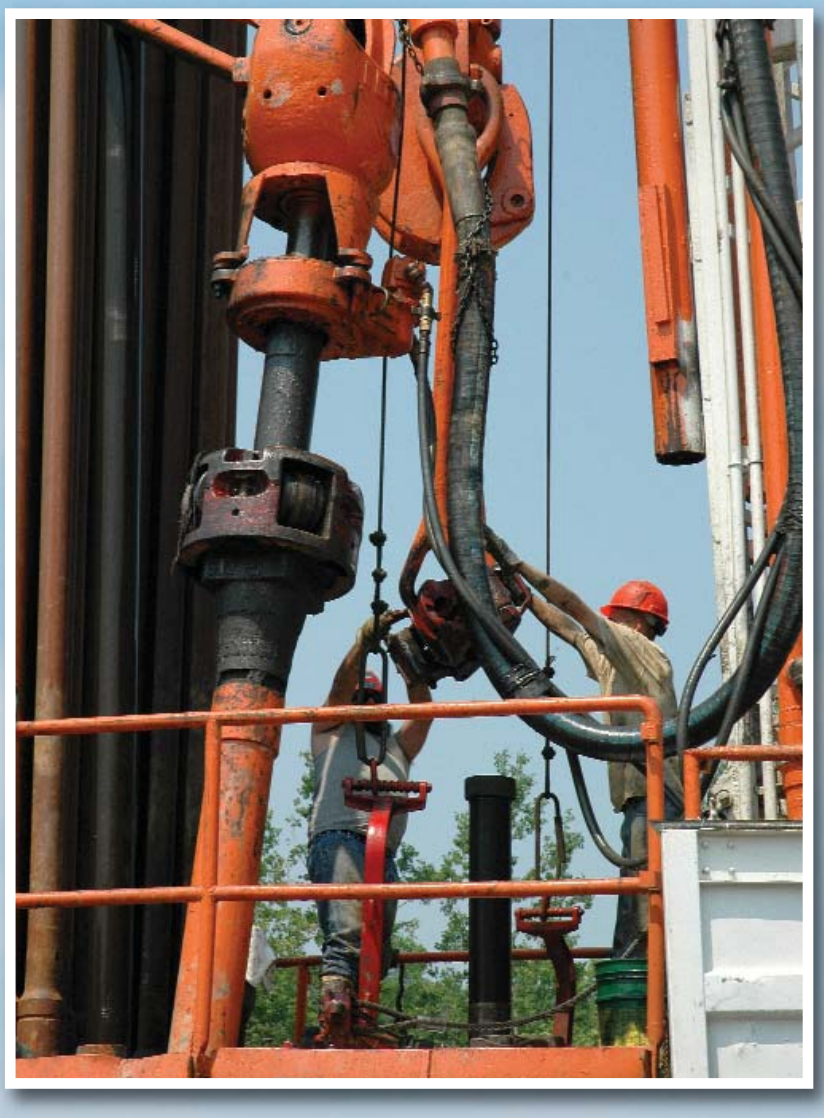

Ohio Coal Development Agenda

November 2009

Issued by the Ohio Air Quality Development Authority, Ohio Coal Development Office

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COVER PHOTO: Drilling operations of the Ohio Department of Natural Resources, Division of Geological Survey CO_2 No. 1 Well in Tuscarawas County, Ohio. This photo shows "roughnecks" (workers on a drilling rig) making a connection of drill pipe on the rig floor as they drill deeper. To the left of the swivel are stands of drill pipe. Sections of drill pipe ("joints") are 30 feet in length.

The Ohio Air Quality Development Authority

November 2009

CLEAN AIR & CLEAN ENERGY ARE GOOD BUSINESS

OHIO COAL DEVELOPMENT AGENDA

To our Stakeholders:

Ohio is a recognized world leader in clean coal technology. Our state also ranks high in coal production, consumption and research. Ohio is positioned to expand its leadership by making advancements toward attracting and nurturing advanced energy businesses. To illustrate Ohio's recent accomplishments and plan for coal in Ohio's future, the Ohio Air Quality Development Authority (OAQDA), as directed by statute, presents this Ohio Coal Development Agenda for the years 2007-2008.

Perhaps the highlight of these years was the acceptance of expanded responsibilities for OAQDA concerning the $1.57 billion bipartisan job stimulus package that was signed into law by Governor Ted Strickland in June, 2008. A total of $150 million was set aside in the package for the Advanced Energy Job Stimulus Program. Of that total, $66 million was designated for additional clean coal projects, with OAQDA, through the Ohio Coal Development Office (OCDO), administering the process. A transparent, easily accessible application process was established in late 2008, and the office is now receiving and reviewing proposals from Ohio companies interested in securing funding for their projects.

The two-year period covered in this report also saw OCDO remain true to its core mission, which is to co-fund the research, development and deployment of new clean coal technologies, enabling the expanded use of Ohio coal in an economical, environmentally sound manner. A total of 26 clean coal research projects at Ohio universities received OCDO funding in 2007 and 2008, through a continued working partnership with the Ohio Coal Research Consortium. Also, a total of 21 pilot scale and demonstration projects received funding in 2007 and 2008. These projects are described in this Agenda.

As part of our effort in this document to "look forward," we thought it would be timely and helpful to present information on a pressing issue confronting Ohio, the nation and, indeed, the world – global climate change. This is in line with Governor Strickland's call for action to address this issue during his unveiling of his Energy, Jobs and Progress Plan in August, 2007. Hence, we have prepared an article as part of this Agenda that examines some of the actions being taken by OAQDA and other state agencies to address this issue.

As always, we appreciate your continued support and interest in Ohio coal and would welcome any comments or suggestions you might offer.

Respectfully,

Gayle Channing Tenenbaum
OAQDA Chair

Mark R. Shanahan
OAQDA Executive Director

Michael T. W. Carey
Chairman, OCDO Technical Advisory Committee

Characterization of Ohio Coal

Coal is a reliable, abundant "home-grown" source of energy for Ohio and the nation. Its importance to Ohio was evident even before the dawn of statehood. Forty eastern and southeastern Ohio counties have coal-bearing rock formations. Of those, 32 counties have engaged in mining operations since the practice began in the state in 1800. More than 3.72 billion tons of coal have been mined in Ohio. Coal production peaked in Ohio in the 1960s at more than 55 million tons annually. Coal employment reached its high point during the first two decades of the 20th century, when more than 50,000 Ohioans worked as coal miners.

Today, coal is mined in 16 Ohio counties. They are **Athens, Belmont, Carroll, Columbiana, Coshocton, Harrison, Jackson, Jefferson, Mahoning, Monroe, Muskingum, Noble, Perry, Stark, Tuscarawas and Vinton Counties**. Reports were filed in 2007 for 139 coal mining operations in Ohio. Coal production was reported from 86 of these 139 operations.

Coal mining activities in Ohio have experienced fluctuations during the current decade.

- In 2000, coal mining employed 2,717 Ohioans. In 2007, the number was 2,204 – down from 2,423 in 2006.
- In terms of tonnage, Ohio coal production has remained about the same, with 22.5 million tons being mined in 2000 compared to 22.3 million tons in 2007.
- Coal miners worked an average of 193 days in 2007 compared to 171 days in 2006.
- Average annual wages for coal miners began the decade at approximately $47,400, rising to $58,229 in 2007.
- Total coal mining wages in 2007 were $128.3 million, down from $137.5 million in 2006 and $141.1 million in 2000.

Ohio's coal consumption rankings in 2007 did not change from their 2006 levels. Ohio was third in coal consumption, trailing only Texas and Indiana. This ranking reflects the critical role that coal plays in our daily lives, with approximately 90 percent of all electricity in Ohio being generated by coal. More than nine percent of the remaining electricity is created by nuclear generation, with the rest coming from oil and gas.

Preliminary estimates indicate that 25.3 million tons of coal were produced in Ohio in 2008, a more than nine percent increase from 2007. The value of Ohio coal sold was in excess of $1 billion for the first time since 1987. Two new mines in Jefferson County combined to produce 1.1 million tons of coal in 2008, using surface mining with a mining technology

known as highwall mining that is new to Ohio.(In highwall mining, the coal seam is penetrated from the side rather than the surface, as is the case in augur mining. It produces far less debris than other forms of surface mining, but is a costlier operation).

(The source for statistics cited above is the 2000-2007 Reports on Ohio Minerals, prepared by the Ohio Department of Natural Resources, Division of Geological Survey.)

Characterization of Current and Potential Markets for Ohio Coal

Coal production and electricity generation go hand-in-hand, especially in states like Ohio, where nearly 90 percent of our electricity comes from coal (Nationally, coal is responsible for approximately 49 percent of all electricity generation).

As reported, preliminary data for 2008 indicate that Ohio coal producers sold more than $1 billion worth of coal in that year – a level not reached in 21 years. In addition, a large, new coal mine and riverside loading facility is now under construction in Meigs County, offering the promise of additional coal production in the near future. Further, the ongoing progress at the AMP Ohio 1,000-megawatt base-load power plant, also in Meigs County, should lead to increased production of Ohio coal.

Ohio exports more than 500,000 tons of coal annually to other countries, much of it to Canada. Data also suggest that demand for Ohio coal is generally on the rise, although specifics were not available at this writing. In addition, the inclusion of $66 million for clean coal technology projects in the Advanced Energy Job Stimulus Program should bode well for continued demand for Ohio coal in the future.

The Ohio Coal Development Office

The Ohio Coal Development Office (OCDO), a program of the Ohio Air Quality Development Authority (OAQDA), co-funds the development and implementation of technologies that can use Ohio's vast reserves of high-sulfur coal in an economical, environmentally sound manner. This work is critical for Ohio, which generates nearly 90 percent of its electricity from coal. Nationwide, coal is forecast to fuel at least half of the nation's electric power production through 2015, and probably beyond.

Projects supported by OAQDA are sought through public solicitations and requests-for-proposals (RFPs). Cost-sharing is required. While OCDO can support projects ranging from applied research through commercial demonstration, it is this latter category that is of particular interest.

OCDO projects include technologies that improve combustion efficiencies, remove various pollutants from emissions such as sulfur and nitrogen oxides and air toxics, develop productive uses for the by-products of combustion and investigate new uses for coal as a feedstock for other fuels. OCDO projects frequently involve multiple project participants, such as the technology developer, a university or other research institution, the federal government and/or other private sector co-sponsors.

Types of projects and funding levels are defined within the RFPs. Proposals are reviewed by independent technical reviewers, then submitted to OCDO's statutorily created Technical Advisory Committee (TAC) – a 15-member group comprised of public and private members having an interest in coal, power production and the environment. Projects favorably recommended by the TAC are submitted to OAQDA for final approval, then grant negotiations commence. Public abstracts describing the type and range of the nearly 300 projects funded to date by OCDO are available on the OAQDA website, clicking on the "Coal" bubble on the home page and following the link under "about OCDO" to find a current listing.

OAQDA, working through OCDO, is now responsible for administering a process to provide an additional $66 million in funding for advanced clean coal projects over the next three years as part of the Advanced Energy Job Stimulus Program announced in 2008. The funds are part of the $150 million set aside in total for the Program. The remaining $84 million will be awarded to non-coal advanced energy projects, with OAQDA serving as the administering agent for this process as well.

