OHIO AIR QUALITY DEVELOPMENT AUTHORITY

CLEAN AIR & CLEAN ENERGY ARE GOOD BUSINESS

Ohio Coal Development Agenda for 2003-2005

Issued by the Ohio Coal Development Office

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COVER PHOTOS (clockwise, from left):

The crystallizer pilot facility of the Powerspan multi-pollutant reduction technology demonstration project at First Energy Corp.'s R. E. Burger Plant in Shadyside, OH, produces fertilizer crystals from the Electro-Catalytic Oxidization (ECO) Commercial Unit. (Courtesy of Powerspan)

The 50-megawatt ECO Commercial Unit removes sulfur dioxide, nitrogen oxides, mercury, and fine particulate matter from the Burger Plant. (Courtesy of Powerspan)

Installation of the Sorbent Technologies flue gas desulphurization process at Ohio University's Lausche Power Plant. (Courtesy of Sorbent Technologies)

Completed Sorbent Technologies facility at the Lausche Power Plant, Athens, OH. (Courtesy of Sorbent Technologies)

These projects illustrate OAQDA's priority through its Ohio Coal Development Office to support research, development, demonstration and deployment. Both projects were under construction during the time of this Coal Agenda.

To our Stakeholders:

Established in 1970, the Ohio Air Quality Development Authority (OAQDA) is an independent, non-regulatory state government agency dedicated to making Ohio's air cleaner. OAQDA strives to accomplish this goal by helping businesses, government agencies, universities, and not-for-profit organizations finance projects that improve air quality and increase energy efficiency.

On July 1, 2003, the Ohio Coal Development Office (OCDO) was transferred to OAQDA by the Ohio General Assembly. The move immediately expanded the services provided by OAQDA and fortified its strong history of supporting new technologies and cleaner sources of energy to improve the environment and drive economic development in Ohio. It also provided OAQDA with a unique opportunity to communicate the importance of clean coal as a viable, efficient, and plentiful energy resource for Ohio.

The program mission of OCDO dovetails seamlessly with the agency mission of OAQDA. OCDO 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.

The Ohio General Assembly has mandated the publishing of a bi-annual Ohio Coal Development Agenda to update interested stakeholders on OCDO's specific activities and on the broader status of Ohio coal. For various reasons, the Agenda has not been published in recent years. Therefore, this edition will address the years 2003, 2004, and 2005.

The Coal Development Agenda you are reading was created during a period of important change for the Ohio Coal Development Office. In late 2004, OAQDA commissioned the first-ever, independent review of the OCDO program. The goals of the review were: to determine program accomplishments and effectiveness; to assess the program's ability to analyze its results and use that information to reassess its focus; and, to identify key issues and concepts to construct the foundation for future work. The review was conducted by Taratec Corporation and Energy Resources International and submitted to OAQDA in August, 2005. Perhaps the most important recommendation is to develop and implement a strategic planning process for OCDO. This process is now under way. The full "Third Party Review of the Ohio Coal Development Office" is available for your perusal on the OAQDA website.

Because OCDO is presently in a mode of vigorous evolution – and because the future direction of the program has yet to be determined – this Coal Agenda will focus on the recent past, and not the future. However, we expect the Coal Agenda to be a much more dynamic document in future iterations – one that reports both our progress in hitting the targets identified by our strategic plan, as well as our view of the road ahead for OCDO, specifically, and Ohio coal, generally.

During this important period of constructive change, we will keep all interested parties and stakeholders apprised of our work. We also invite and encourage you to make known to us your thoughts and suggestions. They will be warmly welcomed and greatly appreciated.

At OAQDA, we regard the future of OCDO as very bright. Indeed, our goal is to make this excellent program even better.

Respectfully,

Clifford R. Cloud
Chairman

Mark R. Shanahan
Executive Director

Jacqueline F. Bird
OCDO Director

Michael T. W. Carey
Chairman
OCDO Technical Advisory Committee

EXECUTIVE SUMMARY

Coal is an important state, national, and international resource. Ohio depends on this resource more than most other states. Ohio is the fourth largest coal-consuming state in the nation, while ranking 13th in coal production.

There are many industrial markets for coal, but its predominant use is for the generation of electricity. Coal is used to generate approximately 90 percent of Ohio's electricity.

While energy experts and economists debate how fast the global supply of petroleum and natural gas is being depleted, no one disputes the vast, untapped quantities of coal that are available in this country and in the state of Ohio. Nor is there any significant dispute about the difficult environmental challenges facing the use of coal. These include: sulfur dioxide (SO2), oxides of nitrogen (NOx), and particulate emissions; management of by-products; regulations governing trace elements such as mercury and other metals; and, the anticipated future regulation of the discharge of carbon dioxide (CO2) emissions.

This last point is of increasing significance to many coal and power-generation stakeholders as the broader discussion over global climate change (GCC) intensifies. It is a fact that coal has more carbon than the other fossil fuels. It releases methane when mined and more CO2 when burned than the other fossil fuels.

The relatively high sulfur content of Ohio coal contributes significantly to the cost of environmental compliance. The high cost of compliance introduces the potential for importing more low-sulfur coal from out of state to achieve compliance. This poses a significant near-term challenge to the continuous use of Ohio coal.

In 1984, Ohio legislators established the Ohio Coal Development Office (OCDO) 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…"

In fulfillment of one of its statutory obligations, OCDO proffers this Coal Development Agenda covering the period 2003-2005. The Agenda reviews OCDO's mission, objectives, budget, and strategies to accomplish its objectives. It includes a summary of OCDO's results and accomplishments; completed and on-going projects, and dissemination of the results; and a current assessment of the national and international context for OCDO's work and Ohio coal.

The Agenda delivers several key messages: (1) the development of technologies to expand the use of Ohio coal is emerging as a *strategic state and national energy security interest*; (2) energy markets have substantially changed over the last three years, and along with them, the outlook for Ohio coal; (3) OCDO has executed its programs through an RD&D "continuum," from basic research to commercial systems; (4) OCDO takes a holistic view in achieving its mission and objectives, meaning that the program seeks to extract as much beneficial use out of coal as possible, from using coal as a fuel, as a feedstock to make other fuels or products, and productively using the byproducts produced from coal's use; and (5) OCDO must be prepared to keep up with rapidly changing market, environmental and technological demands.

INTRODUCTION: HOW COAL IMPACTS EVERY OHIOAN

Coal, electricity, and Ohio's economy are integrally linked in Ohio. Coal accounts for approximately 90 percent of the state's electricity production. Through advanced conversion processes, coal also has the potential to displace the premium energy sources of natural gas and petroleum, especially in today's environment of steadily rising prices for these fuels. Therefore, coal must be considered both in terms of its primary product today–electricity flowing into homes, offices, businesses, health care facilities, schools and more–and its potential role as a foundation for the state's industrial and economic base tomorrow.

Energy is, without question, a driving force in Ohio's economy, primarily because of the key role played by this state's energy-intensive industrial sectors. [12] Underscoring this point, in 1999, Ohio ranked fourth in the nation in industrial energy consumption. In terms of jobs, nearly 40 percent of manufacturing employment in Ohio is based in Standard Industry Classification (SIC) Codes 34, 35, and 37 (Fabricated Metal Products, Industrial Machinery and Equipment and Transportation Equipment, respectively).

Table 1: Ohio's position within energy intensive industries

	Ohio's Rank among States	
	By Employment	**By Shipment Value**
Glass	1	2
Steel	1	3
Metal Casting	1	3
Aluminum	3	5
Forest Products	6	7
Chemicals	6	9
Mining	13	9

Source: 2002 Economic Census, US Census Bureau.

Energy in the industrial sector is used in two ways. Approximately 70 percent is comprised of combustible fuels or electricity used to generate the heat and power needed in industrial processes. The remainder of the energy is used directly as a raw material to produce such intermediates as polymers, petrochemicals, agricultural chemicals and fertilizers, lubricants and waxes. As examples, natural gas is the raw material for ammonia-based fertilizers commonly used in agriculture, and petroleum-derived intermediates form the base materials for plastics, lubricants, waxes, etc.

