lawrence Livermore National Lab | \$500,000 \$0.00 | \$1,643,827 \$0.00 | DOE | \$2,143,827 \$0.00 | In-Situ Gasification | Award Withdrawn |
| Conceptual Design of a System for Treating Formation Waters Produced as Part of Geologic CO ₂ Sequestration Operations in Wyoming Award Withdrawn – Couldn't meet match requirement | Lawrence Livermore National Lab | \$500,000 \$0.00 | \$600,000 \$0.00 | NETL | \$1,100,000 \$0.00 | Carbon Capture & Storage | Award Withdrawn |
| Retrofit Impacts of Oxy-coal Combustion of PRB Coal on Deposit Formation & Mercury Speciation | University of Utah | \$540,691 | \$540,691 | Univ of Utah, Praxair, DOE | \$1,081,382 | Post-Combustion | In Progress |
| 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 | \$100,000 | \$100,000 | University of Wyoming | \$ 200,000 | Carbon Capture & Storage | In Progress |
| Low Cost Route to Commercial Iron FT Catalysts for CTL & BTL | BYU | \$420,004 | \$420,009 | Research Consortium | \$840,013 | Coal-to-Liquids | In Progress |

Table 10. 2011 Funded Projects

| Proposal Title | Submitted By | Funding Requested | Outside Match | Outside Match Source | Total Funds | Technology Areas | Project Status |
|----------------|--------------|-------------------|---------------|----------------------|-------------|------------------|----------------|
|----------------|--------------|-------------------|---------------|----------------------|-------------|------------------|----------------|

| | | | | | | | |
|---|--|--------------------------------|--------------------------------|---|-------------|---|-----------------|
| Advanced Technology for Cleaning Sour Syngas with Capture of CO ₂ Award Withdrawn – No Contract Issued | Air Products and Chemicals, Inc. | \$731,984 \$0.00 | \$731,984 \$0.00 | Air Products and Chemicals, Inc. | \$1,463,968 | Post-Combustion Gas Clean-Up | Award Withdrawn |
| Advancement of Chemical Looping Combustion with Oxygen Uncoupling | University of Utah | \$446,292 | \$446,292 | University of Utah, DOE | \$892,584 | Combustion & Gasification Design | In Progress |
| Coal-Derived Warm Syngas Purification and CO ₂ Capture-Assisted Methane Production | Pacific Northwest National Laboratory | \$1,205,596 | \$1,205,596 | DOE | \$2,411,192 | Post-Combustion Gas Clean-Up, Carbon Capture, Coal-to-Natural Gas | In Progress |
| Pilot Scale Demonstration of MicGAS Coal Biotechnology for In Situ Biological Gasification of Unmineable Wyoming Sub-Bituminous Coals | ARCTECH | \$499,924 | \$500,000 | ARCHTECH | \$999,924 | In-situ Gasification | In Progress |
| Pore-to-Core-to-Reservoir Modeling of Geologic Storage of Supercritical CO ₂ in Deep Fractured Saline Aquifers | University of Wyoming | \$1,407,900 | \$1,407,934 | Brazilian National Lab for Scientific Computing | \$2,815,834 | Carbon Capture & Storage | In Progress |
| Multi-Stage Processing of WY Coal-to-Liquid Fuels | Thermosolv, LLC/ Western Research Institute (WRI) | \$500,000 | \$500,000 | AmbreEnergy, WRI | \$1,000,000 | Coal-to-Liquids | In Progress |
| Development of a Novel Helical Channel Reactor for Syngas Conversion | AmbreEnergy/WRI | \$720,000 | \$740,000 | AmbreEnergy, WRI | \$1,460,000 | Post-Combustion, Gas Clean-Up | In Progress |
| Novel Carbon Capture Technology Development for Power Generation Using Wyoming Coal | University of Kentucky | \$744,780 | \$745,000 | Los Alamos National Lab CERC, Univ of Kentucky | \$1,489,780 | Combustion, Gasification, Carbon Capture & Storage | In Progress |
| Skid-Scale, Cryogenic Carbon Capture | Sustainable Energy Solutions | \$2,513,237 | \$2,513,237 | Sustainable Energy Solutions, Jiaotong Univ, China, WRI | \$5,026,474 | Carbon Capture & Storage | In Progress |