While advanced energy technologies are under development and receiving strong support from the State of Ohio, coal will remain the backbone of this state's and nation's energy supply for years to come. However, it should be used cleanly, and this can be accomplished only through the development and deployment of clean coal technologies supported by OCDO.

*A copy of the Ohio Coal Development Office Strategic Plan appears at the end of this document.

Description of Academic Year 2007 Clean Coal Research Projects

On July 10, 2007, OAQDA approved $1,987,909 in OCDO funding for 16 clean coal research projects at seven Ohio universities. Nine projects were funded for one year, with the remaining seven receiving funding for two years.

The projects were evaluated and ranked by the Ohio Coal Research Consortium (OCRC) Review Committee and submitted to OCDO's TAC. They were reviewed by TAC and OCDO, resulting in their favorable recommendation to OAQDA. The OCRC Review Committee is composed of engineers and researchers from the public and private sectors and was established in 1989 by OCDO to better coordinate university coal research and development and to foster awareness and collaborations among Ohio universities.

These 16 projects reaffirm Ohio's continued leadership nationally and internationally in the development of energy-efficient, environmentally sound ways to use Ohio's abundant supplies of coal. They also recognize the critical role that coal plays in our state, as a supplier of electricity, a feedstock – or source – for other fuels and a driving force in our economy.

The funded projects are described below according to category. All projects met the cost share requirement of 20 percent for an OCRC grant. The university share is included following each project description.

Mercury Capture Projects

- $80,000 to fund a one-year laboratory project at the University of Dayton to assess the role played by fly ash in determining the portion of flue gas mercury that can be easily captured during coal combustion. University share: $20,000.
- $239,206 for two projects at the University of Cincinnati to test different adsorbents for their ability, not only to aid in the capture of mercury during combustion, but also to help reduce capture costs from a U.S. Department of Energy (USDOE) estimated $30,000 per pound to as low as $1,000 per pound – a groundbreaking feat if successful. One project is funded for the next academic year, and the other for the next two. University share: $75,530.

Carbon Dioxide (CO2) Geologic Sequestration Projects

- $79,996 for a one-year project at Case Western Reserve University to study potential chemical reactions between CO2 and other chemical byproducts from combustion, and brine-rock from the Rose Run geologic formation in eastern Ohio. Data gleaned from the project will help guide the state's preparations for anticipated federal regulation of CO2 emissions. University share: $20,611.
- $159,998 for a two-year Ohio University project to evaluate how clean a CO2 gas stream must be for compression and transport from a power plant to an injection well. The University's Institute for Corrosion and Multiphase Technology is nationally renowned for its work on corrosion in gas transmission pipelines. University share: $41,492.

Clean-coal Technologies of the Future

- $80,000 for a groundbreaking one-year University of Akron project that will attempt to determine design factors which could facilitate the building of a direct-coal fuel cell. Although considered by OCRC to be a high-risk study in terms of potential commercial development, the project nevertheless could transform the world of power generation with respect to the direct conversion of coal energy into electricity. University share: $21,510.
- $79,991 for a one-year chemical-looping project at The Ohio State University that could dramatically change the way coal is converted to power or chemicals. The project's chief goal is to construct a scaled-up chemical looping reactor that closely simulates a commercial reactor. Chemical looping is a technique that uses dual reactors to create pure streams of sequestration-ready CO2 and hydrogen. The project is viewed as one of OCRC's most important undertakings. University share: $23,865.
- $79,991 for a second, one-year chemical-looping project at The Ohio State University that will examine the reaction of syn-gas with iron oxide particles as it pertains to production of a hydrogen stream which is suitable as a feedstock for a Fischer-Tropsch reactor (Syngas is a mixture of carbon monoxide, CO2 and hydrogen generated during coal gasification). Such reactors are used to create liquid fuels from coal. University share: $23,865.
- $160,000 for a two-year joint project between The Ohio State University and the University of Akron that, in its first year, will evaluate the use of iron particles in the first reactor of the chemical-looping combustor as a fuel for the direct-coal fuel cell. In its second year, the project will consider optimization of the size and composition of the supported iron for an integrated system. University of Akron share: $21,504. The Ohio State University share: $19,168.
- $159,986 for a two-year project at The Ohio State University to use the chemical-looping process with calcium oxide and calcium carbonate to convert a mixture of syn-gas and off-gas (a hazardous byproduct of manufacturing) from a Fischer Tropsch reactor to a gas stream that is free of hydrogen sulfide and CO2. The potential to remove sulfur to the parts-per-billion level and to eliminate WGS catalysts in one reactor, is a major breakthrough concept. This project has also received additional funding from the U. S. Department of Energy. It is one of the most promising OCRC projects. University share: $51,884.
- $79,996 for a one-year project at The Ohio State University to develop and test different catalysts that can resist poisoning of carbon deposits and sulfur during the water-gas-shift (WGS) conversion of syn-gas into hydrogen. University share: $21,762.

Coal and Syn-gas to Hydrogen Projects

- $160,000 for a two-year University of Cincinnati project to demonstrate a method for removing hydrogen from a water-gas-shift reactor, via a defect-free inorganic membrane, as it is produced, rather than allowing amounts of the chemical to accumulate during conversion of coal to hydrogen. The goal is to better enable the complete conversion of carbon monoxide to CO2, to create a sequestration-ready stream of CO2, and to improve reactor efficiency. University share: $54,454.
- $160,000 for a two-year University of Toledo project that will use organic, rather than inorganic, membranes to produce relatively pure amounts of hydrogen in the WGS process for use in power generation or chemical production. This concept differs from similar, past OCRC projects in that this class of membranes can be commercially manufactured without defects. University share: $186,339.
- $79,996 for a one-year project at The Ohio State University to develop chemical catalysts that can help facilitate the production of hydrogen from coal syn-gas. University share: $23,865.
- $79,998 for a one-year project at The Ohio State University to develop catalysts that can remove carbon monoxide from hydrogen produced by the WGS method for use in PEM (Polymer Electrolyte Membrane) fuel cells. Importantly, such catalysts show promising mine-safety application as a component in gas masks worn by coal miners that can remove carbon monoxide from the air during mine fires. University share: $21,411.
- $160,000 for a two-year joint project between The Ohio State University and the University of Cincinnati that will attempt to demonstrate an improved total WGS reaction system by bringing an inorganic membrane, plus the catalysts, together as an enhanced reactor. University of Cincinnati share: $27,225. The Ohio State University share: $20,001.

Ohio Coal Research Consortium AY07-08 Projects

#	PI	Title	OCDO	University
ADM	Ohio University	Administration of Non-technical Aspects of Projects	$148,750	
		Goal A Projects – Mercury Capture		
A1	Dr. Sidhu – UDRI	Surface Catalyzed Mercury Transformation Reactions	$ 80,000	$20,000
A2	Drs. Thiel and Pinto – UC	Advanced Adsorbent for Hot Gas Removal of Mercury in Coal Gasification	$79,975	$23,864
A3	Drs. Thiel and Pinto – UC	Advanced Adsorbents for the Direct Capture of Gas-Phase Toxics	$159,231	$51,666
		Goal B Projects – Geologic Sequestration		
B1	Dr. Saylor CWRU	Carbon Dioxide Sequestration in the Rose Run Formation of Eastern Ohio	$79,996	$20,611
B2	Drs. Nesic and Bayless – OU	Corrosive Properties and Suitability for Compression of Separated CO_2	$159,998	$41,592
		Goal C Projects – Conversion of Coal to Power or Chemicals -- CO2 Ready for Sequestration		
C1	Dr. Chuang – UA	Coal-based Fuel Cell	$80,000	$21,510
C3	Dr. Fan – OSU	Chemical Looping Combustion	$ 79,991	$23,865
C4	Dr. Fan – OSU	Hydrogen Production from Syn Gas using Novel Metal Oxide Composite Particles	$79,991	$23,865
C5	Dr. Ozkan – OSU	Novel Electrode Catalysts for Enhanced Coke and Sulfur Resistance in Reduced Temperature Coal Gas-Fed SOFC Systems	$79,996	$21,762
C16	Dr. Chuang Dr. Fan – UA & OSU	Integrated Fuel Cell with Chemical Looping	$160,000	UA $21,504 OSU $19,168
C17	Drs. Zakin and Fan – OSU	Enhanced Coal to Liquid Technology Using Calcium Looping Process	$159,986	$51,884
		Goal C Projects – Catalysts and Membrane Systems for Water Gas Shift of Syn-gas to Hydrogen		
C2	Dr. Ozkan OSU	Hydrogen Production via High Temperature Water Gas Shift Reaction of Coal-derived Synthesis Gas	$79,996	$21,762
C6	Dr. Guliants – UC	Chemically and Thermally Stable Sodalite and DD3R Membranes for Hydrogen and CarbonDioxide Separation	$160,000	$54,454
C7	Dr. Coleman – UT	Copolymerized Ionic Liquid-Polyimide Membranes for CO_2 Removal from Gasified Coal	$160.000	$186,339
C8	Dr. Ozkan – OSU	Low-temperature catalytic preferential oxidation of CO	$79,998	$21,411
C9	Dr. Guliants Dr. Verweij UC & OSU	Multi-Scale Catalytic Membrane Reactors for Hydrogen Production in Coal Gasification Systems	$160,000	UC $27,225 OSU $20,001

Totals

OCDO – $1,987,909.00
University Share – $ 672,483.00
Grand Total – $2,660,392.00

Cost Share at 34% of OCDO Grants

Description of Academic Year 2008-2009 Clean Coal Research Projects

On July 8, 2008, OAQDA approved $1,900,473 in OCDO funding for 10 clean coal research projects at four Ohio universities. For the first time in the history of the program, projects were funded on a two-year basis *only* – a departure from past years when most projects received funding for one academic year. The change was made to give principal faculty researchers added stability and flexibility in addressing the highly complex nature of their work.

As in the process previously described for the 2007 projects, these projects were evaluated and ranked by the OCRC Review Committee and submitted to TAC. They were reviewed by TAC and OCDO, resulting in their favorable recommendation to OAQDA. The OCRC Review Committee is composed of engineers and researchers from the public and private sectors and was established in 1989 by OCDO to better coordinate university coal research and development and to foster awareness and collaborations among Ohio universities.

These 10 projects reaffirm Ohio's continued leadership nationally and internationally in the development of energy-efficient, environmentally sound ways to use Ohio's abundant supplies of coal. They also recognize the critical role that coal plays in our state, as a supplier of electricity, a feedstock for other fuels and a driving force in our economy.

The funded projects are described below according to category. All projects met the cost share requirement of 25 percent for an OCDO project. The university share is included following each project description.

Mercury Capture Project

- $159,804 to fund a **University of Cincinnati** project aimed at the development of a mercury sorbent for use at higher temperatures during coal combustion to capture elemental and oxidized mercury in a very small waste stream that can be easily disposed of in a secure landfill. A key goal of the project is to develop a sorbent that can reduce capture costs from U.S. Department of Energy estimates of $30,000 per pound to $1,000 per pound. University share: $51,755.

Geologic Sequestration Project

- $159,389 for a **Case Western Reserve University** project to assess chemical reactions between CO_2 and sulfur dioxide (SO_2) in Ohio's deep brine geologic formations. This project will consider whether SO_2 removal from the CO_2 gas stream is required for underground CO_{22}uestration. If not, the cost of sulfur capture by scrubbers would be eliminated. University share: $43,932.