Table 2: Profile of energy consumption within energy intensive industries (measured in trillion BTUs)

Sector	Residual Fuels	Distillate Fuels	Natural Gas	LPG, NGL	Coal Derived	Net Electric	Other	Total Use, Net
Agriculture	0	339	77	221	0	221	14	1072
Mining (incl. Oil and Gas)	5	262	1268	0	77	355	631	2598
Aluminum	0	1	189	1	1	246	3	441
Chemicals	50	9	1984	51	284	602	749	3729
Forest Products	152	21	659	9	279	327	1825	3272
Glass	3	0	194	1	0	54	2	254
Steel	29	5	456	0	48	163	971	1672
Petroleum Refining	70	4	948	33	0	123	2300	34
Metal Casting	0	1	136	2	0	63	31	233
TOTALS	309	642	5911	318	689	2154	6526	16749

Source: Taken from "Profile of Total Energy Use for US Industry", Energetics, Inc. for the USDOE, 12 / 04.
LPG / NGL = Liquefied Petroleum Gas / Natural Gas Liquids
Table does not include energy sources used as raw materials.

The use of natural gas in Ohio-based industries is especially notable given (1) the sharp increase in the cost of natural gas over the last few years, and (2) the potential for coal-derived fuels to displace some of this natural gas.

Table 3. Gaseous fuel intensity as a percentage of total energy consumption

All IOF Sectors	Agr.	Mining	Alum.	Chem.	F.P.	Glass	Steel	Pet. Ref.	M. C.
37.1	27.7	48.8	43.1	54.6	20.4	76.8	27.3	28.2	61.9

Source: Taken from "Profile of Total Energy Use for US Industry", Energetics, Inc. for the USDOE, 12 / 04.
Gaseous Fuels were taken as the sum of natural gas and LPG / NGL usage from Table 2.
Percentages do not reflect the energy used as raw materials.

This clearly shows that the price of natural gas has a profound impact on the competitiveness of Ohio industries. By one estimate, more than 67 percent of the energy used in energy intensive industries is represented by gaseous fuels and, consequently, is a potential market for coal-derived synthesis gas that could be burned as fuel or converted to hydrocarbon raw material streams.

Coal is perceived as a resource that requires greater handling. It is a solid heterogeneous material, extracted from dense beds within strata of rock, and contains contaminants that are released during mining, transport, and combustion and must be controlled. These same characteristics can make it more difficult to work with as a raw material for industrial processes than natural gas and petroleum.

However, recent events and some new realities on the energy landscape have underscored the importance of OCDO's mission. Those same forces also indicate that Ohio coal is poised for a resurgence.

Petroleum and natural gas – two chief energy-source competitors – have experienced a doubling, and even tripling, in price. Deregulation and competition have changed the complexion of the electricity industry. New devices required on Ohio coal-based power stations, such as sulfur dioxide (SO_2) scrubbers and selective catalytic reduction (SCR), integrated gasification combined cycle (IGCC) units, electro catalytic oxidation (ECO) reduction units, and others are anticipated to facilitate use of higher volumes of Ohio coal.

Additionally, energy infrastructure security has become a much more focused part of electricity supply planning as a result of such occurrences as the Y2K scare, the September 11 tragedy, the blackout of 2003, and Hurricanes Katrina and Rita.

Finally, the electricity industry is coalescing around the application of advanced clean coal technologies (CCTs). These technologies not only improve efficiencies and lower emissions and costs, but convert environmental liabilities into beneficial products. CCTs can transform coal's inherent energy value into premium energy intermediates and primary products.

At the same time, increasing concern regarding global climate change (GCC) has become part of electricity supply planning and energy consumption patterns in general. Mercury removal regulations have been promulgated by Congress and various states, adding another emissions control component to coal-fired power stations. Fine particulate removal (PM2.5) is challenging the existing devices already installed at coal-fired plants for particulate removal. These latest requirements are in addition to the existing ones embodied by the Clean Air Amendments of 1990 (CAA), National Emissions Standards for Hazardous Air Pollutants (NESHAP), Clean Water Act, solid waste management regulations, New Source Review (NSR), NOx State Implementation Plans (SIP), Particulate Matter 2.5 (PM2.5), Clean Air Interstate Regulation (CAIR), and others.

Since its inception in late 1984, OCDO has striven to provide leadership in meeting these evolving challenges. Many forces beyond the control of any state program have impacted coal production and use in Ohio. Nevertheless, it is fair to state that OCDO's leadership has helped sustain Ohio coal through some very difficult market periods. Today, OCDO is poised to help the industry capitalize on near-term growth opportunities for Ohio coal.

This Agenda demonstrates OCDO's efforts to help maintain existing markets and develop new ones for Ohio coal.

Characterization of Ohio coal

In the first two decades of the 20th century, the number of coal miners in Ohio had grown to its record peak of more than 50,000. By 1972, the number had fallen to approximately 10,300 miners who extracted nearly 51 million tons of coal that year. In 2004, coal mining employment had dropped to 2,295 workers, with 23 million tons of coal extracted. The relatively low number of employees reflects both the impact of various environmental regulations on the use of high sulfur coal and improvements in coal mining technology that have resulted in production of greater tonnages per man hour.

For the most part, Ohio coal is relatively high quality, averaging 12,500 Btu/lb (moisture-free basis) with a high volatiles content, and 13.5 percent ash. [1] Unfortunately, Ohio coal is relatively high in sulfur content, which averages 3.5 percent. Sulfur in coal is converted into sulfur dioxide (SO_2) during combustion, or hydrogen sulfide (H_2S) during gasification.

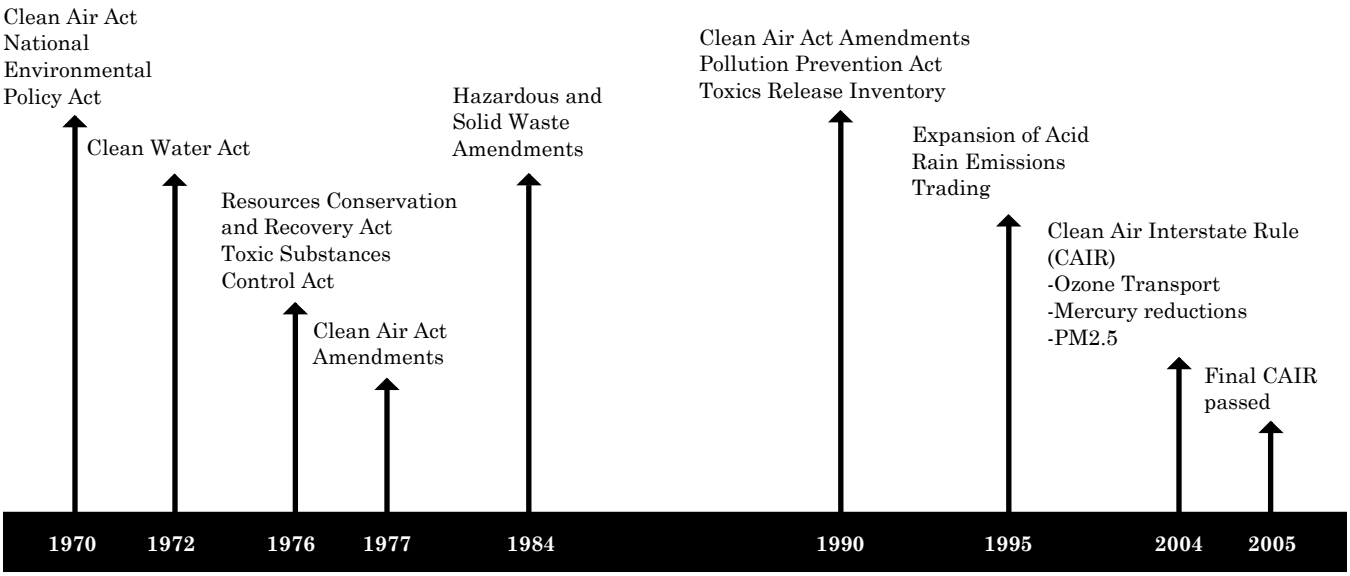
Current production of coal is concentrated in 16 eastern and southeastern Ohio counties. Sixty-one percent of this energy source comes from seven underground mines, with the remaining 39 percent being produced from 94 surface mines. Railroads carry 57 percent of the product from the mines to the power plants and industrial customers; the balance is trucked or barged to its destination.

