



SCHOOL OF ENERGY RESOURCES



UNIVERSITY OF WYOMING

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Annual Report of the Advanced Conversion Technologies Task Force to the Joint Minerals, Business, and Economic Development Interim Committee

September 30, 2015

(W.S. 21-17-121c)

This report summarizes the activities of the Advanced Conversion Technologies Task Force (formerly known as the Clean Coal Task Force) for Fiscal Year 2015 (July 1, 2014 – June 30, 2015). For the purposes of this report, the Advanced Conversion Technologies Task Force will hereafter be referred to as the Task Force and the Advanced Conversion – Clean Coal Technologies Research Account as the Account.

Creation and Appropriations Background

In 2007, House Bill 301 created the Task Force consisting of the current voting 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 conversion technologies. The objectives of the program are to:

- Enable and accelerate demonstration and early commercial deployment of conversion 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 conversion 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 or improved conversion technologies that reduce emissions
- 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) provided 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 Advanced Conversion 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	---

In the 2012 budget session, SF15/SEA3 revised the sunset date of the Task Force from June 30, 2013 to June 30, 2017 to ensure the Task Force has oversight of the program one year after the June 30, 2016 reversion date.

FY 2015 Task Force Funding Sources

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 derived from several sources including the Account and the Wyoming Carbon Underground Storage Project (WYCUSP). A portion of these funds was appropriated to the University of Wyoming, School of Energy Resources (SER) to fund research projects under the recommendation of the Task Force (Table 2). The status of each of these programs is discussed in more detail below.

Table 2: AML Funded Efforts Assigned to the Task Force and SER

Program Name	2012 Appropriation	End Date or Fund Reversion Date	Project Status
Advanced Conversion Technology Research	\$10,000,000	Reverts June 30, 2016	On-going
Minerals to Value-Added Products Feasibility Study	\$500,000	Study end date, September 30, 2012, Funds revert June 30, 2014	Completed
Commercial-Scale Minerals to Value-Added Products Facility	\$9,000,000	Reverts June 30, 2016	Reassigned to Governor's Office
Natural Resources to Manufacture Glass and Glass Products in Wyoming	\$100,000	Reverts June 30, 2014	Funds repurposed to rare earth element research

FY 2015 Program Updates

Integrated Test Center

In the 2014 legislative session, a \$15 million appropriation was made under section 334(n) of the state budget bill to the Wyoming governor's office for design, construction and operation of an Integrated Test Center (ITC) to study the capture, sequestration and management of carbon emissions from a Wyoming coal fired power plant. Allocation of test bay space in the ITC will be determined in a manner similar to the X Prize Foundation. The X Prize is a focused contest with specific rules for competition that would, in Wyoming's case, challenge researchers to 1) improve efficiency of carbon capture, and 2) develop a beneficial use of CO₂ at utility scale. The legislation also calls for construction of more test bays in addition to the contest test bays, which will be executed under future Wyoming law.

In the legislation, the Task Force is assigned several duties, including:

- Establishing a cooperative effort with SER for construction, management and operations of the ITC.
- Advising the governor on the size of the research facilities in the test center.
- Signing off on facility design to accomplish stated objectives.
- Electing to stop progress on the project if the construction of the test center is deemed unsatisfactory.
- Making recommendations to the governor of partners interested in the test center should there be more interest than can be accommodated by the test center.

In 2014, Governor Mead appointed members to the ITC Working Group to assess the challenges associated with construction of the test bays and to generate solutions to those impediments. The working group is composed of representatives from state government, utilities and power plant host sites, and other consultants. Following scoping efforts from the ITC Working Group, the Task Force made a recommendation to Governor Mead to continue the ITC project.

In January 2015, the ITC Working Group, with the assistance of SER, issued a Request for Information (RFI). The RFI solicited information from developers of advanced post-combustion carbon capture technologies that are nearing readiness for testing at a pilot scale of 1 MWe or greater. The RFI was used to confirm Wyoming's and the energy industry's interest in further pursuing the ITC project. The RFI garnered 10 responses, containing technical information about candidate test technologies. The responses represent a field of candidate technologies for testing at the ITC and will be used to inform the test facility design and construction.

The working group continues to determine technical compatibility between candidate test technologies and host sites. It is also working to estimate design, construction, and operation costs that will likely exceed the legislatively allocated \$15 million. As the project progresses, the Task Force will be involved in contracts and agreements among the State of Wyoming, ITC host sites, X Prize, and test technology owners and will continue to advise Governor Mead on the ITC project's viability.