Conversion of Coal to Power or Chemicals Projects

- $159,947 to fund a chemical looping combustion (CLC) project at **The Ohio State University**. CLC uses dual reactors to create pure streams of sequestration-ready CO_2 and hydrogen, which can be used in power production or as a reagent for chemical production. This project aims to enhance understanding of the rapid movement of oxygen during combustion, a key component of the CLC process. University share: $43,879.

- $159,996 to fund a second chemical looping project at **The Ohio State University.** This project involves the reaction of syn-gas (a mixture of carbon monoxide, CO_2, and hydrogen) and metal oxide composite particles. It can be used to produce hydrogen or a mixture of hydrogen and carbon monoxide for feedstock for a Fischer-Tropsche reactor – a process used to produce a synthetic substitute for petroleum. University share: $43,884.
- $159,994 for a project at **The Ohio State University** aimed at developing electro-catalysts capable of reducing the temperature required to operate a solid oxide fuel cell (SOFC). SOFCs are highly efficient and produce low emissions. The greatest barrier to their use is the cost of materials required for operation at close to 1,000°C. This project seeks to develop catalysts that can reduce operating temperatures on the surface of the cathode layer of a SOFC by approximately 300°C. University share: $41,097
- $159,994 for a related project at **The Ohio State University** intended to address issues with the anode layer of a solid oxide fuel cell. Under reduced temperatures, the anode can experience reduced resistance to sulfur poisoning and a loss of reactivity due to coking, or the accumulation of un-reacted carbon deposits on the surface. University share: $41,097
- $160,000 to fund a project at the **University of Cincinnati** to develop ceramic membranes that can separate oxygen from air in a more economical manner than is now possible. Oxygen, when used in oxy-fired pulverized coal power plants and in the "oxygen blow gasification" of coal, helps produce a sequestration-ready stream of CO_2. The current high cost of oxygen-from-air separation can be prohibitive for these applications. University share: $41,097.
- $160,000 for a second "oxygen-from-air" project at **The Ohio State University.** It differs from the project above in that it is not dependent on a sieving mechanism based on the molecular diameters and pore sizes of the membrane. In this case, the membrane is nearly free of pores, and separation results as oxygen ions pass through the membrane. The two projects together present a well-balanced start in the investigation of this topic. University share: $50,310.
- $160,000 for a **University of Akron** project aimed at determining the design factors that would enable the scale-up of a direct coal fuel cell. Specific goals of the project include establishing the consistency of the coal fuel cell performance data, evaluating the material and energy balance, developing seals for the fuel cell, and continuing to improve the mechanical strength of the overall fuel cell. This project is regarded as high-risk because of the challenges that must be overcome. If successful, however, it represents a concept that would change the world of power generation. University share: $53,340.

Catalyst and Membrane Systems for Water Gas Shift of Syn-gas to Hydrogen

- $159,982 to fund a project at the **University of Cincinnati** aimed at building a reactor capable of achieving the water gas shift of raw syn-gas to hydrogen and CO_2 (Water gas shift is a chemical reaction in which water and carbon monoxide react to form hydrogen and CO_2). The work will conclude with a computer model that compares a comparably sized membrane reactor with the syn-gas reactor to determine the cost and commercial potential of the latter. University share: $49,865.

Ohio Coal Research Consortium AY08-09 Projects

#	PI	Title	OCDO	University
ADM	Ohio University	Administration of Non-technical Aspects of Projects	$ 301,363	
		Goal A Projects – Mercury Capture		
A2-C	Drs. Thiel and Pinto – UC	Advanced Adsorbent for Warm- Gas Capture of Gas Phase Toxics	$ 159,804	$51,755
		Goal B Projects – Geologic Sequestration		
B1-C	Dr. Saylor CWRU	CO_2 and SO_2 Co-solubility and Reactions in Ohio's Deep Brine Formations	$ 159,389	$ 43,932
B2	Drs. Nesic and Bayless – OU	Corrosive Properties and Suitability for Compression of Separated CO_2	$ 159,998	$41,592
		Goal C Projects – Conversion of Coal to Power or Chemicals – CO_2 Ready for Sequestration		
C1-C**	Dr. Chuang – UA	Coal-based Fuel Cell	$ 160,000	$ 53,340
C3-C	Dr. Fan – OSU	Chemical Looping Combustion	$ 159,947	$ 43,879
C4-C	Dr. Fan – OSU	Hydrogen Production from Syn Gas using Novel Metal Oxide Composite Particles	$ 159,996	$43,884
C5-C	Dr. Ozkan – OSU	Novel cathode electro-catalysts for reduced temperature coal gas fed SOFC	$ 159,994	$ 41,097
C18-N	Dr. Ozkan – OSU	Sulfur and Coke Resistance in Reduced Temperature Coal Gas-Fed SOFC Systems	$ 159,994	$ 41,097
C19-N	Dr. Guliants – UC	Novel high flux and selective air separation membranes for oxy-fired combustion	$160,000	$50,310
C20-N	Dr. Verweij – OSU	Dual phase nano-composites for O_2 separation	$ 160,000	$60,000
		Goal C Projects – Catalysts and Membrane Systems for Water Gas Shift of Syn-gas to Hydrogen		
C2	Drs. Dong and Smirniotis – UC	High Temperature Water Gas shift Membrane Reactors for Production of Hydrogen from Ohio Coals	$79,996	$21,762
		Grand Totals	**$ 1,900,473**	**$479,669**

Pilot and Demonstration Project Summaries

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-96-19	Sorbent Technologies	Commercial Demonstration of FGD at Ohio University's Lausche Heat Plant	$9,450,000	$13,243,000	4/1/98	3/31/07

The objective of this project was to demonstrate the Fluesorbent dry SO_2 scrubbing system on two 70,000-pound coal-fired boilers at the Ohio University's Lausche Heating Plant. Following design, installation and start-up, the system was operated successfully for short periods of time; however, the economics of the Fluesorbent dry SO_2 scrubbing system have changed significantly since the inception of this project. It is now clear that the cost of sorbent has risen to the point that even if the technology were successfully demonstrated, it would not be economically viable and therefore would not achieve any significant level of commercialization. Based on the present status of the project and the revised economic considerations, OCDO, Sorbent Technology Corp. and Ohio University decided to cease work on the project and restore the plant to pre-project operation status. The project was closed out on 3/31/07. This action saved OCDO $500,000 in unexpended funds.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-02-04	Energy Industries of Ohio	Weldability Study to Join Thick Sections of Inconel Alloy 740	$112,296	$653,564	10/1/03	10/31/07

This project serves as a complement to the UltraSuperCritical Boiler Materials Project (D-00-20). Inconel 740 has been selected as a desirable alloy for the heavy sections of an UltraSuperCritical boiler, but it cannot be welded by conventional means. This project has been designed to evaluate the weldability of Inconel 740 and identify the best ways to weld this alloy into a boiler.The objectives of this project were completed on time.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-04-01	Energy Industries of Ohio	Commercialization of FASAND (Fly Ash/Foundry Sand) in Expendable Tool Applications	$213,036	$475,496	8/1/06	8/31/08

Energy Industries of Ohio, General Motors, Thompson Aluminum, Dayton Power and Light and FirstEnergy, along with Foundry Research Institute and Motor Transport Institute of Poland demonstrated in an actual production environment the use of coal fly ash as a replacement for virgin sand in mold and core production in foundry applications. The project demonstrated that mold and core shapes could be produced with fly ash if care is given to selection of the ash binder formulation. The surface properties of castings using fly ash were superior to that of castings made with foundry sand in that the final product was much smoother and the machining required to prepare the final product was greatly reduced.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-05-02(A)	Energy Industries of Ohio	Boiler Materials for UltraSuperCritical Power Plants	$3,882,375	$25,907,930	6/1/01	12/31/11

This comprehensive project involves the development of new materials that can be used to build a coal-fired boiler capable of operating at more efficient UltraSuperCritical (USC) conditions. The expected emission reduction from the efficiency gain is 15% to 22%. The challenge is that such conditions require boiler parts that can endure much higher temperatures and pressures. Tasks for the project are undertaken by the four major US boiler manufacturers, along with scientists at Oak Ridge National Lab, along with support at the University of Cincinnati. The overall project manager is Energy Industries of Ohio. Major tasks in the project include preliminary design and economic studies, evaluation of mechanical properties, steam side and fireside corrosion studies, weldability studies, fabricability studies, coatings and design approaches. Work is progressing, pursuant to the test plan, and significant progress is being made in achieving the goals of the consortium.

OCDO#	Grantee	Title Support	OCDO Budget	Total	Start Date	End Date
D-05-02(B)	Energy Industries of Ohio	Advanced Materials for Ultra-SuperCritical Power Plant – Turbines	$246,591	$2,702,720	11/1/05	11/31/09

This project involves the development of new materials that can be used to build more efficient USC turbine systems. The project will address major areas of research as follows: 1) identifying and investigating materials related issues in oxygen fired boiler plants and 2) developing materials technology for steam turbines in parallel with the boiler R&D for USC plants. The project is progressing satisfactorily.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-05-04	The Ohio State University	Research and Demonstration of Beneficial Agricultural Uses of flue gas desulfurization – Products in Ohio	$170,362	$529,500	11/1/05	6/31/08

The Ohio State University and Ag Spectrum demonstrated use of FGD gypsum as an agricultural amendment. The benefit of FGD gypsum to agriculture as a potential sulfur fertilizer and as an amendment to improve water infiltration and soil aeration was studied. Replicated field plots were used to investigate the response of corn and forages to FGD gypsum applied at a rate of approximately 30 lbs of sulfur per acre. Other field studies evaluated potential increases in nitrogen-fertilizer use efficiency by corn when fertilized with FGD gypsum. The demonstration also evaluated the enhancement of soil drainage resulting from using FGD gypsum at rates of 1,000 lbs per acre on soils poorly drained soils. The work was completed on time.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-05-06	The Ohio State University	Demonstration of Reactive CO2 Separation Process Using Tailored Nanoporous Calcium Sorbent	$ 890,185	$2,351,177	7/1/06	12/30/08

It was demonstrated in a small pilot size process at the west campus of The Ohio State University, a method for separation of CO_2 from flue gas wherein the flue gas is suitable for sequestration and heat costs are minimal. The project is an out growth of four years of research in the OCRC. The unique feature of the process is that sorbent developed in the consortium will be used to capture the CO_2 at a high process temperature. This capture chemical reaction releases large quantities of heat that can be used to generate power. This off sets the heat required to separate the sorbent- CO_2 complex into fresh sorbent for reuse and a pure stream of CO_2 suitable for sequestration. Industrial partners are involved and the objective of the project will be to determine design parameters for scaling up the process to an industrial scale. Work is on schedule. The project has successfully demonstrated the reactive CO_2 separation process.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-05-07	The Ohio State University	Coal Combustion Products Extension Program	$248,719	$663,677	1/1/06	5/31/09