Coal is responsible for almost 90 percent of the electricity produced in this state. Ohio is the third largest consumer of coal, topped only by Texas and Indiana. While the average citizen is not aware of this connection, it is important that the public realize the contribution of lower-cost, coal-based electricity to his or her pocketbook and the state's economy in general. At present consumption rates, Ohio has approximately 250 years of coal reserves. This estimate assumes that only one-third of the known resource base will be economic to mine [5] although improved extraction technologies could change that number.

The decline in Ohio coal production is the result of various factors. They include the adoption of stricter environmental regulations, utility compliance strategies which included coal switching to lower sulfur western coal to achieve compliance at the lowest cost, competition from natural gas and petroleum, and deregulation of the electric utility industry.

Environmental regulations have certainly impacted Ohio coal, principally through the Clean Air Act (CAA), originally promulgated in 1970, with key amendments in 1977 and 1990, and most recently by the Clean Air Interstate Rule (CAIR). The CAA has mandated progressively sharper reductions in sulfur dioxide (SO2) emissions from coal-fired power stations, but also oxides of nitrogen (NOx), flyash, and trace quantities of what are often described as hazardous air pollutants (HAPs). CAIR includes new regulations for mercury control, tightens restrictions on NOx emissions for ozone control, and establishes control for particulate matter less than 2.5 microns in size (PM2.5).

Major Federal Environmental Legislation Affecting Coal-fired Power Stations



[Source: Pearl Street Inc]

Premium fuels (natural gas and petroleum) were in plentiful supply and available at attractive prices for most of the last 20 years. These fuels were considered viable alternatives both for environmental compliance and chemical feedstock. However, this has changed recently with the dramatic and continued escalation in the price of natural gas and oil making coal much more attractive as the fuel of choice.

Deregulation in the electric utility industry and private investment in power project development has had a significant impact on the decision-making process for power generating plants. The natural gas supply "bubble" following the Fuel Use Act (passed in 1979 and repealed in 1986) led the electricity industry to build natural-gas-fired power plants for added generation capacity. Meanwhile, a number of existing Ohio coal-burning power stations were and still are being switched to low-sulfur coal from the Powder River Basin (PRB) in the western US as the low-cost strategy for environmental compliance. Low gas and oil prices also led many industrial concerns to convert to these fuels as an economic source of energy.

Powder River Basin (PRB) and western coal generally exhibit very low-sulfur content relative to Ohio coals, but relatively high-moisture content. In addition, western coal is extracted through relatively inexpensive surface-mining techniques. While the raw material is cheap, transportation costs to move it thousands of miles are high. Typically, transportation costs for PRB coals are three or four times the cost of the coal itself, and the energy required to transport it involves its own environmental impact.

Current and potential markets for Ohio coal

The national context. Electricity demand in the US is growing at an average rate of 2-3 percent (1.8 percent in 2004, 2.5 percent in 2005 and projected 1.9 percent in 2006) annually, with noteworthy fluctuations year to year and region to region. Coal-based electricity generation accounts for approximately 50 percent of this country's installed capacity base (total megawatts) and typically 50-60 percent of its actual generation (megawatt-hours) year to year.

Coal and electricity production are integrally linked, as are the demand for electricity and the economic health of the US. Indeed, electricity demand growth has been directly and closely correlated to economic growth for decades. Bulk electricity powers the motors, pumps, compressors, and other equipment in the nation's factories and manufacturing facilities. High-quality, highly reliable electricity is needed for health-care facilities, telecommunications, computer networks, and high-precision manufacturing (e.g. silicon wafers). In many ways, electricity is the lifeblood of the nation. Maintaining a reliable, secure, affordable electricity supply is critical to the economy.

Electricity at historically stable prices has generally come from three sources: coal-based, hydroelectric, and nuclear plants. However, while nuclear is very favorably priced at this time, only two decades ago it escalated in price to unacceptably high levels and as a result, no new nuclear plants were ordered by electric utilities for the ensuing 25 years. Further, there remains no near-term solution to the issue of long-term nuclear waste storage.

Hydroelectric capacity is also low-cost, but is subject to river conditions, precipitation, and weather. Sensitivity to the environmental consequences of hydroelectric power production has made it less favorable in recent decades.

During the 1990s, natural gas prices were relatively low on an historical basis, and the electricity industry embarked on a substantial gas-fired power plant construction program for four years (1997-2001). When gas prices began to escalate in 2001, the effort ended somewhat abruptly. In general, natural gas price and supply exhibit higher volatility than coal, although coal prices have risen substantially over the last two years as well.

As noted earlier, energy infrastructure security is now of the utmost importance. Electricity is at the root of our state's and nation's ability to withstand and recover from national security events and natural disasters. It powers the pumps at the water and sewer plants, the refrigeration at the grocery stores, the telecommunications towers, and everyone's computers.

Regardless of how much oil and gas may be available, most energy experts agree that it will always be substantially more expensive than coal. Close to 60 percent of the petroleum used in the US is imported, and the importation of natural gas (as liquefied natural gas, or LNG) is expected to escalate dramatically over the next two decades, according to Energy Information Administration (EIA) projections. Much of this fuel is imported from troubled areas of the world. Nuclear fuel is another resource that is largely imported, much of it from Canada and Australia.

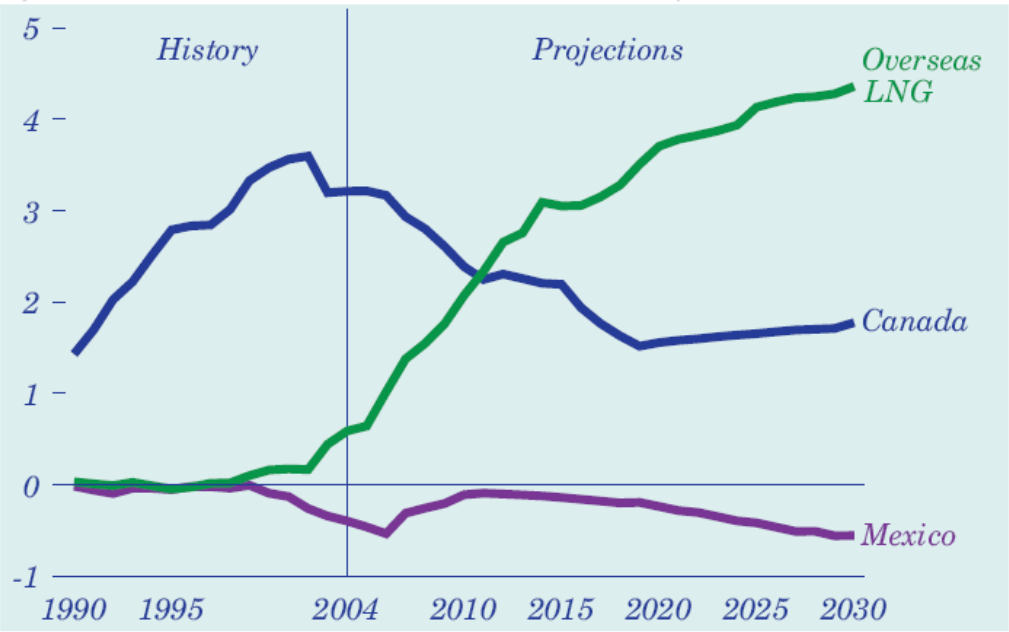
The US has abundant coal reserves—estimated to be approximately 250 years worth at current consumption rates—located throughout the country. Ohio supplies are located in the eastern and southeastern portions of the state in what is known as the Northern Appalachian Basin.

Given the need for affordable, secure, and reliable electricity, coal's importance to this nation is significant and therefore the environmental challenges must be met. Over the last 30 years, many different interests ranging from academia to industry and the public and private sectors have collectively engaged in R&D programs to develop a variety of commercial control technologies that address many of the most pressing of the environmental concerns. This work continues to refine these control processes to produce new, more efficient, cost-effective options, such as processes for mercury removal, for commercial application.

The national context for electricity and coal has changed radically over the last four years. Below are just a few of the factors that have altered the landscape:

- Natural gas prices are at historic highs. While they may moderate, the general consensus is that if and when prices settle, they will settle in the range of approximately $4.50 to $5.00/million Btu. The essential question is: How long will the escalation in gas prices persist?
- Energy costs in general have substantially increased over the last two years. Consumers presently feel the pinch of gasoline prices; during the 2005-6 winter, they paid higher home heating bills. As costs of fuels get factored into electricity prices, ratepayers may see significantly higher utility bills. Whole industries, such as fertilizer production and glass manufacturing, are moving offshore because natural gas costs are so high. Electricity-dependent industries, such as aluminum production and steel-making, are also at risk.
- A significant liquefied natural gas (LNG) importation industry is emerging in this country to bring gas sourced overseas to compete with domestically sourced natural gas. The price of this product will be high compared with coal.