Table 11. 2012 Task Force Recommended Projects

| Proposal Title | Submitted By | Funding Requested | Outside Match | Outside Match Source | Total Funds | Technology Areas | Project Status |
|--|----------------------------------|-------------------------------------|--|---|--|---|---------------------|
| Advanced Solvent for CO ₂ Capture and Separation Technology for CO ₂ Sequestration to Enhance Utilization and Reduce Emissions from Wyoming Coal | University of Kentucky | \$686,032* \$300,000 | \$694,614 (potentially subject to change) | West Virginia CERC/Univ of Kentucky Research Foundation | \$1,382,646 To be determined | Carbon Capture & Storage | Contract Initiation |
| Demonstration of Pilot-Scale Hydrogen and CO ₂ Separation Membrane Technology on Wyoming Coal-Derived Syngas | EERC | \$450,000 | \$1,315,000 | Praxair | \$1,765,000 | Coal-to-Liquids | Contract Initiation |
| Engineering Demonstration of a Modular Fischer-Tropsch for Wyoming Coal-to-Liquid Fuels | Ceramatec | \$2,491,710 | \$2,491,712 | Ceramatec | \$4,983,422 | Coal-to-Liquids | Contract Initiation |
| Energy Storing Cryogenic Carbon Capture | Sustainable Energy Solutions | \$3,000,000 | \$3,000,000 | DOE/ARPA-E, CCSEM | \$6,000,000 | Post-Gas Clean-Up, Carbon Capture & Storage | Contract Initiation |
| Pilot-Scale Demonstration of Catalytic Wyoming Coal Gasification and Syngas Processing (Diesel Production) Technologies | University of Wyoming | \$1,000,000 | \$1,000,000 | FMC, SIDCOM, WRI, CERC, West Virginia University | \$2,000,000 | Combustion, Gasifier Design, Coal-to-Liquids | Contract Initiation |
| Testing and Feasibility Study of an Indirectly Heated Coal Gasifier | Emery Energy | \$603,494** \$387,481 | \$976,550 (potentially subject to change) | University of Utah, Emery Energy, Kiverdi | \$1,580,045 To be determined | Combustion, Gasifier Design, Coal-to-Liquids | Contract Initiation |
| Evaluation of Staged Oxyfuel Combustion for CO ₂ Capture | Washington University, St. Louis | \$479,651 | \$479,657 | Washington University Clean Coal Consortium, WU School of Engineering | \$959,308 | Combustion, Gasifier Design, Carbon Capture & Storage | Contract Initiation |
| Advanced Polygeneration Platform: Optimizing Oxy-Combustion Burner for Utilizing PRB & GRB Coals | LP Amina | \$1,770,000 | \$1,770,000 | LP Amina | \$3,540,000 | Combustion, Gasifier Design, Coal-to-Liquids | Contract Initiation |
| Fischer-Tropsch Conversion of Wyoming Coal-Derived Syngas Using a Small Channel Reactor for Improving Efficiency and Limiting Emissions | University of Kentucky | \$988,136 | \$989,322 | University of Kentucky, Chart Energy & Chemical | \$1,977,458 | Coal-to-Liquids | Contract Initiation |
| Validation, Modeling & Scale-Up of Chemical Looping with Oxygen Uncoupling | University of Utah | \$183,332 | \$184,000 | CPFD Software, University of Utah | \$367,332 | Combustion, Gasifier Design, Carbon Capture | Contract Initiation |
| Totals | | \$11,050,309 | \$11,585,856+ | | \$22,636,165 | | |

* The Task Force felt this proposal was really comprised of two distinct research efforts and decided to only fund the enhanced water recovery portion of the research in the amount of \$300,000. University of Kentucky may choose to revise their match; however it cannot be less than \$300,000.

** This project is a follow-up to a currently on-going study funded by the Task Force in 2009. The 2009 project is currently behind schedule; therefore, the Task Force recommended partial funding of this project in the amount of \$387,481.

+ Assumes projects with a reduced award provide the originally proposed amount of outside match.