This project promotes the responsible and productive beneficial uses of coal combustion products (CCP) among stakeholders in Ohio through technology transfer and education efforts. The program provided unbiased technical information to end users and regulators and is considered to be a "voice of trust." Some of the activities included: 1) work with regulatory agencies to produce environmental and technical guidelines and standards for CCP use; 2) work with Ohio Environmental Protection Agency (OEPA) in developing the new state regulatory framework for CCPs and other related by-products under consideration by the agency; 3) promoted the use of OAQDA's financing opportunities for small and large businesses for air pollution control equipment and facilities, especially as applicable to the construction of fly ash silos at ready mix concrete plants; 4) prepared educational materials for end-users which provide detailed instruction of various uses of CCPs and serve as a resource person to end-users; 5) produced fact sheets and papers and related materials for distribution and make presentations in various forums on the topic; and 6) work with generators, manufacturers, and others to produce value added products from or with CCPs that will benefit the use of coal. The program has been very successful.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-05-8/9	The Ohio State University	Use of Lime-Activated High-Carbon class F fly Ash in Full Depth Reclamation of Asphalt Pavements in Delaware and Warren Counties	$682,026	$2,072,806	1/1/06	5/31/08

The Ohio State University, in cooperation with Brookhaven National Laboratory (BNL), Oak Ridge National Laboratory (ORNL), American Electric Power, Oxford Mining, and B&N coal will demonstrate management methods, which enhance accumulation of soil carbon (C), pool in reclaimed mine land soils (RMSs). In addition, the project will develop protocol for trading C credits on the Chicago Climate Exchange (CCX) for C sequestered in RMSs. The goal of the project is to demonstrate management practices for reclamation of mine land soils, which will enhance soil C sequestration and lead to long-term soil C storage. The impacts of soil compaction, soil management (mulching, manuring, deep ripping), and land use (pasture, hay, forest) on soil C pool of RMSs will be studied. The data from conventional laboratory methods for determining soil organic carbon (SOC) will be compared with newer, less expensive and rapid field methods of SOC measurement developed by BNL and ORNL. The long-term goal is to prepare a fact sheet entitled "Technologies for Reclamation and Sustainable Management of Mine Soils" based upon the results of the research. The field data obtained and the field methods demonstrated for verifying SOC pool would be sufficient to develop protocols for trading C credits on the CCX for RMSs. The project is on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-05-12	Ohio University	Pilot-Testing of Sieving Electrostatic Precipitator	$ 622,923	$ 1,887,644	5/1/06	3/31/09

The Medical Center Company, in cooperation with General Electric, propose the demonstration of methods for bringing existing industrial scale stoker fired coal boilers into compliance with limits on mercury and hydrochloric acid (HCl) emissions of the ICI Boiler MACT Rule (U.S. EPA National Emissions Standards for Hazardous Air Pollutants for Industrial, Commercial and Institutional Boilers). The goal of the project is to demonstrate that by carefully controlling the temperature of the flue gas slightly above the dew point just up stream of the bag house, that sorbents can be injected into the flue gas for removal of acid components. In addition, once the acid content has been reduced to compliance levels, that mercury will be adsorbed on the carbon content of the fly ash and will be removed from the system as particulates in the bag house. The project will optimize temperature conditions. The project will also evaluate a number of sorbents and optimize the sorbent selection and injection rates. The project will be considered successful if the optimized system enables the MCCo stoker fired coal boilers to meet the ICI Boiler MACT Rule while burning Ohio coal at a cost equal to or less then costs associated with alternative mercury and HCl emission control systems. The project was completed on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-05-13	Battelle	Midwest Regional Carbon Sequestration Partnership	$3,050,000	$18,067,378	2/1/06	1/31/10

This project will demonstrate, at the USEPA Research Triangle Park Multipollutant Control Research Facility, a method for capture of both elemental and oxidized mercury in which the captured mercury is isolated from other waste streams such as fly ash and FGD scrubber sludges. The project will also investigate methods for reducing the costs of production of the mercury sorbent. Ohio and eastern bituminous high sulfur coal will be used during the tests.

The goal of the project is to demonstrate that the proposed process will enable capture of mercury at equal to or lower costs than capture of mercury by the Sorbent Technologies sorbent which was developed in OCDO projects D-98-13 and D-00-25. Specifically, the project will observe the following: 1) the long term stability of the sorbents in the flue gas environment; 2) the pressure drop associated with packed bed and fluidized bed contacting systems; 3) the ease of removal of particulate accumulations from the pack bed contacting system; 4) the percent of elemental and oxidized mercury captured from high sulfur flue gases; 5) the cost of mercury capture in $/lb mercury based upon cost of production of sorbent in the UC laboratory; and 6) possible reductions in cost of sorbent when produced in a commercial system. The goals are: 1) 80% or higher capture efficiency of total mercury at a cost of less than $3000 per pound of mercury; 2) sorbents stable enough in the flue gas system to remain active for six months or more; and 3) system pressure drops of 5 inches of water or less. The project is on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-06-02	The Ohio State University	Enhancing Carbon Pool in Coal Mined Soils of Ohio	$249,972	$376,743	9/1/06	8/31/08

The Ohio State University, in cooperation with Brookhaven National Laboratory (BNL), Oak Ridge National Laboratory (ORNL), American Electric Power, Oxford Mining, and B&N coal will demonstrate management methods, which enhance accumulation of soil carbon (C), pool in reclaimed mine land soils (RMSs). In addition, the project will develop protocol for trading C credits on the Chicago Climate Exchange (CCX) for C sequestered in RMSs. The goal of the project is to demonstrate management practices for reclamation of mine land soils, which will enhance soil C sequestration and lead to long-term soil C storage. The impacts of soil compaction, soil management (mulching, manuring, deep ripping), and land use (pasture, hay, forest) on soil C pool of RMSs will be studied. The data from conventional laboratory methods for determining soil organic carbon (SOC) will be compared with newer, less expensive and rapid field methods of SOC measurement developed by BNL and ORNL. The long-term goal is to prepare a fact sheet entitled "Technologies for Reclamation and Sustainable Management of Mine Soils" based upon the results of the research. The field data obtained and the field methods demonstrated for verifying SOC pool would be sufficient to develop protocols for trading C credits on the CCX for RMSs. The project is on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-06-03	Medical Circle Company	Reduction of HCl and Mercury Emissions from Industrial Stoker Boilers Using Duct Sorbent Injection	$250,000	$603,600	12/1/06	3/1/10

The Medical Center Company, in cooperation with General Electric, propose the demonstration of methods for bringing existing industrial scale stoker fired coal boilers into compliance with limits on mercury and hydrochloric acid (HCl) emissions of the ICI Boiler MACT Rule (U.S. EPA National Emissions Standards for Hazardous Air Pollutants for Industrial, Commercial and Institutional Boilers). The goal of the project is to demonstrate that by carefully controlling the temperature of the flue gas slightly above the dew point just up stream of the bag house, that sorbents can be injected into the flue gas for removal of acid components. In addition, once the acid content has been reduced to compliance levels, that mercury will be adsorbed on the carbon content of the fly ash and will be removed from the system as particulates in the bag house. The project will optimize temperature conditions. The project will also evaluate a number of sorbents and optimize the sorbent selection and injection rates. The project will be considered successful if the optimized system enables the MCCo stoker fired coal boilers to meet the ICI Boiler MACT Rule while burning Ohio coal at a cost equal to or less then costs associated with alternative mercury and HCl emission control systems. The project was completed on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-07-01	University of Cincinnati	Slipstream Testing of Novel Nano-structured Chelating Metal Vapor Adsorbents for Direct Capture of Mercury from Coal Combustion Flue Gas	$309,225	$$623,178	10/1/07	9/30/09

This project will demonstrate, at the USEPA Research Triangle Park Multipollutant Control Research Facility, a method for capture of both elemental and oxidized mercury in which the captured mercury is isolated from other waste streams such as fly ash and FGD scrubber sludges. The project will also investigate methods for reducing the costs of production of the mercury sorbent. Ohio and eastern bituminous high sulfur coal will be used during the tests.

The goal of the project is to demonstrate that the proposed process will enable capture of mercury at equal to or lower costs than capture of mercury by the Sorbent Technologies sorbent which was developed in OCDO projects D-98-13 and D-00-25.

Specifically, the project will observe the following: 1) the long term stability of the sorbents in the flue gas environment; 2) the pressure drop associated with packed bed and fluidized bed contacting systems; 3) the ease of removal of particulate accumulations from the pack bed contacting system; 4) the percent of elemental and oxidized mercury captured from high sulfur flue gases; 5) the cost of mercury capture in $/lb mercury based upon cost of production of sorbent in the UC laboratory; and 6) possible reductions in cost of sorbent when produced in a commercial system. The goals are: 1) 80% or higher capture efficiency of total mercury at a cost of less than $3000 per pound of mercury; 2) sorbents stable enough in the flue gas system to remain active for six months or more; and 3) system pressure drops of 5 inches of water or less. The project is on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-07-02	The Ohio State University	High Purity H2 Production with In-situ CO2 and Sulfur Capture in a Single Stage Reactor	$150,000	$1,566,992	6/1/08	5/31/10

The project will scale up work done in the laboratory at The Ohio State University and will demonstrate a method for production of hydrogen from coal, a stream of CO_2 suitable for sequestration, and sulfur capture in one reactor. If this leads to a commercial development, it will substantially reduce costs for production of hydrogen from coal by an environmentally friendly process. The basic research leading to this proposed demonstration has been reviewed and approved for funding by the ORCR Review Committee in three projects directed toward H_2S capture, four projects directed toward CO_2 capture, and one project where all concepts were brought together in the configuration of the single reactor. This represents a total investment by OCDO of about $640,000 over a period of six years with university cost share of about $240,000. DOE-NETL has provided the major portion of monies for scale up of this work. The work is on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-07-03	The Ohio State University	Large-Scale Demonstration of Soil Carbon Sequestration in Reclaimed Mine Soils in Ohio	$398,406	$630,278	9/1/08	8/31/11

This project is a continuation of OCDO Project D-06-02 wherein small plots were used to determine the rate of carbon accumulation in soils as impacted by management systems for reclamation of the soils. This project will continue these activities on larger plots. About 500 acres of mine-lands will be reclaimed and planted in trees without the level of soil compaction commonly employed in reclamation. This will be compared with tree plantations on mine soils reclaimed by conventional practice. Observations will be made regarding the impact of compaction on the survival of the tree seedlings. Estimates of the impact of seedling survival on long-term soil organic carbon accumulation will be possible based upon the studies of the previous project. A second set of plots (ten acres) will evaluate the effectiveness of FGD in alleviating soil compaction on reclaimed mine soils. These plots will also be planted in trees and tree survival as well as carbon accumulation in soils will be monitored. A third set of plots (ten acres) will evaluate use of FGD for soil structure enhancement on newly reclaimed mine soils. These plots will also be planted in trees. A fourth set of plots (5 acres) will be established in cooperation with The Wilds and Rentech. These plots will be planted in conventional reclamation grass mixtures and compared with plots in tall grass under management of The Wilds. The enhancement of plant growth in response to chisel plowing of compacted mine soils will be evaluated. Another objective of these plots is to determine accumulation of soil organic carbon under a management system where biomass is removed and used as an alternative energy source. Long-term estimates of soil organic carbon accumulation will be based upon experience as of the previous project. Work is on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-07-06	The Ohio State University	FGD By-Product Utilization at Ohio Coal Mine Sites: Past, Present, & Future	$206,299	$412,838	3/1/08	6/30/10