Net U.S. imports of natural gas by source, 1990-2030 (trillion cubic feet)



Source: Energy Information Administration, *Annual Energy Outlook 2006*, Reference Case.

Fig 5: The Energy Information Agency's (EIA) projection for LNG imports, which is more modest than what the petroleum industry is now anticipating, is shown dramatically increasing over the next two decades.

- China and India are emerging as global economic forces. Both countries have a tremendous amount of coal and are seeking clean coal technologies from the global market.
- The merchant power business and electricity trading have largely stalled. Utilities, in their "back-to-basics" mode (working under regulated models rather than further competition), are more in control of new generating capacity today, either through plants that they will own and operate, or plants from which they will buy power on long-term contracts. Non-utility power plants can no longer be financed without a "credit-worthy" counter-party, usually a utility, to purchase the output.
- Currently, from 40-110 GW of coal-fired capacity is being planned in this country. Five years ago, that figure was less than 5GW.
- There continues to be a shift from eastern coal to western coal for electricity generation. Part of this has to do with utility economics; it is more difficult to get approval for capital cost rate-of-return

than to recover fuel and maintenance costs. Therefore, utilities are motivated to avoid large capital expenditures, such as the addition of emissions control devices, unless they are sure they can get rates of return guaranteed. The significant fraction of eastern power generation that is now "non-utility" also looks to western coal to avoid capital expenditures.

- Environmental restrictions on coal-based plants are expected to continue, either through regulatory activities at the federal level, or, absent additional federal regulation, through regulations enacted by individual states, an increasing trend. These new restrictions, however, are creating new demand for clean coal technologies in general and reopening markets for Ohio coal.
- Utilities continue to disaggregate. Transmission assets are now being bundled into regional transmission grids and markets, as compelled by various Federal Energy Regulatory Commission (FERC) orders. This complicates the electricity production and delivery value chain, but ultimately will drive the industry even further towards lowest cost sources of power.
- Construction of nuclear power stations has re-emerged as a credible option for base-load power.

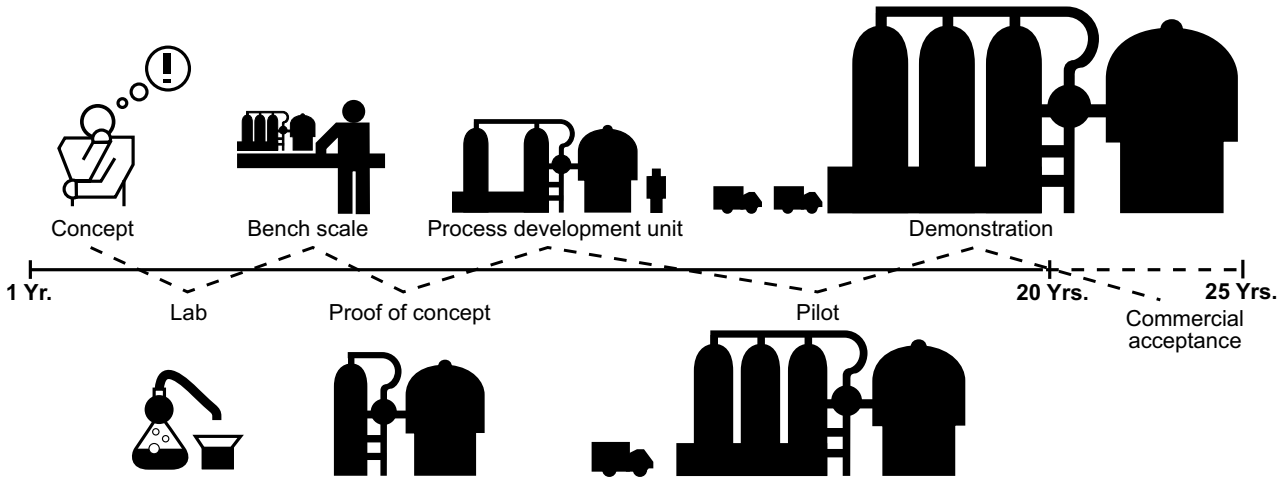
Markets for Ohio coal. The dominant position of coal in Ohio's utility sector places Ohio in the enviable position of having a reliable and economical source of power. The research and development programs which have been funded over several decades have helped to maintain the viability of coal. However, the challenges to coal's use remain: ever more stringent environmental standards imposed by various regulatory bodies; the technology and economic factors driving utility compliance strategies; and, relatively low-cost, low-sulfur Powder River Basin coal making inroads into Ohio's power-producing sector. These challenges can be addressed by continuing R&D efforts aimed at utilizing coal more efficiently and in ways which minimize the environment impact of coal based technology. The continued use of coal, and more specifically Ohio coal, will provide Ohio's power producing industry the ability to take advantage of membership in Regional Transmission Organizations (RTOs), helping them compete more effectively in marketing excess power.

Identification of OCDO's programs and relations to its purpose

OCDO's purposes, delineated by statute, are broad and described in the text box that follows. OCDO is authorized to support clean coal technology (CCT) projects all along the RD&D continuum—basic scientific research, scientific application, bench and pilot-scale process facilities, and demonstrations of commercial-size facilities. [2]

The Ohio Air Quality Development Authority is a non-regulatory government agency created to help Ohio businesses comply with clean air regulations. Through its Ohio Coal Development Office (OCDO), OAQDA also oversees the State of Ohio's coal research, development, and technology deployment efforts. Since its creation in 1970, the Authority has provided technical and financial help to hundreds of large and small Ohio businesses, awarding more than $4 billion to finance air quality projects. Meanwhile, OCDO has awarded more than $170 million for clean-coal technology research and development, leveraging another $540 million in additional funds from other sources.

THE RD&D CONTINUUM



Importantly, OCDO takes a *holistic* view of the use of coal. The program seeks to extract as much beneficial use from coal as possible. In practice, this means not simply producing power efficiently while lowering emissions but, where possible and practical, converting "waste" material into a usable byproduct. The program also seeks new, non-traditional ways to produce beneficial products from coal, such as carbon nanofibers. This approach is part of a growing field, industrial ecology.

Given the continuum of RD&D inherent in OCDO's statute and the holistic framework within which the program is executed, the following identifies the office's programs and how it corresponds to the purposes of the office.

Ohio Coal Research Consortium. OCDO currently funds the Ohio Coal Research Consortium (OCRC) in support of fundamental and applied research. The Consortium is currently comprised of researchers from six Ohio-based universities: Case Western Reserve, Ohio University, The Ohio State University, the University of Akron, the University of Cincinnati, and the University of Dayton. [6]

OCRC is open to all Ohio-based universities that respond to competitive solicitations. OCRC's mission is guided by the Consortium Review Committee (CRC), whose volunteer members are drawn from electric utilities, private research institutions, technology companies, the federal government, and other state agencies.

OCRC is charged with the following objectives, listed by priority: (1) address technical problems being experienced by end users of Ohio coal and improve technologies that enhance its continued or expanded use; (2) minimize the environmental impact of coal-based technologies, (3) generate innovative research in the field of coal use, and (4) train Ohio-based scientists and technologists in clean coal and emissions control technologies.

OCRC supports approximately 13 projects annually. Every four years, OCDO conducts interviews with the coal user community to determine what its needs are and what issues it is facing. The technical goals and objectives and annual solicitations for these projects are based on the feedback received from users. Projects are reviewed annually by the CRC to track progress. The CRC considers new proposals annually.

The peer review and mentoring functions performed by the CRC are unique features of the OCRC. This drives the research towards cost-effective practical applications desired by coal users. The mentoring function has led to close collaboration among universities and industry, serving as an effective bridge to the private sector for especially promising technologies and projects.

It is the nature of fundamental and applied research that most technologies do not progress to the commercial stage, and that the cycle time from idea inception to commercial product deployment often can be many years. For most of these projects, it is simply too early to evaluate commercialization, marketplace adoption, and enhancement of user markets. However, OCDO and the CRC work to ensure that these research projects are *guided down* this path, and have been rewarded with several notable successes.