Appendix A

Report of the Advanced Conversion Technologies Task Force (Task Force) To the Joint Minerals, Business and Economic Development Interim Committee

Minerals to Value Added Products Facility Feasibility Study Report Summary

September 1, 2012

Introduction

In the Sixty-First Legislature of the State of Wyoming 2012 Budget Session, House Bill No. 0121, House Enrolled Act No. 25 was passed by the full Legislature and signed into law by Governor Mead. This legislation appropriated \$500,000 in Abandoned Mine Land (AML) funds to the School of Energy Resources (SER) and authorized studies to identify:

- Whether a commercial scale facility which converts minerals to value added products would be economically viable in Wyoming given projected energy prices and regulatory trends;
- Attributes unique to the state of Wyoming which mitigate for and against construction of a commercial scale minerals to value added products facility in the state;
- The best available technologies for the commercial scale conversion of minerals to value added products in Wyoming;
- Potential obstacles to the construction of a minerals to value added products facility in Wyoming and possible strategies to address those obstacles, including, but not limited to the following:
 - ✓ Regional and national political climate;
 - ✓ Economic issues;
 - ✓ Regulatory issues; and
 - ✓ Transportation.
- Potential input sources of minerals and water for the facility and potential markets for the final value added product and any other products created during the conversion process; and
- Whether, and at what level and in what form, state support is necessary for the development of such a project. The study shall identify possible state incentives available for the construction of a commercial scale minerals to value added products facility and determine which incentives are likely to have the most benefit to industry and the citizens of the state of Wyoming.

Advanced Conversion Technologies Task Force

The Advanced Conversion Technologies Task Force (Task Force) issued a Request for Proposals on April 20, 2012 seeking submissions from principal investigators to conduct studies described above. Proposals were due to the School of Energy Resources (SER) by May 25, 2012. Fourteen proposals were received from thirteen organizations. A total of \$2,471,241 was requested. Ten reviewers evaluated two or three proposal each.

On June 18th, the Task Force met in special session and approved the following two studies:

- Western Research Institute received \$162,000 for “Distributed Production of Fuels/Chemicals from Stranded Natural Gas.”
- ArcTech, Inc. received \$329,243 for “Techno-Economic Analysis of MicGASTM Coal Biorefinery Plants for Deployment in Wyoming.”

Reports for each of the studies were received on August 20, 2012, and the principal investigator for each study presented an overview to the Task Force on August 24, 2012. The Task Force voted to accept the Western Research Institute (WRI) report as complete, and findings of the report are summarized below. A copy of the complete report is attached.

The Task Force declined to accept the ArcTech, Inc. report. ArcTech, Inc. was advised by the Task Force on how to revise their report in order to achieve acceptability and was asked to do so as a priority. Their contract was extended to October 1, 2012. **At such time as the ArcTech, Inc. report is accepted, their findings will be summarized and this report will be amended and re-issued.**

Summary of WRI Report: “Distributed Production of Fuels/Chemicals from Stranded Gas”

The authors of the WRI report made several basic assumptions for design of a modular processing plant at the proposal stage. These were:

- Cost – the maximum plant cost could not exceed \$100 million
- Capacity – the output capacity of the plant would be 150 barrels per day (bpd) of product, or largest capacity possible that does not trigger EPA oversight. (Following their discussions with DEQ this ended up being around 500 bpd)
- Siting – siting of the plant would avoid federal lands. The plant would be sited on private property only when the resource owner holds an equity position in the plant.
- Product – the plant will produce a fungible product (gasoline, olefins, diesel in that order.)

The plant proposed in this study is configured as a compact, modular process that can be assembled at a fabrication shop and delivered to a natural gas field requiring minimal field assembly. Conversion is carried out without expensive oxygen and with minimal water consumption. Advanced controls allow remote operations and process control of a single or distributed set of units by a remotely monitored, semi-automatic control station to produce and store the product. Modular design will also allow field replacement of components such as desulfurization modules and reactor modules. Refurbishing of gas clean-up modules and catalyst reloading/regeneration is similarly affected in central facilities. Small modular units reduce manufacturing costs and provide scalability.

WRI coined the term Wyoming Stranded Gas (WYSG) to define the resource for the study. WYSG refers to natural gas reserves that are impeded from getting to market by either physical or economic hurdles. With the local price of natural gas at or below \$3.00/Mscf, all of Wyoming's natural gas could be considered economically stranded. Wyoming coalbed natural gas (CBNG), because of its higher production cost, is especially stranded.

Historically on an energy content basis, gas prices and oil prices have been linked. Increased shale gas, associated natural gas, and CBNG production have created an abundant supply of marketable natural gas which has resulted in delinking of the gas and oil prices. Excess production will likely keep the prices low into the foreseeable future.

A major product from refining of crude oil is fuels for the transportation sector. The transportation sector in the United States currently makes no significant use of natural gas. Lower resource prices represent a major incentive for conversion of natural gas to transportation fuels (gasoline and diesel) and to petrochemicals. The process is called gas-to-liquids (GTL).