This project is to be Phase I of an effort to increase the beneficial usage of FGD solids in mine land reclamation. The project will review the past and current state of mine land reclamation in Ohio and conclude with a recommendation of two or three options for a Phase II demonstration project using large volumes of FGD solids in mine land reclamation. It is predicted that the production of FGD material from Ohio coal-fired power plants will increase in the next 10 years to about 10 million tons per year. It is the goal of this project to demonstrate beneficial usage of these materials in mine land reclamation as an alternative to landfill disposal. The Ohio State University, in collaboration with state and federal agencies, utilities, marketers and trade groups will investigate the following:

a) Review of Existing Information – Review of: i) past FGD projects, with a focus on Ohio, in collaboration with U.S. Department of the Interior, USEPA, Ohio Department of Natural Resources (ODNR) – Division of Mineral Resources, and OEPA, ii) current use of FDG materials under Ohio regulatory framework; and iii) scope and nature of reclamation problems in Ohio that are amenable to FGD by-product use.
b) Material and Site Characterization – i) Review physical and chemical properties of FGD currently produced and anticipated from new sources and ii) determine the state of the art for underground mine void detection.
c) Stake Holder Input – Solicit level of interest and concerns from stakeholders and the public regarding use of FGD materials at mine sites.
d) Recommendations for Phase II – Recommend: i) 2-3 demonstration projects, and ii) institutional changes needed to promote high-volume use of FGD materials at mine sites on the basis of technical, environmental, and economic factors, and the incentives/disincentives for such use. The project is on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-08-01	The Ohio State University	Phase 1: Studies of the Syngas Chemical Looping (SCL) Process	$448,151	$896,905	8/1/08	7/31/09

The project will scale up work done in the laboratory at The Ohio State University and demonstrate a method for production of hydrogen from coal syngas and a stream of CO_2 suitable for sequestration. The process can be controlled to provide the hydrogen to carbon monoxide ratio required for feed into to Fischer-Tropsche processes in the production of liquid fuels or chemicals from coal. The process can also convert undesirable products and off gases from the Fischer-Tropsche process back to the desired ratio of hydrogen to carbon monoxide for a second pass through the Fischer-Tropsche process enabling an increased efficiency in the conversion of coal carbon to chemicals and liquid fuels. The process can also be used to produce hydrogen from coal for use in fuel cells or other power production systems. The project is on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-08-02	The Ohio State University	Coal Direct Chemical Looping Combustion Technology Retrofit to Existing PC Power Plant for Effective CO2 Capture	$300,000	$3,976,327	12/1/08	11/30/11

This project will scale up work done in the laboratory at The Ohio State University and demonstrate a method for retrofitting existing pulverized coal (PC) fired power plants for direct chemical looping combustion of coal to produce power and a CO_2 stream ready for sequestration. In one possible layout of the process direct chemical looping combustion of coal occurs in a Fuel Reactor and a Combustor which are located adjacent to an existing PC fired power plant. Hot gases from the chemical looping combustor

would enter the PC fired power plant and provide heat for steam generation. The hot gas from the fuel reactor would be CO2 ready for sequestration. System efficiency is maintained by recovery of heat from the CO_2 stream before it leaves the site for sequestration. The project can be divided into three major thrusts as follows: 1) The Ohio State University and project partners will continue to optimize the particle that provides oxygen to coal for combustion in the chemical looping system; 2) the project will scale up The Ohio State Univeristy reactor and demonstrate integrated continuous operation of the chemical looping system; and 3) optimization of a process layout for ease of retrofitting to existing PC power plants and optimization of the efficiency of the system. Much of the hardware of the reactor system has already been funded by OCDO in Demonstration project D-08-01. Project D-08-01 will be completed within the coming year. Use of the reactor for Project D-08-02 is not scheduled until the second year of the project. B&W and CONSOL Energy will provide leadership to the project team development of an optimized system layout. The work is on schedule.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-08-03	Energy Industries of Ohio	Phase 1: Studies to establish the feasibility of coal gasification for use by industrial companies in Ohio	$118,436	$360,045	10/1/08	9/30/09

Energy Industries of Ohio proposes a 12-month effort intended to investigate the use of Ohio's coal resources in support of Ohio manufacturing economy. The objective of the proposed program is to build a basis for a coal-based energy resource for Ohio's manufacturers that could provide energy stability for Ohio's manufacturing economy and increased competitiveness in world markets. The project will demonstrate methods of identifying viable clusters of industrial companies as either stand alone users, cluster anchors or cluster members, with sufficient aggregate demand that could support the construction of an industrial gasification park based on Ohio's coal resources. These parks are envisioned to be "polygeneration facilities" consisting of units that would produce electricity, synthetic natural gas (methane), industrial syngas, Fischer-Tropsche liquids, etc. as needed by the cluster participants.

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-08-04	DOE-NETL	NETL Cooperative Research and Development Agreement (CRADA) for the Design of an Industrial Scale Coal Gasifier	$250,000	$500,000	10/10/08	10/10/10

DOE-NETL and OCDO share a common interest in the development of industrial scale coal gasification to enable the nation's industry to stabilize fuel costs in this time of rapidly rising costs of natural gas and petroleum. DOE-NETL also is designing an industrial scale hybrid poly-generation coal gasifier for the University of Alaska. The system would produce 20 MW electrical power and an equivalent of 40MWt of syn-gas that could be used in gas fired boilers, or as a feed stock to chemical production. Therefore, it is proposed that OCDO and DOE-NETL work together in on a detailed design of this industrial scale poly-generation gasifier. DOE-NETL would complete the design and conduct testing of system details at DOE-NETL facilities.

In the proposed design, partial gasification of coal is conducted in an oxygen-blown industrial-scale bubbling fluidized bed gasifier. Char that remains after partial gasification of coal is transferred to an air fired bubbling fluidized combustor. The movement of char from the gasifier to the combustor is key to the system and will be based upon DOE-NETL work. The bubbling fluidized beds will be based upon a design demonstrated in OCDO Project D-97-12 which was co-funded by DOE-NETL. This system is a combustor that provides heat to a greenhouse in Wooster, Ohio and has been in operation for four years.

Final designs would include details specific to an Ohio application yet to be identified. The long term goal would be actual construction of such a system at an Ohio location in another project. OCDO staff would work with DOE-NETL in identifying Ohio site. Two Ohio based industries have expressed interest in such applications. Considerations would also be given to smaller municipal power facilities.

Global Climate Change, Ohio, and OAQDA

When Governor Ted Strickland unveiled his Energy, Jobs and Progress Plan on August 29, 2007, he outlined a way for Ohio "to ensure the predictability of affordable energy prices and to serve as a catalyst in enhancing energy industries in Ohio, bringing new jobs while protecting existing jobs." Near the end of his remarks that day, he addressed another issue that confronts not only Ohio, but the nation and the world – global climate change.

> *"While acknowledging that standards must be flexible enough to account for differences in the type of energy used and the technology available when a power plant was built, we should begin carbon control planning for each site. As a first step, under my plan each power plant in Ohio will make a full annual report of its greenhouse gas emissions.*
>
> *"Coal has been, is and will be an integral part of Ohio's economy. By using clean coal technology, we can take steps to reduce the carbon impact of coal. Carbon sequestration offers us that opportunity. By injecting carbon dioxide deep into the Earth instead of sending it into the atmosphere, we can significantly reduce the effect of coal on our climate. Under my plan, we will pursue pilot and demonstration projects to fully measure the potential benefits of carbon sequestration."*

This reference to global climate change reflected the Governor's awareness that the federal government is likely to issue regulations on the emission of carbon dioxide at some point in the not-too-distant future. Accordingly, he expects Ohio to be proactive in addressing the subject of carbon control.

Why is this important? What, exactly, is global climate change? And what role can and should OAQDA play in addressing this issue?

In the broadest of terms, climate change refers to long-term, significant changes in expected average weather patterns for a specific region, or for the Earth as a whole. It occurs because of a variety of factors, including the dynamic internal forces of our planet, variations in external forces such as sunlight or orbital variations, and human activities.

There is disagreement as to the full impact of human activity on global climate change. But there is virtually no debate that climate change is now a factor in the energy and environmental policies of many cities, states and nations.

Regarding the impact of human activity on climate change, increasing carbon dioxide levels in the atmosphere are believed to have an adverse "greenhouse effect" by increasing the temperature of the atmosphere. Some experts believe that heightened temperatures in the atmosphere will have a significant negative effect on weather patterns and sea levels, especially long-term. Recent statistics regarding carbon dioxide make one thing absolutely clear – humankind is, indeed, sending large quantities of CO_2 into the air:

- The average U. S. citizen produces 19 tons of carbon dioxide per year – in Ohio, the number is 23 tons per year.
- While representing five percent of the earth's population, the U. S. contributes more than 20 percent of all CO_2 emissions.
- Ohio ranks fourth (behind Texas, California and Pennsylvania) in CO2 emissions among states.
- Carbon dioxide levels are substantially higher now than at any time in the last 750,000 years, and have accelerated since the Industrial Revolution of the 19th century.

An emerging issue regarding carbon dioxide is the "cap-and-trade" program called for in President Obama's proposed budget. This program would give companies incentives to reduce greenhouse gas emissions and move toward "greener" technologies by trading air pollution allowances in an open market. At this writing, the proposed economy-wide cap on emissions would see carbon prices starting at around $20 per ton.

Energy and environmental experts believe that the federal government will move to curb emissions of carbon dioxide into the air. The President's cap-and-trade program would seem to set the nation on that course. Based on assumptions in his proposed budget, carbon emissions would be reduced from 2005 levels by 14 percent as of 2020 and 83 percent by 2050.

The implications of instituting CO_2 emissions standards for coal-reliant states like Ohio are significant. However, action is already under way in our state to address this potential challenge.

OCDO supports and has supported a variety of clean coal projects over the years that address numerous issues regarding carbon dioxide and carbon emissions. Nine of the 26 clean coal technology projects funded by OCDO at several Ohio universities in 2007 and 2008 focused on these subjects. Several of the carbon-related projects are viewed as groundbreaking in nature.

OAQDA approved funding for two additional carbon-related projects over this time period, including a highly innovative 2008 project aimed at evaluating the potential for naturally occurring terrestrial carbon sequestration to offset CO_2 emissions from coal-based power plants.