As recent examples, three OCRC-funded technologies are progressing from the laboratory scale to larger scale tests and demonstrations:

- The Electric Power Research Institute (EPRI) and American Electric Power (AEP) plan to pilot-test a novel concept in electrostatic precipitation, ultimately leading to a smaller, less costly system that can remove fine particles more efficiently and separate high-carbon ash from low carbon ash. OCDO was instrumental, both in initiating the development of this technology, and in getting AEP and EPRI on board to move it into the pilot phase.
- OCDO played a key role in getting a scale-up test accomplished for a process which uses high surface area calcium oxide to capture CO2 and SO2 at high temperature, then recovers the heat from the chemical reactions in the power generation process. OCDO helped the inventor work through process concerns expressed by the Technical Advisory Committee (TAC) and this very promising, though nascent, technology has been funded. A second phase involving a pilot plant with significant DOE support is anticipated.
- A very inexpensive and high capacity sorbent for capturing oxidized mercury from flue gas showed great promise under simulated flue gas conditions in the laboratory. OCDO is working with the inventor and potential industrial partners to find funding to support a demonstration at a USEPA facility using Ohio coal.

For several other OCRC projects, OCDO functions as a bridge between the inventors with exciting new ideas for improving the use of coal, the companies who can scale-up the ideas, the firms who can "take the product to market," and the end user utilities and industrial customers.

Coal Combustion Products Extension Program. As stated earlier, OCDO takes a progressive, holistic view of coal. It is unacceptable, or at least undesirable, to transfer pollution problems from the air to the land, especially since coal-combustion products (CCPs) can be beneficially recycled. Often, what is lacking is demonstration, awareness, and communication. Slag and bottom ash from coal-based plants can be used in high volumes for road and highway construction; flue gas desulphurization (FGD) gypsum is a feedstock for wallboard manufacture. Lower volume applications include aggregate for asphalt, additives for cement-making, amendments for soil enhancement, and ingredients of special metal composites.

For this reason, OCDO supports the Coal Combustion Products Extension Program at The Ohio State University. It serves as a marketing adjunct to OCDO, helps in the technology transfer function by disseminating technical information about various ways to use CCPs, and provides expert opinion to both the user and regulatory communities. In addition, the Extension Program prepares and presents papers at technical conferences and seminars, and hosts tours of Ohio CCP projects.

CCP activities do not end here. OCDO participates in the DOE-sponsored Coal Combustion Byproducts Recycling Consortium (CBRC) and serves on its steering committee. Several Ohio-based CCP projects have been jointly supported by OCDO and CBRC. OCDO also actively collaborates with the Midwest Coal Ash Association, a group of Ohio electric utilities and ash marketers, as well as the nationally based American Coal Ash Association. Additionally, OCDO is a charter member of USEPA's Coal Combustion Products Partnership (C^2P^2), and has garnered commendation in 2004 from USEPA for its efforts in this field.

Midwest Regional Carbon Sequestration Partnership. The consensus among experts and industry observers is that carbon dioxide mitigation and the general challenge of global climate change remains the greatest long-term challenge facing coal today. Ohio-based electric utilities are coming to believe that restrictions on carbon are inevitable. Today, the leading potential solution is carbon sequestration.

For this reason, OCDO supports the Midwest Regional Carbon Sequestration Partnership (MRCSP), one of seven entities sponsored by the USDOE, and the largest and most ambitious of the group. Other states in the MRCSP include Michigan, Indiana, Kentucky, West Virginia, Maryland, and Pennsylvania. These states represent one-sixth of the total US population, 15 percent of the US economy, and produce 21.5 percent of the electricity generated in the US. Seventy-seven percent of the electricity generated in this region comes from coal. The MRCSP is managed by Battelle. More details concerning OCDO's support of MRCSP can be found in later sections, and detailed information on the project can be found on its web site: www.mrcsp.org.

Ohio FutureGen Task Force.
(NOTE: After the period covered by this report, Ohio submitted two strong proposals to the FutureGen Industrial Alliance, one in Meigs County and one in Tuscarawas County. On July 25, 2006, the FutureGen Industrial Alliance announced it had chosen finalist sites in Texas and Illinois. Information on the benefits Ohio gained from its participation in the competition can be found in the "Interim Report" and the Task Force's "Final Report" on the FutureGen site evaluation process can be found on the OAQDA website at www.ohioairquality.org.)

One of the most significant programs on the horizon linking environmental concerns about the use of coal with advancements in clean coal technology is the USDOE's FutureGen effort. According to some energy experts, FutureGen is to coal-fueled electricity generation what landing a man on the moon was to the space program in the 1960s. It represents a vision of coal-based power generation that seeks very high efficiency, levels of emissions and discharges that are negligible and benign to the environment, competitive economics, and conversion of coal into other high-value energy products, including hydrogen to power fuel cells. In short, FutureGen seeks to combine a variety of technologies that extracts the most value from coal with little sacrifice to the environment and none to human health.

The importance of this project to Ohio was underscored by the letters of support sent by Gov. Bob Taft to President Bush, the endorsement of the Ohio Congressional delegation, and the unanimous support of the Ohio General Assembly.

OAQDA served as the lead agency of the task force assigned to coordinate the state's response to the anticipated project solicitation. The task force, facilitated by former Ohio House Speaker Jo Ann Davidson, included the Directors and staff from: Ohio Air Quality Development Authority and its Ohio Coal Development Office; Ohio Public Utilities Commission and its Ohio Power Siting Board; Ohio Department of Natural Resources and its Ohio Geological Survey (OGS) and Division of Mineral Resources Management; Ohio Department of Development and its Economic Development and Technology Divisions; Ohio EPA and its Division of Air Pollution Control; Ohio Rail Development Commission; Ohio Consumers' Counsel; Ohio Coal Association; Ohio Oil & Gas Association; Ohio universities represented by Ohio University and The Ohio State University; and the Ohio Environmental Council. A representative of the United Mine Workers of American, who also is an OCDO Technical Advisory Committee member, attended these meetings as well.

Ohio spent more than two years reviewing sites and collecting data for the competition. The process included a variety of collaborative efforts at the state and local levels, with exemplary work and cooperation put forth by teams in the communities that were potential Ohio FutureGen sites.

Outreach, education, and community. OCDO advocates for Ohio's needs through its membership and/or participation with many organizations. OCDO is a member of the National Coal Council, an advisory body to the US Secretary of Energy. OCDO participates in the preparation of studies and programmatic recommendations on the needs of the coal and power industries. It is a member of the Coal Utilization Research Council (CURC), which helps to set the national research agenda for coal-based electric power through the development of technology road maps.

Closer to home, OCDO serves on the board of the Ohio Energy Project (OEP), a statewide non-profit organization that educates Ohio teachers and student leaders on the pros and cons of all energy sources, including coal. OEP reaches hundreds of Ohio K-12 school teachers and thousands of Ohio students each year. OCDO supports OEP efforts to develop and disseminate age-appropriate, balanced teaching units regarding coal and clean coal technologies.

OCDO staff members serve on various conference and seminar steering committees. In 2004, OAQDA hosted the very successful Ohio Air Quality and Coal Research Symposium, held at Ohio University. The Symposium combined two conferences usually held separately before OCDO's transfer to OAQDA. This event drew approximately 200 industry and research personnel from the region. There was a strong presence at the event by USDOE/National Energy Technology Lab (NETL) personnel, including its Director, who was the keynote speaker.

OCDO also hosted during this period several more in its signature series of technology transfer open houses. These began in 1989 and have continued every year since. They occur near the conclusion of a pilot or demonstration project; the public is invited on-site to receive technical presentations regarding the performance and economics of a specific project and offered the opportunity to tour the facility. This form of technology transfer allows potential users to talk with the researchers and plant personnel and to "kick the tires" of the latest in clean coal developments.

Recognizing that the US may soon face constraints on carbon emissions, OCDO has during this timeframe worked with the Chicago Climate Exchange (CCX) to promote the concept of voluntary CO_2 trading. In 2005, OAQDA joined CCX as an associate member.