Large facilities, such as Shell's Pearl GTL plant under construction in Qatar has an estimated capital cost of \$24 billion and a capacity of 140,000 bpd, are not suited for Wyoming due to limits in the availability of:

- Natural gas feedstock
- Process water
- Work force
- Market

Smaller (± 500 bpd), modular plants are far more suited to the attributes unique to Wyoming. Such plants are appropriate for monetizing WYSG for the following reasons:

- A plant can be assembled at a fabrication shop and delivered to a natural gas field requiring minimal field assembly.
- Advanced controls will allow remote operations and process control of single or distributed sets of units at a remotely monitored, semi-automatic control station. This will apply to both production and storage of the product.
- Modular design will also allow field replacement of components such as desulfurization modules and reactor modules, and refurbishing of gas clean-up modules and catalyst reloading/regeneration units.
- Small modular units reduce manufacturing costs and provide scalability.

Plant sizes as small as 150 bpd can be made profitable. Facilities in the range of 500 bpd to 2000 bpd could be located on gathering facilities or gas compressor stations.

For this study, WRI evaluated GTL conversion to gasoline. Their plant configuration has the following attributes:

- No air separation unit is required. Their design uses steam/methane reforming and can accept elevated levels of CO₂ and is thus suited for CBNG.

- No recycle. Tail gas rich in hydrogen is used for reforming (lower carbon emissions).
- Compact reactors that result in a smaller plant footprint.
- Integral water treatment for water reuse that results in the consumption of one bbl of water for each bbl of product.
- Integration of proven technologies.
- Product is shipped in tanker trucks.
- The market is refineries in WY, CO and MT for:
 - ✓ Gasoline blending
 - ✓ Diluents for heavy oil in Canada
- Product fetches a \$5 to \$23/bbl premium over West Texas Intermediate (WTI). For present day WTI at \$89/bbl, the product price is in the \$94 - \$112/bbl. Similar or better spreads are expected for diesel production.

Simple economics show that a 500 bpd plant is estimated to have a capital cost of approximately \$40 million, and the payoff is calculated to be around 9 years. Multiple units and centralized control and servicing centers improve profitability substantially.

Process simulation shows that 500 bpd will need about 10 MMcf/d of natural gas. Smaller GTL plants in Wyoming can be operational in 3-5 years whereas larger facilities will take considerably longer. Smaller facilities are easier to permit as they fall below many of the critical emission limits. A 500 bpd GTL plant could be classified as a minor source.

The WRI report provides details for required oversight and permits. The following is a brief list of requirements.

- OSLI – Special use lease for siting GTL facilities on state land
- DEQ-AQD – minor source permit
- DEQ-SHWD – Although not a major producer of solid waste oversight required
- DEQ-WQD – General Permit Storm Water Pollution Prevention Plan
- SEO – Permit to appropriate ground water or surface water
- County Zoning – Specific to individual county potential zoning requirements

Potential hurdles for permitting exist where the statutes are either silent or vague as far as they would affect GTL facilities. These include:

- OGCC: Need to clarify whether the GTL process and facilities are subject to the Oil and Gas Act, providing that such processes are not considered part of the natural gas operations or production
- OGCC: Need to clarify whether OGCC has authority to regulate the sale of natural gas from the producer directly to the end user
- PSC: Provide a statutory exemption that the PSC does not have authority to oversee the sale of natural gas to GTL facilities
- DEQ-AQD: Consider assumption of state primacy over the PSD permitting program for greenhouse gas emissions, currently regulated by the EPA.

OSLI – Office of State Lands and Investments
DEQ – Department of Environmental Quality (WQD – Water Quality Division; AQD – Air Quality Division; SHWD – Solid and Hazardous Waste Division)
SEO- State Engineer’s Office
OGCC - Oil and Gas Conservation Commission
PSC – Public Service Commission
PSD – Prevention of Significant Deterioration
EPA – Environmental Protection Agency

Finally, WRI suggests potential incentives and recommendations for encouraging GTL conversion in Wyoming. Chief among these are:

- The state should consider a severance tax exemption by reducing or eliminating the severance tax for natural gas consumed by the plant. This would incentivize new technology development and implementation.
- To attract investment in small-scale GTL in Wyoming, consider a sales tax exemption or reduction for a number of years to help developers recoup construction costs sooner.
- The state should consider direct investment in a pilot or first commercial facility. Such a facility can be used for process refinement for efficiency improvements and for work force development and education.