Advanced Conversion Technology Research

The 2012 appropriation of \$10,000,000 toward advanced conversion technology research was committed to 10 research projects through a competitive request for proposal process. All of the appropriations directed toward clean coal and advanced conversion technology research since 2007 have been fully committed to 49 different projects. Of the 49 projects originally funded, 39 have been completed to date, 7 projects are in progress, 2 projects were terminated prior to completion and 1 project failed to negotiate a contract. All projects will be completed by March 31, 2016. On behalf of the Task Force, SER staff continues to monitor and support the ongoing research projects. Listings of all the projects funded by the Task Force are shown in Tables 4-10 at the end of this document.

By legislation, the 2007 funds do not have a reversion date. (Table 1) In addition, the 2007 funds were set up as an interest bearing account. The original 2007 appropriation of \$2.5 million has been accumulating interest; however, over time the rate of interest growth has slowed as the 2007 funds have been spent on research projects. Since 2007, this account has accumulated \$602,506.33 in interest, some of which has been deployed by the Task Force.

In 2007, \$285,000 of the interest was allocated by the Task Force as supplemental funding to a 2007 project, and in 2011, \$44,639 of the interest was used to partially fund a 2011 project. According to the State of Wyoming, Department of Administration and Information Accounting Office, as of May 31, 2015, the balance of interest on the 2007 account was \$272,868.07. (Table 3) The Task Force continues to discuss options on what to do with the interest funds. Because the Task Force has a sunset date of June 30, 2017, a decision regarding the fate of the interest on the 2007 funds will need to be made by the Task Force prior to that date.

2015 Advanced Conversion – Clean Coal Technologies Fund Research Symposium

SER hosts an annual research symposium to provide a forum for researchers funded through the Advanced Conversion – Clean Coal Technologies Fund to present the results of their work to the public. Because all but one research projects will be completed by December 31, 2015, the 2015 symposium will likely be the final event for the program. The remaining research project, set to end March 31, 2016, will be presented in another venue.

Research Project Follow-up

As the research projects near completion, information regarding follow-on work and steps toward pilot or commercial scale-up of the technologies funded by the Task Force would be helpful in determining the success of the program. SER staff has started collecting survey data from researchers funded by the Task Force to identify key technological advances as well as barriers researchers have had relative to scaling up their technology. The final survey results will be presented in next year's annual report.

Table 3. Advanced Conversion Technology Account Balance

Appropriation	Amount
2007 Appropriation	\$2,500,000
<i>Interest generated 7/1/2007-5/31/2015</i>	\$602,506
2008 Appropriation	\$3,800,000
2009 Appropriation	\$10,613,047
2010 Appropriation	\$14,000,000
2012 Appropriation	\$10,000,000
Subtotal	\$41,514,107
2007 Awards	(\$2,783,221)
2008 Awards	(\$3,699,986)
2009 & 2010 Awards (From 2009 Appropriation)	(\$6,046,360)
2011 Awards (From 2010 Appropriation)	(\$12,412,655)
2012 Awards	(\$11,050,309)
Redirected Funds (From 2008-2011)*	(\$5,250,154)
Subtotal	(\$41,242,685)
Remaining Balance <i>(As interest from 2007 funds)</i>	\$272,868

*Redirected funds derive from projects that were funded but were either terminated early or never entered into a contract. All of these funds were put back into the Account and committed to new projects.

Table 4. 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
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
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

Table 5. 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
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;	Complete
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 6. 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	Complete
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	Complete

Table 7. 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	Complete
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
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 8. 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	Complete
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	Complete
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	Complete
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	Complete
Development of Compact Heat Exchange Reactor for F-T Synthesis	WRI	\$450,000	\$600,200	WRI(DOE), Chart	\$1,050,200	Advanced Cycle Technologies	Complete
Modular Fischer Tropsch for Wyoming Coal-to-Liquid Fuels	Ceramatec	\$596,105	\$596,105	WRI(DOE), Ceramatec	\$1,192,210	Coal-to-Liquids	Complete
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	Complete
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	Complete
Low Cost Route to Commercial Iron FT Catalysts for CTL & BTL	BYU	\$420,004	\$420,009	Research Consortium	\$840,013	Coal-to-Liquids	Complete

Table 9. 2011 Funded Projects

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

Table 10. 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	\$300,000	West Virginia CERC/Univ of Kentucky Research Foundation	\$600,000	Carbon Capture & Storage	Complete
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	In Progress
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	Complete
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	In Progress
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	In Progress
Testing and Feasibility Study of an Indirectly Heated Coal Gasifier	Emery Energy	\$603,494** \$387,481	\$867,683	University of Utah, Emery Energy, Kiverdi	\$1,580,045 To be determined	Combustion, Gasifier Design, Coal-to-Liquids	Complete
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	In Progress
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	In Progress
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	In Progress
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	In Progress
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.

** 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.