Deployment of Pilot Demonstration and First-of-a-Kind Clean Coal Technologies. While OCDO can and does support projects all along the RD&D continuum, its priority, as emphasized in its statute, is toward large pilot and the larger demonstration projects for emerging technologies. In fact, approximately 80 percent of OCDO funding goes to such projects. At OCDO's creation, the General Assembly recognized that there was a paucity of programs that could get research and development out of the labs and "onto the street." It was also recognized that those technologies that have achieved commercial status often need help penetrating the marketplace, and that the first units – simply because of their newness and limited track record – are more expensive than subsequent units will be. For this reason, OCDO is also geared to assist up to three of "first-of-a-kind" units.

Description of current projects

The specific projects funded by OCDO during 2003-2005 reflect the continuum of RD&D embodied by the office's mandate and its integration into OAQDA, the consensus-driven need to address global climate change in CCT development, and OCDO's role within the national context for coal. (3) A complete list of OCDO's projects during this time frame can be found in Appendix II. Some are highlighted below. Projects can be broadly categorized as (1) demonstration and deployment of near-term technologies and (2) applied research. (Abstracts of all OCDO projects can be found at http://www.ohioairquality.org/ocdo/projects.asp.)

NEAR-TERM TECHNOLOGIES

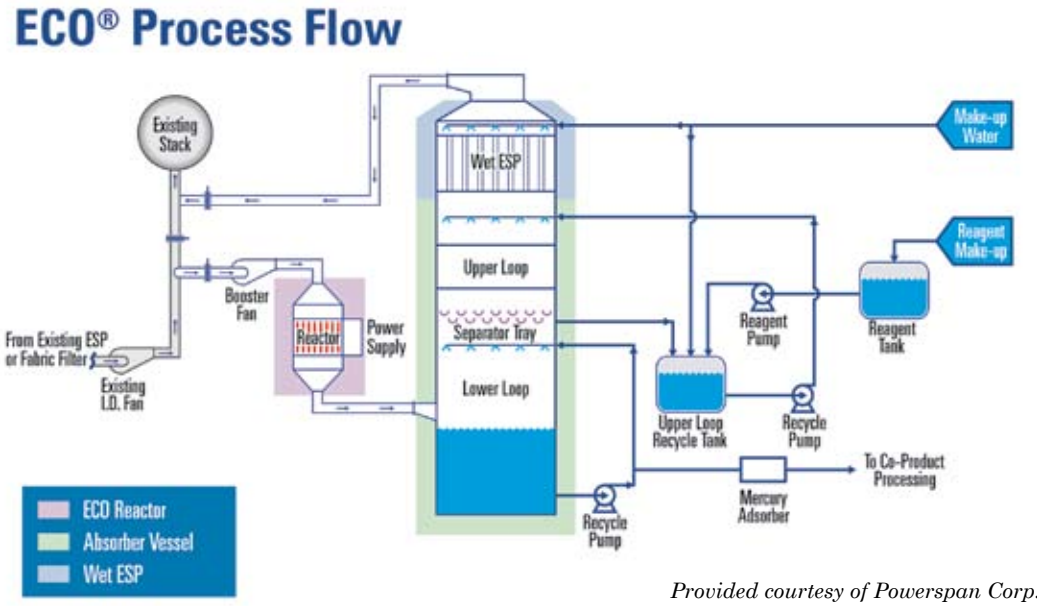
(defined as "potential to result in commercial products and services within 5 years)

Advanced mining techniques. Although advanced mining has not been a major focus for OCDO, it falls within the continuum described earlier. One successful project involved the modification of a long-wall mining machine with an agile head positioning system and sensor to detect the coal interface. This allows the machine to avoid bands of coal with higher levels of ash, sulfur, and mercury, improving coal product quality and reducing potential emissions.

Multi-pollutant control technologies. The back end of a modern coal-fired power plant includes multiple devices in series, each of which typically deals with one pollutant—an electrostatic precipitator (ESP) or fabric filter for flyash, a scrubber for SO2, and a selective catalytic reduction (SCR) unit for NOx. The current generation of power plants includes a wet ESP for fine particulate removal, and a separate process for mercury removal.

To avoid this series of control devices, multi-pollutant control technologies aim to handle multiple pollutants within one process, often converting pollutants into useful products. They are a prime example of the holistic approach to coal with the added benefit of reducing the cost of pollutant removal, increasing efficiency of removal, etc.

OCDO's activities in this area have focused on the Electro-catalytic Oxidation (ECO) process that is capable of removing SO2, NOx, fine particulates, and mercury. The ECO process converts SO2 into a marketable ammonium sulfate fertilizer product; therefore, *it is most effective when applied to high sulfur coal.* High NOx removal efficiencies are aided by high-sulfur coal as well, due to the nature of the process chemistry. This process has been tested at 50-MW scale at FirstEnergy's Burger station. Enhancements to the process may also allow capture of carbon dioxide. For these reasons, ECO is considered the "flagship" of OCDO's demonstration and deployment activities.



Provided courtesy of Powerspan Corp.

OCDO's support of ECO has been leveraged at the national level. The Electric Power Research Institute (EPRI) has studied the reliability (vital to electric utilities) of the ECO process and found it to be comparable to existing options. DOE and Powerspan are collaborating under a cooperative research and development agreement to develop a cost-effective CO_2 removal process, which is readily integrated with the ECO process. Most recently, the commercial potential of this technology has been confirmed: FirstEnergy Corp recently announced that it will apply the ECO process to its Bay Shore power station. Other Ohio and out-of-state entities are reviewing ECO for possible application to their units.

In anticipation of mercury control regulations, OCDO funded the full-scale testing of enhanced commercial FGD processes for mercury removal. The benefit is that the current fleet of wet lime/limestone FGD systems already operating in Ohio could be modified for mercury removal, rather than utilities having to install a separate new control device for mercury alone. To date, work has shown that up to 78 percent mercury removal can be accomplished through this approach. OCDO is also funding a project to develop better sorbents, called brominated powdered activated carbon (B-PAC) for mercury removal that can be injected downstream of the boiler.

Boiler improvements. The prospects for Ohio coal can be improved by raising the efficiency of its use in electricity production (which reduces emissions per unit of heat input, the standard designation used by EPA), and mitigating operating issues.

Five projects funded during this reporting period address boiler improvements: (1) development of a real-time, on-line boiler tube corrosion monitor to better manage tube failures, the number one cause of coal-fired boiler unavailability; (2) testing of advanced boiler tube materials that can withstand the high-temperature corrosion conditions when burning high-sulfur Ohio coal; (3) assessment of ultra-supercritical (USC) boiler materials for deployment in power stations firing Ohio coal; (4) weldability studies for Inconel 740, one of the most promising USC materials identified; and (5) development of a steam turbine that can be matched to the USC boiler. An adjunct to (5) will be the development of an oxygen-fired USC boiler, which, compared to traditional air-fed boilers, promises higher efficiency, smaller size, and a concentrated CO2-rich stream that can be sequestered.

Combustion products management. The more value that can be extracted from the raw constituents in coal the better, especially when pollutants are transformed into useful products. For example, in Ohio, most of the flue-gas desulphurization (FGD) systems employ lime as a reagent. While the lime effectively removes SO2 through chemical reactions, the process results in a difficult-to-manage solid waste sludge. An OCDO project demonstrated the production of aggregate from lime-based FGD sludge using a patented disk-pelletization technology. The benefit is that FGD sludge requiring disposal (a cost) can potentially be recycled for highway construction, masonry construction, and other uses (a revenue stream). A related project investigated the long-term use of stabilized FGD materials in the construction of low-permeability liners for ponds and wetlands.

FGD gypsum offers the potential to be used as a large-volume amendment for direct agricultural applications. OCDO-funded field tests demonstrated that FGD gypsum increases alfalfa yields when applied to soil as a soil amendment rather than as a fertilizer.

Other projects sought to improve the marketability of coal combustion products (CCP). Three of the projects are focused on the CCP Extension Program at The Ohio State University, which is engaged in technology transfer activities. OCDO's efforts have resulted in an increase in CCP recycling in the state from 21 percent in 1997 to 30 percent in 2005. Mine reclamation, highway civil works, and agricultural soil amendments are just three of the uses developed and promoted through this program.

Given the projected increase in FGD applications in the state, OCDO funded a continuation of the program with an emphasis on FGD products. The goal of this part of the program is to boost CCP recycling to over 50 percent by mid-2008. An added project will result in an integrated database and information management system that will help coordinate CCP supply and demand.