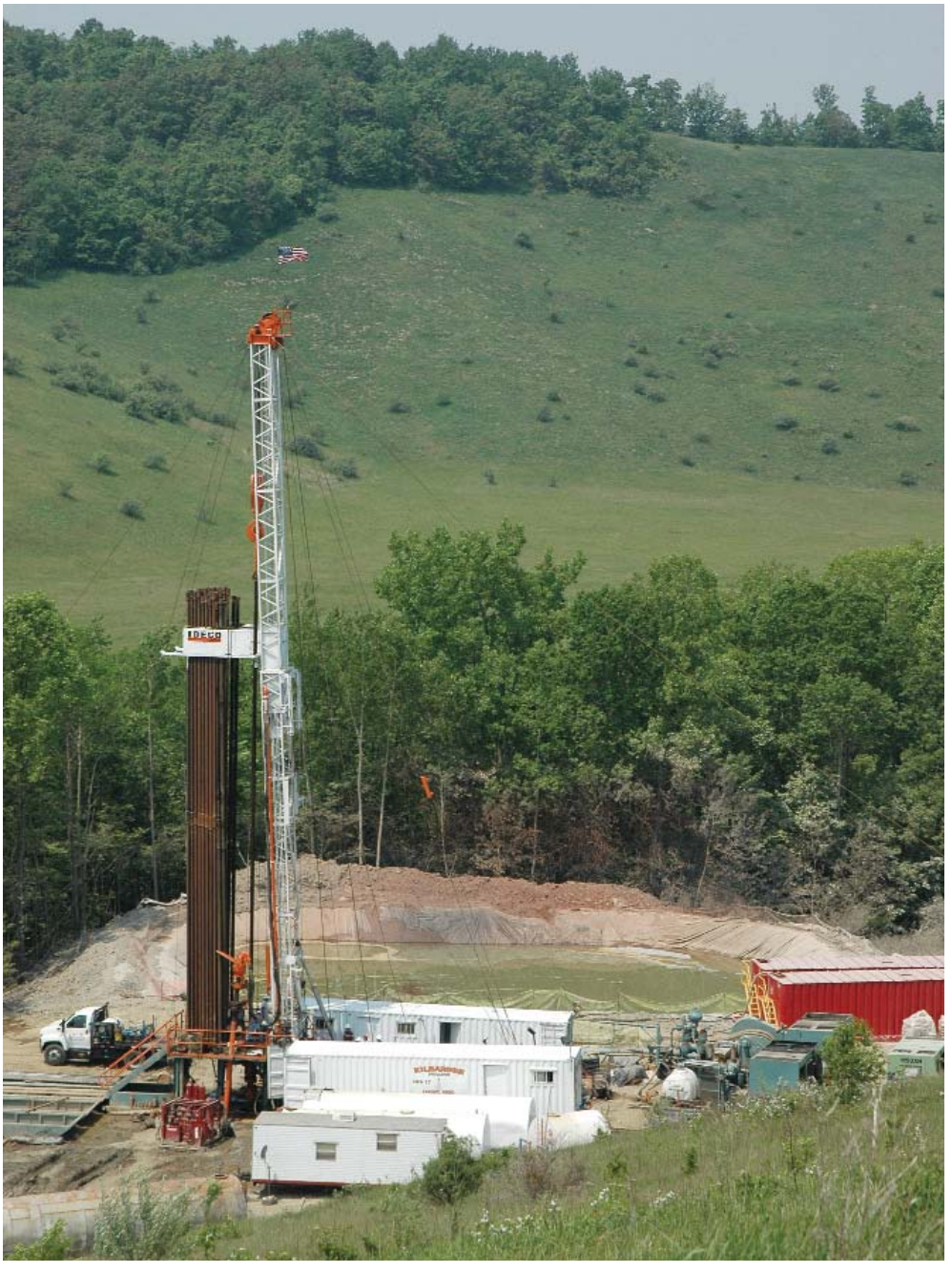
In November 2006, OAQDA approved $1 million in funding to support a $2.3 million project to drill a deep geologic test well for the purpose of better understanding Ohio's underlying rock formations and their ability to serve as reservoirs for the sequestration of CO_2. Deep sequestration is increasingly viewed as one potential solution for dealing with CO_2 emissions. Governor Strickland announced the selection of a site in Tuscarawas County in March 2007, and formation testing at the site by the Ohio Division of Geological Survey of the ODNR was completed in August 2007.

Project researchers have completed all initial analyses and interpretations of the results. Detailed tests for porosity, permeability and injection and storage capacity were conducted at two deep geologic layers – the Rose Run Sandstone and the basal sandstone unit encountered above the Precambrian surface. A technical report detailing the drilling, testing and interpretations has been drafted and is currently in peer review. As soon as the review process is complete, it will be made available to all. The important information gained from this project will help researchers develop profiles of geologic units in the east-central portion of Ohio and will be necessary for policy makers when making critical decisions about carbon dioxide sequestration in this region.

In addition, the Geological Survey is helping lead Ohio's work with the MRCSP in a new phase of work that ultimately will result in a large-scale injection pilot test of carbon dioxide at a yet-to-be determined industrial site in Ohio. The MRCSP is one of seven regional partnerships established by the USDOE consisting of state agencies, universities, private companies and non-governmental organizations. These were created to address climate change through studying and evaluating the technical and economic viability of different approaches for capturing and permanently storing carbon dioxide. Each of the seven participating states in the MRCSP will conduct similar pilot test projects.

The OEPA also has taken proactive steps toward helping Ohio businesses prepare for potential federal CO_2 regulations. In 2007, the Agency joined the international Climate Registry, an organization of governmental and private organizations committed to tracking their carbon emissions. In January 2008, OEPA sent letters to Ohio businesses encouraging them to join the Registry and begin the voluntary tracking of their own carbon emissions.

OAQDA is proud to join with these and other state agencies now actively engaged in important work to better understand and deal with Ohio's carbon "footprint." Thanks to the ongoing support by OCDO of clean coal technology – specifically those systems and processes that can improve carbon control and reduce carbon emissions into the air – Ohio has fortified its reputation as a leader in this area as we prepare for what likely will be a carbon-constrained future.



The CO_2 No. 1 Well in Tuscarawas County, Ohio was completed in August, 2007. This joint project between the Ohio Department of Natural Resources, Division of Geological Survey and Battelle Memorial Institute was accomplished with partial funding from the Ohio Coal Development Office (OCDO). The well was drilled to a total depth of 8,695 feet in Precambrian crystalline rock to provide data for evaluation of CO_2 injectivity and storage capacity of potential reservoirs.

Appendix I

OCDO Demonstration Projects That Were Active in 2007 and 2008

OCDO#	Grantee	Title	OCDO Support	Total Budget	Start Date	End Date
D-96-19	Sorbent Technologies	Commercial Demonstration of FGD at Ohio University's Lausche Heat Plant	$9,450,000	$13,243,000	4/1/98	3/31/07
D-02-04	Energy Industries of Ohio	Weldability Study to Join Thick Sections of Inconel Alloy 740	$112,296	$653,564	10/1/03	10/31/07
D-04-01	Energy Industries of Ohio	Commercialization of FASAND (Fly Ash/ Foundry Sand) in Expendable Tool Applications	$213,036	$475,496	8/1/06	8/31/08
D-05-02(A)	Energy Industries of Ohio	Boiler Materials for UltraSuperCritical Power Plants	$3,882,375	$25,907,930	6/1/01	12/31/11
D-05-02(B)	Energy Industries of Ohio	Advanced Materials for Ultra-SuperCritical Power Plant – Turbines	$246,591	$2,702,720	11/1/05	11/31/09
D-05-04	The Ohio State University	Research and Demonstration of Beneficial Agricultural Uses of FGD-Products in Ohio	$170,362	$529,500	11/1/05	6/31/08
D-05-06	The Ohio State University	Demonstration of Reactive CO2 Separation Process Using Tailored Nanoporous Calcium Sorbent	$ 890,185	$2,351,177	7/1/06	12/30/08
D-05-07	The Ohio State University	Coal Combustion Products Extension Program	$248,719	$663,677	1/1/06	12/31/08
D-05-8/9	The Ohio State University	Use of Lime-Activated High-Carbon class F fly Ash in Full Depth Reclamation of Asphalt Pavements in Delaware and Warren Counties	$682,026	$2,072,806	1/1/06	12/31/08
D-05-12	Ohio University	Pilot-Testing of Sieving Electrostatic Precipitator	$ 622,923	$ 1,887,644	5/1/06	3/31/09
D-05-13	Battelle	Midwest Regional Carbon Sequestration Partnership	$3,050,000	$18,067,378	2/1/06	1/31/10
D-06-02	The Ohio State University	Enhancing Carbon Pool in Coal Mined Soils of Ohio	$249,972	$376,743	9/1/06	8/31/08
D-06-03	Medical Circle Company	Reduction of HCl and Mercury Emissions from Industrial Stoker Boilers Using Duct Sorbent Injection	$250,000	$603,600	12/1/06	3/1/10
D-07-01	University of Cincinnati	Slipstream Testing of Novel Nano-structured Chelating Metal Vapor Adsorbents for Direct Capture of Mercury from Coal Combustion Flue Gas	$309,225	$623,178	10/1/07	9/30/09
D-07-02	The Ohio State University	High Purity H2 Production with In-situ CO2 and Sulfur Capture in a Single Stage Reactor	$150,000	$1,566,992	6/1/08	5/31/10
D-07-03	The Ohio State University	Large-Scale Demonstration of Soil Carbon Sequestration in Reclaimed Mine Soils in Ohio	$398,406	$630,278	9/1/08	8/31/11
D-07-06	The Ohio State University	FGD By-Product Utilization at Ohio Coal Mine Sites: Past, Present, & Future	$206,299	$412,838	3/1/08	6/30/10
D-08-01	The Ohio State University	Phase 1: Studies of the Syngas Chemical Looping (SCL) Process	$448,151	$896,905	8/1/08	7/31/09
D-08-02	The Ohio State University	Coal Direct Chemical Looping Combustion Technology Retrofit to Existing PC Power Plant for Effective CO2 Capture	$300,000	$3,976,327	12/1/08	11/30/11
D-08-03	Energy Industries of Ohio	Phase 1: Studies to establish the feasibility of coal gasification for use by industrial companies in Ohio	$118,436	$360,045	10/1/08	9/30/09
D-08-04	DOE-NETL	NETL Cooperative Research and Development Agreement (CRADA) for the Design of an Industrial Scale Coal Gasifier	$250,000	$500,000	10/10/08	10/10/10

Appendix II

GLOSSARY OF TERMS

Adsorption – A process that occurs when a gas or liquid solute accumulates on the surface of a solid or a liquid (adsorbent),forming a film of molecules or atoms (the adsorbate). It is different from absorption, in which a substance diffuses into a liquid or solid to form a solution.

Anode – An electrode through which an electric charge flows into a polarized electrical device. The anode layer within a solid oxide fuel cell is the point at which oxidation occurs during operation of the fuel cell.

Brine geologic formations and brine rock – Refers to porous formations of rock containing high levels of brine or salt. Such formations are thought to be potential receptacles for carbon dioxide produced at coal-based power plants because of the capacity of CO2 to displace the brine when injected into the rock formation.

Carbon sequestration – The storage of carbon dioxide (usually captured from the atmosphere) through biological, chemical or physical processes, for the mitigation of global climate change.

Chemical looping combustion (CLC) – Typically employs a dual fluidized bed system (circulating fluidized bed process) where a metal oxide is employed as a bed material providing the oxygen for combustion in the fuel reactor.

Coking – Coking is the deposition of carbon on the surface of a catalyst

Direct coal fuel cell – An emerging technology that converts the chemical energy in coal directly to electricity without gasification. The fuel cell can use pulverized coal, coke, tar, biomass and organic waste as fuel. Also referred to as "direct carbon fuel cell."

Elemental and oxidized mercury – Elemental mercury, or Hg, and oxidized mercury, or HgO, are two contaminants released during the combustion of coal.

Feedstock – Any bulk raw material used as the principal source in an industrial process.

Fischer-Tropsche reactor – Used in the catalyzed chemical reaction process in which synthesis gas (or syngas) is converted into liquid hydrocarbons of various forms. Typical catalysts are based on iron and cobalt. The chief purpose of the Fischer-Tropsche process is to produce a synthetic fuel alternative to petroleum, typically from coal, natural gas or biomass.

Flue gas mercury – Refers to mercury produced during coal combustion that becomes a component of the gas and other byproducts exiting the power plant.

Fly ash – One of the residues generated in the combustion of coal.

Fuel cell – An electrochemical conversion device. It produces electricity from fuel (on the anode side) and an oxidant (on the cathode side), which react in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate virtually continuously as long as the necessary flows are maintained.