The fourth project involves the testing of pavement systems built with CCPs. These slightly different tests will be performed in two different counties. Early work through this project clearly shows that CCPs can enhance the performance and durability of highways and roadways. Information from this activity is being shared with the Ohio Department of Transportation, county engineers, and highway contractors. This represents a potentially high volume beneficial repository of coal-derived products.

CO_2 control and management. Four OCDO projects fall in this category. The first is Phase 1 of the Midwest Regional Carbon Sequestration Partnership (MRCSP), managed by Battelle. OCDO is the second largest sponsor of this effort, after USDOE. The components of this program include characterizing

CO2 sources and sinks as well as CO2 capture and transport technologies, identifying regulatory issues, developing cost models, identifying sequestration opportunities, and public outreach and education. To date, the project has identified geologic sinks that, conservatively, can sequester an estimated 240 years of CO2 at current emission rates.

The second project, a follow-up to the first, adds several small-scale demonstrations of CO2 concentration and sequestration.

A third project involves the active demonstration of feasibility and safety of geologic sequestration in the Ohio River Valley, home to the highest concentration of power plants in the nation. Initial evaluation of the data suggests that there is significant CO_2 storage potential in sandstone and carbonate rock zone formations around AEP's Mountaineer plant, the site of the project, and probably similar potential within the surrounding region.

The fourth project is a study of the possible reactions between carbon dioxide and minerals of deep geologic formations that might be used for CO_2 sequestration. The objectives are to determine the rate of conversion of CO_2 into carbonate minerals and possible reactions that might impact the security of CO_2 injection wells. This is a long-term study of the Ohio Coal Research Consortium described above.

Human exposure to fine particulate and gaseous emissions. One project in this category provides for indoor and outdoor sampling for fine particulate less than 2.5 micron ($PM_{2.5}$) and various co-pollutants in Steubenville, Ohio. One purpose was to determine the source of pollutants (e.g., coal plants or other sources) so that any future controls would address the proper source of the problem. An additional outcome of this project will be a database useful for epidemiological studies, long-range transport studies, and fine particulate compliance programs.

Improved SO_2 control. One project completed in this area is the pilot demonstration of the Ohio State Carbonization and Ash Reactivation (OSCAR) process. This technology seeks to improve limestone as a reagent for SO2 absorption and other contaminants. OSCAR sorbents proved to be effective in removal of additional SO2 (beyond conventional limestone) and significant quantities of mercury.

Another project seeking better SO2 reduction methods by improving sorbent utilization is the demonstration of the Gas Suspension Absorber on a 50-MWe power unit at the City of Hamilton. This technology was successfully demonstrated and a technology transfer open house was conducted in 2003. This technology is now being used to enable the City of Hamilton to use Ohio coal in a unit that previously burned low-sulfur coal from Kentucky.

Finally, OCDO has funded the development of a dry sorbent injection system that represents a low capital cost, flue-gas duct injection system for removal of SO2 from small coal-fired boilers. The process is currently undergoing shake down testing at the Lausche Heating Plant of Ohio University. Such a technology could help commercial and small industrial facilities displace high-cost natural gas with more moderately priced coal.

APPLIED RESEARCH

Thirty-nine applied research projects have been completed through OCRC during this Agenda period; 15 projects are currently in progress. The OCDO solicitation for research projects is based on input from both the Consortium Review Committee (CRC) and the coal user community.

The initial slate of projects in late 2002 and 2003 were focused on SO2 capture because coal sulfur content was identified as the primary market barrier for Ohio coal. Later, NOx emissions and air toxics control were added and the emphasis on SO2 capture receded. In 2004, the OCRC recognized the heightened international and domestic concern with global climate change and its significant potential to affect coal use, so research relating to carbon management was expanded.

Most recently, with the emphasis from the White House and the DOE on the hydrogen economy and near-zero emissions coal-based power systems, OCRC added applied research projects related to coal gasification, including high temperature gas clean-up, production of hydrogen from coal, use of coal syngas in fuel cells, carbon capture and sequestration, and development of fuel cells directly fired by coal.

Demonstrations and Deployments: OCDO projects at work
Ultimately, the benefits of RD&D programs must be proven through the commercialization of the technologies, adoption by the marketplace, and enhancement of user markets. The time scales for these outcomes are multi-year at best, and often can take decades.

Referring back to the RD&D continuum described earlier, new ideas proceed through conceptual design grounded in scientific theory, computer simulation, lab-scale model, bench-scale and/or pilot test, full-scale demonstration, and, finally, commercial demonstration and widespread marketplace adoption. Clearly, any new technology must clear enormous hurdles and challenges along the way. As is the nature of R&D, some technologies, despite everyone's best efforts, do not succeed. Data garnered from such research efforts also should be recognized as a critical component of R&D.

In this section, the commercial and marketplace status of selected projects from the Agenda's time period are outlined:

- The successful pilot and demonstration work at Burger has led FirstEnergy Corp. to order a commercial ECO unit for its Bay Shore power station.
- AFBC Transitions Ltd. and Enercon Systems are marketing a coal-fired atmospheric fluidized-bed combustor for industrial and commercial facilities as an alternative to natural gas. OCDO and NETL actively promoted this technology, beginning with an open house in November 2004, and participated in the development of a marketing plan.
- The City of Hamilton has successfully converted a 50 MWe boiler from low-sulfur coal from Kentucky to high-sulfur Ohio coal through the application of the Gas Suspension Absorber developed with OCDO funding.
- Applied Sciences Inc. (ASI) has demonstrated production of carbon nanofiber from coal gas. This process has the potential to reduce the cost of production of carbon nanofiber by an order of magnitude.
- An OCDO project conducted by McDermott Technologies/Babcock & Wilcox has led to proprietary additives that can be injected into wet scrubbers to enhance mercury removal up to 91 percent. Given that scrubbers are being added to Ohio power stations and mercury removal is being required from existing plants, there is significant market potential.
- Universal Aggregates LLC is promoting a commercial process for producing synthetic aggregate from FGD sludges and flyash for use in concrete blocks destined for highway construction. OCDO continues work on this technology to overcome a specific challenge to widespread adoption of this technology: the iron content of the flyash.
- OCDO helped establish the OSU Coal Combustion Products Extension program to offer leadership in the use of CCPs. This mechanism was put in place after OCDO realized that no vendors are available to promote the adoption of these new technologies. OCDO also participates in the Midwest Coal Ash Association. Such activities continue to facilitate the ultimate adoption of CCP for a variety of construction related and agricultural end markets.

Future Projects
The types of projects to be funded in the succeeding biennium will meet the broad mandate set forth in the statute and OCDO's specific priorities and objectives. The priorities for each solicitation are revised to consider the results of past projects, to address the latest problems facing Ohio coal, and to incorporate revised environmental standards.

Generally, the types of clean coal projects that are funded must pass the following means test: The project must support the category of technologies requested in the Request for Proposal and improve the efficiency and/or environmental performance of applications using Ohio coal and/or useful products produced from Ohio coal. Further, the technology involved must be applicable to Ohio coal, show a high likelihood of maintaining or increasing the use of Ohio coal, and show a high probability of being adopted by end users of Ohio coal. The cost and relative risk to the state must be balanced by the participation of other investors or interested parties (e.g. cost sharing), and the project must be characterized by a high likelihood that the technology would not be developed in the absence of OCDO assistance.

For example, the OCDO Request for Proposals 2005 sought projects in the following categories, ordered in priority: (1) deployment of innovative, cost-effective clean-coal technology at full scale; (2) demonstration of technologies for reducing, mitigating, or sequestering gases thought to contribute to global climate change; (3) advanced steam turbine materials that could be matched to an ultra-supercritical boiler; (4) demonstration of an advanced clean coal technology, at pilot or larger scale, that combines multiple emissions and efficiency goals; and (5) demonstration of technologies, or technology transfer, related to coal combustion product (CCP) management.

Within each category, there are specific, well-delineated additional "objectives" which the proposal, and ultimately the project, must meet. In most cases, three to seven objectives are listed, and one to three of them must be met by the project.

Ohio Coal Research Consortium projects. Applied research through the OCRC is expected to reflect the objectives described earlier as well as specific requirements developed by OCDO. Researchers making proposals are also expected to apply for federal or private funds. Each proposal must demonstrate that the technology can be applied practically; in addition, proposers must supply some rudimentary economic evaluations.