Greenhouse gas effect – Refers to the change in the Earth's temperature brought on by the presence in the atmosphere of gases that absorb and emit infrared radiation. These gases include water vapor, carbon dioxide and methane. They warm the atmosphere by absorbing infrared radiation emitted by the Earth's surface, the atmosphere itself and by clouds.

Highwall mining – A method of coal mining in which a continuous mining machine bores, by remote control, into a coal seam exposed by previous open cut operations.

High sulfur coal – Bituminous, or high sulfur coal, is found in Ohio and other states and produces roughly 50 percent of the nation's coal production. The high sulfur content results in increased production of contaminants during combustion. Conversely, lower sulfur coal - such as lignite and sub-bituminous – produce fewer contaminants, but also have lower heating and energy values.

APPENDIX II

Membrane – A thin, permeable layer of organic or synthetic material (ceramic, for example) inserted between connecting regions within the combustion process to separate different elements of combustion.

Ohio Coal Research Consortium (OCRC) – Created in 1990 to assist the Ohio Coal Development Office in engaging Ohio universities in the pursuit of clean coal technology research, development and deployment projects. It is comprised of experts in various fields of coal expertise, including electric utilities, coal producers, federal and state government agencies, private research entities, private coal consultants and scientists. Following the solicitation of two-year projects, OCRC meets in June every other year to evaluate submissions and recommend projects on a merit and priority basis to the Technical Advisory Committee.

Ozonated Air – Air in which a portion of the normal oxygen (O2) has been converted to ozone (O3).

PEM fuel cell – A Polymer Electrolyte Membrane (PEM) fuel cell – sometimes called a Proton Exchange Membrane fuel cell – that typically uses hydrogen fuel and oxygen from the air to produce electricity. It is the type of fuel cell commonly used in automobiles.

Reagent or reactant – A substance or compound consumed during a chemical reaction. Solvents and catalysts, although they are involved in the reaction, are usually not referred to as reactants.

Scrubbers – Air pollution control devices that can be used to remove some particulates and/or gases from industrial exhaust streams.Traditionally, the term "scrubber" has referred to pollution control devices that use liquid to wash unwanted pollutants from a gas stream. Recently, the term is also used to describe systems that inject a dry reagent or slurry into a dirty exhaust stream to "wash out" acid gases.

Solid oxide fuel cell (SOFC) – An electrochemical conversion device that produces electricity directly from oxidizing a fuel. Fuel cells are characterized by their electrolyte material and, as the name implies, the SOFC has a solid oxide, or ceramic, electrolyte.

Sorbent – A material used to adsorb either liquids or gases.

Sulfur poisoning – Can occur during the operation of a solid oxide fuel cell, adversely impacting the efficiency and effectiveness of operation.

Syngas – (From synthesis gas) is the name given to a gas mixture that contains varying amounts of methane, carbon monoxide and hydrogen. Examples of production methods include steam reforming of natural gas or liquid hydrocarbons to produce hydrogen, the gasification of coal and in some types of waste-to-energy gasification facilities. The name comes from their use as intermediates in creating synthetic natural gas (SNG) and for producing ammonia or methanol. Syngas is also used as an intermediate in producing synthetic petroleum for use as a fuel or lubricant via Fischer-Tropsche synthesis and previously the Mobil methanol to gasoline process.

Technical Advisory Committee (TAC) – A 15-member, statutorily created group whose purpose is to assist the Ohio Coal Development Office in the evaluation of clean coal technology projects submitted for funding consideration. The TAC is comprised of public and private members having an interest in coal, power production and the environment.

Water-gas shift (WGS) reaction – The chemical reaction between water and carbon monoxide resulting in the formation of carbon dioxide and hydrogen.

Appendix III

Ohio Coal Development Office Strategic Plan

Core Objectives and Priorities for Action, 2008-09

Background

In 1984, Ohio legislators established the Ohio Coal Development Office (OCDO) to promote the increased use of Ohio coal. Specifically, OCDO was created to:

> *"provide for the comfort, health, safety, and general welfare of all employees and other inhabitants of this state through research and development (R&D) directed toward the discovery of new technologies or the demonstration or application of existing technologies to enable the conversion or use of Ohio coal as a fuel or chemical feedstock in an environmentally acceptable manner."*

OCDO was endowed by a 1985 Constitutional amendment authorizing the issuance of General Obligation bonds and creation of the Ohio Coal Research and Development Fund. Supplemented by General Revenue Appropriations for administrative costs, this fund supports OCDO work, which includes projects along the full research, demonstration and deployment (RD&D) spectrum, from basic research through pilot-scale test facilities to commercial-scale demonstration units. Since its inception, OCDO has awarded more than $170 million for clean-coal technology research and development, leveraging an additional $540 million in funds from other sources.

On July 1, 2003, the Ohio General Assembly transferred OCDO from the Ohio Department of Development to the Ohio Air Quality Development Authority (OAQDA). OCDO's work to support the development and implementation of technologies that enable Ohio's vast reserves of high-sulfur coal to be used in an economically and environmentally sound manner was viewed as complementary to OAQDA's historic mission to improve the environment and drive economic development in Ohio by helping businesses comply with clean-air regulations and by supporting new clean-air technologies and energy sources.

One of OAQDA's first actions was to commission an independent, third-party review of OCDO's work to date. The purpose of the review was to highlight program successes, identify existing and emerging challenges, and assess OCDO's ability to adapt its mission and activities to a rapidly changing energy landscape.

One of the major recommendations to emerge from the third-party review was that OCDO needed to engage in a strategic planning process that included: (a) an updated clear statement of OCDO's mission, and (b) development and implementation of a formal strategic plan with clear objectives, priorities, success indicators, and timelines. The purpose of the plan is to guide OCDO's activities and provide a set of expected outcomes against which to evaluate the program's effectiveness. The third-party review also recommended that the plan be developed in collaboration with stakeholders and outside experts in relevant fields, with special focus on soliciting input from members of OCDO's Technical Advisory Committee.

Strategic Plan Development Process

Key components of the stakeholder engagement process culminating in the creation of this strategic plan document included the following:

- **Telephone interviews with a select group of national and state leaders** in the energy arena to help define the parameters of an effective survey instrument for soliciting input from a broad range of stakeholders;
- **Survey of a targeted and diverse list of stakeholders** (coal industry, electric utility industry, research community, technology developers, environmental advocates, legislative, and regulatory

audiences) to solicit input on issues, needs and priorities to be considered in defining and focusing OCDO's future work;

- **Follow-up telephone or in-person interviews** with selected survey respondents, as needed, to clarify their input;
- **Review and discussion of interview and survey feedback** with members of the OCDO's Technical Advisory Committee (TAC); and
- **A joint work session involving OAQDA members, TAC members, and staff** to identify and prioritize issues shaping OCDO's future strategic direction.

Direct input from OAQDA members and staff

It should be noted that while most stakeholders agree that the OCDO program has generally been successful in its work, there clearly also exists a widespread concurrence with the third-party review's finding that the program's mission, objectives, and activities need to be updated, clarified, and prioritized.

Mission & Vision

OCDO's strategic planning process has clarified and affirmed that the **consensus mission, or purpose,** of the Ohio Coal Development Office is as follows:

"*To promote and assist in the development and commercialization of technologies and other advancements that enable the economic, efficient, and environmentally compatible use of Ohio coal for a broad range of public benefits within changing economic, political, and regulatory conditions.*"

In executing this mission, OCDO will realize the following **vision** for the program, for Ohio coal and for the state and its citizens:

"*OCDO will lead state efforts to maximize the use of Ohio coal in an environmentally responsible manner, ensuring that coal continues to be a vital component of Ohio's energy resource portfolio and delivering optimal value to the state, its citizens and its business enterprises.*"

Relevant Trends, Projections and Other Strategic Considerations

At the time OCDO was established in 1984, achieving the goal of promoting the increased use of Ohio coal was primarily dependent on finding means to mitigate challenges associated with Ohio coal's physical/chemical, production, and market constraints. Principal among these was the ability to burn Ohio coal within existing and proposed air-quality emissions restrictions.

Twenty-plus years later, a broader range of evolving and emerging considerations must be factored into OCDO's strategic planning. Three areas in particular are especially relevant:

Projected trends for energy supply and demand

Energy supply and demand trends are affected by a number of factors, including energy prices, economic conditions and advances in technology. All indications are that the next several decades will be marked by sustained higher prices for oil and natural gas, and that these price trends will force fundamental changes in the energy market. For example, economic considerations will affect fuel choice decisions in both the transportation and industrial sectors. Higher oil prices will increase the demand for unconventional fuels such as ethanol and bio-diesel, and are projected to stimulate coal-to-liquid fuel production. Higher natural gas prices are expected to reduce its use as a fuel for power generation and to stimulate the conversion of industrial boilers to coal as well as the development of renewable generation sources.

In contrast, factors such as the slow but continued improvement in coal mine productivity, the expected expansion of production capability, and competition from renewable and nuclear generation are expected to exert downward pressure on coal prices. Counterbalancing upward price pressure is expected from the need for additional base load generation, which will continue to be mostly coal-fired; from the deployment of a significant number of coal-to-liquid facilities; and from coal's capture of market share from natural gas.

These fundamental shifts will result in expansion of old markets and development of new markets for coal. Eastern coals will be used as feedstock to produce liquid fuels, synthetic natural gas, and a myriad of industrial chemicals. Ohio coal will become a more valuable resource as a chemical feedstock. As more and more premium bituminous coals are used for higher-value end uses, lower-valued and generally lower-priced coals will be imported into the region to heat water for power production. Sub-bituminous coals will fall between these two in usage.

It is clear that coal will continue to play a significant role in meeting Ohio's power needs. Coal-fired power plants will continue to be the primary resource for meeting the expanding need for additional power generation. It is therefore anticipated that coal production will grow rapidly towards the end of the next two decades and that coal prices will remain relatively stable.

New environmental initiatives, including the imminent likelihood of greenhouse gas mitigation rules

The Clean Air Interstate Act (CAIR), which is intended to reduce interstate transport of fine particulate matter and ozone, will require further reductions of both SO_2 and NOx emissions in two phases, beginning in 2009 (SO_2 and NOx are precursors to particulate matter and ground-level ozone). The Clean Air Mercury Rule (CAMR) will impose new limits on mercury emissions from new and existing coal-fired power plants with at least 25 Mw capacity and Combined Heat and Power (CHP) units larger than 25 Mw that sell at least one-third of their capacity. These mercury capture requirements will be implemented in two phases, beginning in 2010.

No environmental issue is more pressing, however, than carbon mitigation. A strong possibility exists that the United States will adopt a major global climate change initiative, including first-ever standards for CO_2 emissions, during the next decade. While the focus of such an initiative will be the control of greenhouse gases, it is likely also to include higher renewable energy standards and also policy incentives to encourage investments in clean coal and nuclear power as well as increased use of bio-fuel. This reality represents a potentially huge impact on Ohio with its substantial coal reserves and heavy reliance on coal-fired generation.

Evolution of existing technologies and the development of new technologies affecting the energy sector

A major dimension of the new vision for OCDO's role in promoting the use of Ohio coal is that the program will assert focused leadership in strategically vital areas of technology development. The program's near-term strategic direction must, therefore, be sensitive to the evolving technology landscape, both with regard to the evolution of existing technologies and the development of new technologies. It also must reflect thoughtful choices about which technologies offer the most promising pathways to a more vibrant future for Ohio coal and the greatest potential for alignment with state energy, environmental and economic development goals.

Determination of OCDO's strategic direction has taken into consideration a number of technology realities:

- **Advanced coal power systems,** such as the Integrated Gasification Combined Cycle (IGCC) and Ultra-supercritical (USC) pulverized coal boilers, which can increase conversion efficiency by as much as 20 percent, appear to be primed for short-term commercial deployment;

- Existing commercial **clean coal technologies** such as Pulverized Coal Combustion (PC) and Circulating Fluidized Bed (CFB) technologies, using sub-critical and supercritical steam conditions, are expected to remain the mainstays of the generation fleet. Technologies that improve environmental performance and that can be cost-effectively applied to existing generation will be at a premium;
- While the separation of CO_2 from flue gas and disposal of CO_2 in geologic formations is a relatively new area of research, projects like FutureGen are moving toward construction and could demonstrate large scale CO_2 sequestration in the early part of the next decade. Meanwhile, other **carbon capture and sequestration** options are being pursued under current OCDO grants, such as CCP sorbents and oxy-combustion. In addition, the Midwest Regional Carbon Sequestration Partnership is aggressively pursuing the characterization of Ohio geologic formations in terms of potential for CO_2 sequestration and will likely demonstrate CO_2 injection in Ohio within three years. A clearer understanding of geologic sequestration and the impact of CO_2 and other combustion gases in various geologic formations will be critical for the safe, effective, long-term use of sequestration. (Geologic sequestration includes sequestration for enhanced oil and gas recovery as well as sequestration in deep formations.);
- While the current favored technology for **converting coal to liquid fuel** is indirect coal liquefaction, there are significant issues associated with coal liquefaction that must be addressed to hasten deployment of the technology and to guide related RD&D efforts. For example, does Ohio coal offer advantages over other coals in this application? Do Ohio coal and Western coal blends offer advantages over unblended coal streams in this process? It is expected that OCDO will participate in development of coal-to-liquid technologies in the intermediate term; meanwhile, other government entities will continue to support the development of other energy sources such as ethanol and biofuels. (OCDO will cooperate with these efforts, particularly with feedstock blending opportunities.); and
- Various types of **fuel cells** are under development on an intermediate time frame, as well as many **other promising technologies with longer-term potential**, including: (a) chemical looping coal combustion, (b) production of syn-gas with the ideal ratio for the Fischer-Tropsch chemical process, (c) catalysts suitable for solid oxide fuel cells, (d) sorbents for mercury capture, and (e) direct coal fuel cells.

Key Opportunities & Challenges

Projected global energy market trends, new and anticipated environmental initiatives, and the evolution of existing and new technologies can be expected to create significant opportunities – and challenges – for Ohio coal. Primary among them are the following:

- There will be an **imperative to maintain and expand Ohio's existing fleet of coal-fired power plants.** Even if IGCC and/or other advanced technology plants are built in Ohio within the next 15 to 20 years, the majority of Ohio's power generation will come from continued and expanded use of PC coal-fired power plants over a transition period of many years;
- Because the most effective, and probably the most cost-effective, means of reducing greenhouse gas emissions is to reduce the levels that initially are generated during the conversion process, there will be **significant incentives for optimizing generating efficiency** through power cycle innovations to reduce both generating costs and emissions;
- While Pulverized Coal Combustion (PC) and Circulating Fluidized Bed (CFB) technologies will remain the mainstays of Ohio's existing generation fleet, there will be a **keener focus on the application of clean-coal technologies in building new coal-fired generation**;
- With ever-growing concerns about global warming and climate change, there will continue to be increasingly **strong interest in demonstrating carbon capture and sequestration technologies**, including oxy-combustion technologies that are effective and economic. In particular, the long-term life of PC coal-fired plants would be greatly enhanced if the existing fleet could be retrofitted with economical CO_2 management systems and new plants were designed with CO_2 management systems;

To help mitigate high oil and natural gas prices, there will be a growing demand for alternate liquid fuels. While some of the demands for alternate fuels will be addressed by the use of ethanol and biofuels, the **need for additional liquid fuels will require viable commercial coal-to-liquid fuel conversion technologies.** Coal-to-liquid technology has the potential to become a major source of high-value coal usage for Ohio; and

As emissions from industrial boilers become more significant, leading to increased emission standards on smaller industrial boilers, there will be a **need to either develop smaller industrial boilers** or to **cost-effectively apply existing technologies at the smaller scale**.

Strategic Objectives and Priority Actions

OCDO has outlined a limited set of strategic objectives and priority actions designed to seize evolving and emerging market opportunities. These objectives and actions will support attainment of the central goal of reducing Ohio's and the nation's reliance on foreign energy sources by creating in Ohio the ability to maximize the use of coal both (a) as an industrial energy source and (b) to produce electricity, transportation fuels, and chemicals – all while minimizing environmental impact.

To attain this goal, OCDO will focus its efforts in 2008 and 2009 on four strategic objectives and corresponding priority actions:

1. Maximize the use of coal, including expanding the use of coal beyond electricity generation, to supply Ohio's energy needs.

a. Support the development of improved retrofit technologies applicable to existing coal-fired generating units. The focus of these technologies would be (i) to increase generating efficiency to significantly reduce CO_2 emissions; (ii) to reduce emissions of conventional pollutants to negligible levels; and (iii) to develop methods for capture and sequestration of CO_2;

b. Provide incentives to upgrade Ohio's existing fleet of coal-fired electric generation plants. Work with appropriate government agencies to facilitate modification of existing units through the use of advanced technology;

c. Support the development of coal-fired technologies capable of cost-effectively supplying the energy needs of Ohio's industrial complex;

d.Support development of advanced coal-based power- and fuel-producing systems. These could include IGCC, Oxy-combustion systems, Ultra-supercritical pulverized coal units, chemical looping systems, etc; and

e. Support coal-to-liquid fuels conversion technologies.

2. Reduce the environmental impact of continued, as well as additional, coal usage.

a. Support development of cost-effective CO_2 capture and sequestration technologies;
   i. Provide support to continually improve CO_2 capture technology;
   ii. Support surveying and cataloging Ohio's candidate CO_2 reservoirs;
   iii. Support research addressing CO_2 purity requirements for saline aquifer sequestration; and
   iv. Support work aimed at addressing the challenges of CO_2 transport.

b. Support development of effective mercury capture technologies;

c. Provide incentives for upgrading existing industrial and generating facilities; and

d. Support high-volume fly ash and flue gas de-sulfurization byproduct utilization in mine remediation.

3. Support university research through the Ohio Coal Research Consortium.

a. Explore novel approaches to increased coal conversion efficiency;

b. Explore novel and less costly approaches to the capture of coal plant pollutants; and

c. Support research projects through bench-scale demonstration phase.

4. Advocacy

a. Work with legislators and regulators, and through properly targeted media outreach and public education initiatives to help create (i) a regulatory environment that enhances the competitiveness of Ohio coal, and (ii) a climate of informed and supportive public opinion that understands coal's vital role in meeting Ohio's energy needs and powering the state's economy.

Guiding Principles for Project Funding Decisions

Guiding principles for project selection should be developed by the Technical Advisory Committee with assistance of the staff within funding cycles to allow for maximum flexibility and consideration of the specific details of a proposed project. However, both the Third Party Review and this strategic planning process identified key elements that should be considered, better defined and weighted in funding decisions.

These include:

- **Mission impact** (clear and strong fit with mission and stated OCDO objectives);
- **Technical risk** (**potential for** technical success and moving to the next stage of development or commercialization);
- **Commercial risk** (likelihood of near-term commercial success, both the competitive performance o the technology and the capability of the applicant commercialize the technology);
- **Exclusivity** (projects that would not otherwise be pursued in private sector without OCDO support);
- **Leveraging potential** (ability to leverage federal and private research dollars for specific projects);
- **Direct financial return (likelihood of commercial licensing and associated royalty revenue streams);**
- **Immediacy of benefits** (time frame within non-financial benefits will be realized); and
- **Research portfolio balance** (contribution to a balanced research portfolio of basic research, technology development and both pilot-scale and full-scale demonstration).

Administrative Implications

In the past, the areas considered for OCDO funding were dictated by the projects proposed as responses to broadly framed OCDO requests for proposals. While there may have been common threads in the varied project proposals, and a great number of "continuation" projects, there was no clearly defined direction or overall goal for the body of R&D being conducted. OCDO selected those projects deemed generally most worthy rather than those projects best aligned with any specific strategic direction or focus.

OCDO will solicit proposals that are consistent with the objectives and priorities identified in this Strategic Plan. In addition, approved projects should follow a logical development chain within specific technology areas. Proactively *leading* technology development in this manner will require OCDO to have access, either through permanent staffing or through consultant services, to greater technical, analytical and financial expertise than the program has required in the past.

Metrics/Timelines for Evaluating Success

The Strategic Objectives and Priority Actions section above identifies areas of study to pursue. In general all projects will have the ultimate goal of the demonstration of technologies that reduce the cost of compliance of usage of Ohio coal with current and anticipated environmental regulations and/or increases in efficiency in conversion of coal to energy or chemicals. Therefore, metrics will be developed and applied on a project by project basis within the following parameters:

1) **Demonstration Projects** – a successful project will demonstrate use of Ohio coal in a system that is equal to or better than the state of the art in terms of reliable operation, process energy efficiency, cost of operation and cost of emission control. Although not all demonstration projects must have cost share by DOE or other governmental agencies, however, the overall goal of the OCDO program is 50% or more cost share from federal government sources for demonstration projects. In addition, a substantial match will be expected from entities directly benefiting from the grant. Metrics for evaluation of a given project will be established at the beginning of a project with specific targets for increased efficiency, reliability, cost reduction, etc. The OCDO goal will be that about 50% of these projects will be considered successful based upon the goals established at the beginning of the project;

2) **Pilot Scale Projects** – these projects range in scale from the first step beyond the university laboratory to as large as 1/10 of a commercial process. Risks in this stage are high especially in the attempt to build a first of a kind model of a process based upon data from the laboratory where many details of stream flow, heat exchange and temperature control, materials of construction, etc. are considered for the first time. Again, metrics for evaluation of a given project will be established at the beginning of a project with specific targets for increased efficiency, reliability, cost reduction, etc. The OCDO goal will be that about 25% of these projects will be considered successful based upon the goals established at the beginning of the project; and

3) **University Consortium Projects and Proof of Concept projects** – these are very high risk projects in terms of those likely to lead to a demonstration scale project and commercially adopted concepts. Still, this is the area of the OCDO program that generates new ideas with the potential to dramatically change methods for conversion of coal to energy and chemicals and reduction in costs of emission controls. The success of this level of work is judged by the number of students trained for research in coal issues, patents filed and awarded for novel concepts, and peer reviewed papers published. The OCDO goal would be that one in ten of these projects would be considered worthy of scale up and testing at the pilot plant level.

It is important to identify two elements that, while providing some measure of accomplishment, may not be appropriate as stand-alone indicators of the program's success. The first is the volume of coal mined in Ohio. Annual tonnage numbers and mining sector employment figures are important. But they are determined by economic and technology factors beyond the control or influence of OCDO research and development work. At best, these numbers can provide some indication of the impact of clean coal technology on the long term trends of Ohio coal production. Secondly, counting "successful" projects may provide a distorted view of a program intended to push the development of advanced technologies. That development process entails, and may actually require, a number of "failures" in order to advance both knowledge and application of new technologies.

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