The four stated topics of the OCRC's Year 4 Solicitation are: sulfur and nitrogen oxide emissions control; control of mercury, arsenic, and selenium emissions; CO2 emissions reduction methods; and, coal gasification technologies. Several sub-goals are provided under each. Criteria are also set for projects to maintain funding. By the completion of the third year of a given project, OCDO expects to see a peer-reviewed paper published or an application for a patent submitted.

Results and dissemination of those results

Results from individual projects are disseminated by release of final reports, papers published in professional journals, presentations at industry meetings, and filing of patents. In addition, abstracts of all projects, current and completed, are maintained on the OAQDA website, www.ohioairquality.org. OCDO staff stays in contact with researchers and notifies them when a request is received for a final report.

OCDO work is regularly showcased at high-profile industry meetings such as the annual DOE Clean Coal & Power Symposium. OCDO also holds periodic seminars and workshops aimed at disseminating project results. Two examples are the Clean Air & Coal Research Symposium held in December 2004 and the CO2 Sequestration Seminar conducted in February 2005. OCDO also makes a great effort to communicate with mainstream media, including local newspapers, trade magazines, and web outlets.

OCDO also conducts technology transfer open houses. At these events, industry leaders, prospective technology buyers, Congressional delegations, and Congressional aides come together to "kick the tires."

Tech transfer open houses represent exceptional opportunities for OCDO to unveil to all of its stakeholders the culmination in the development of a technology.

A typical technology transfer event includes a half-day seminar detailing the technology's performance and economics followed by a tour of the facility. The target audience is the technical and user community and averages approximately 100 people per event.

During this Agenda reporting period, technology transfer open houses were held for:

- The City of Hamilton's power plant with its Gas Suspension Absorber project (September 2003) demonstration, applicable to industrial and commercial applications.
- The Atmospheric Fluidized Bed Combustor at Cedar Lane Farms (November 2004), a demonstration on a small commercial unit, which can be scaled up to for larger commercial/industrial applications; and
- The Powerspan Electro Catalytic Oxidation (ECO) multi-pollutant reduction technology at FirstEnergy's Burger plant (September 2005), a demonstration at utility scale.

To facilitate the publishing endeavors of its researchers, OCDO staff serve on steering committees of relevant industry conferences. It recommends Ohio speakers and OCDO-supported projects or efforts for presentations. OCDO is a "standing member" of steering committees for the Pittsburgh Coal Conference, USDOE's Clean Coal & Power Conference, and the annual Conference on Carbon Capture & Sequestration. It serves on an ad hoc basis on other conference committees, such as the American Coal Council. OCDO staff act as speakers and session chairs throughout the year at important industry venues.

In December 2004, OAQDA and OCDO combined their separate conferences into one, the Ohio Air Quality and Coal Research Symposium, held at Ohio University. The Director of USDOE's National Energy Technology Laboratory gave the keynote overview, setting the stage for a panel drawn from industry, Congress, the environmental community and others to debate needs and paths to solutions. Several of the technical sessions highlighted OCDO's projects. A poster competition followed by a tour of the Sorbent Technologies' sulfur dioxide reduction demonstration at Ohio University's Lausche power plant concluded the very successful event, attended by nearly 200 people.

As an offshoot of its FutureGen and Midwest Carbon Sequestration Partnership efforts, a Carbon Dioxide Sequestration Forum was held for key community leaders in February 2005. Approximately 150 people attended the event. The topic of carbon sequestration is new to most people, especially deep geologic sequestration. OCDO recognized that, when questions arise, the public and the media would first think to contact their community leaders: county commissioners, mayors, economic development directors, state representatives and senators, district Congressional offices, etc. Educating community leaders is therefore the first step to educating the public at large about sequestration. At this forum, experts from USDOE/ Lawrence Berkley National Labs, Battelle, and the Ohio Geological Survey/Ohio Department of Natural Resources addressed the topic from national, regional, and state perspectives.

Current status of Clean Coal Technology programs in this state and elsewhere

Clean coal RD&D is an international endeavor. At the global level, the US, the European Union, and Japan have been pursuing some of the most ambitious programs. However, as the economies of China and India power up, most observers expect efforts to expand dramatically in those countries, given that they represent one-third of the planet's population, are experiencing tremendous economic growth, and have extremely large coal reserves.

The global nature of clean coal RD&D must be a key element in OCDO planning. Growth in coal-fired power generation in Asia is escalating rapidly. Ohio companies developing CCTs have the opportunity to sell their products and applications in these two countries, and elsewhere around the world. OCDO activities support not only utilities and industries using Ohio coal, but also the economic expansion of Ohio equipment and technology suppliers. Thus, while Japan and others support CCT RD&D for indigenous utilities, OCDO addresses both RD&D and the equally important objective of providing advanced technologies that can be sold into emerging energy markets like India and China.

The European Union has funded a fossil energy R&D program for at least the last two decades. [8] It has evolved over the years to focus on global warming and efficiency issues. With this direction, the CCT portion of the program has been shrinking in recent years while the renewables and nuclear portions of the program have expanded. Energy R&D in general accounts for a smaller and smaller share of the EU's budget. Contrast this to the US, where clean coal is still described by our Federal Government leaders as a "cornerstone of our energy portfolio."

Other countries with significant CCT programs include Japan, Germany (some activities separate from the EU), Australia, and the UK.

Despite the range of countries supporting CCT, the funding levels in each are substantially lower than in the US For example, the Australian effort is funded at a $20-million level. The EU's activities in fossil energy R&D are in the $200-million range; however, the CCT component of this is only a small fraction.

In addition, most of the funded projects are big-ticket items, such as integrated gasification combined cycle, pressurized fluidized bed combustion combined cycle, and others. CO2 mitigation has become a significant component of virtually all of these programs. Information about the international programs can be found at the International Energy Agency (IEA) Clean Coal Centre website, and at the NEDO website.

The USDOE Clean Coal Technology Demonstration Program, begun in 1986, is probably considered the flagship endeavor at the national and global level. It began as a response to the acid rain issue, but evolved into a broad, advanced-coal program aimed specifically at demonstrating technologies at commercial scale so the private sector could make decisions about commercial use. Designed as a cost-share program, DOE partnered with private sector organizations over a 20-year period to fund 35 projects in 18 states. As of April 2005, 32 of these projects completed their planned demonstration phase, and many are still operating, according to DOE.

Ohio electric utilities were the beneficiaries of five of these DOE CCT projects. They include the demonstration of the pressurized fluidized bed combustion combined cycle at AEP's Tidd station; the demonstration of limestone-injected, multistage burners (LIMB) for removal of SO2 and NOx in the furnace itself; the pilot application of a robust fabric filter modified to remove SO2, NOx, and flyash; the full-scale demonstration of the low-NOx concentric burner; and pilot application of the WSA-SNOx process for simultaneously removal of NOx and SO2, acid production, and fertilizer byproducts.

Today, there are several other CCT-related programs at the federal level, including the $2 billion Clean Coal Power Initiative (CCPI) and FutureGen. The recently passed Energy Bill includes significant funding for CCT, although much of the benefit flows to coal gasification and related technologies.

Many states with significant coal reserves also conduct coal R&D programs, in addition to Ohio. These include Illinois, Indiana, West Virginia, North Dakota, Pennsylvania, and Texas [13]. With good reason, states that have an indigenous coal industry are willing to protect that part of their economy by investing in long-term technology research and development. [10]

Appendix I: OCDO at a glance—yesterday, today, and tomorrow

The Ohio Coal Development Office (OCDO) was created in 1984 and endowed by a 1985 Constitutional amendment authorizing the issuance of bonds to support its work.

OCDO's mission is to co-support the research, demonstration, and deployment (RD&D) of technologies that can use Ohio coal in an economic, environmentally sound manner. More specifically, the objectives are to: (1) secure a domestic energy resource found in abundance in this state; (2) support the jobs associated with its production and use; (3) improve the environmental performance associated with its use; (4) develop its potential not only as a fuel but as a chemical feedstock; and (5) provide various means for Ohio's coal-based electric power generators to continue producing clean, bulk, reliable, lower-cost power for the benefit of the state's industries, commercial enterprises, and residents.

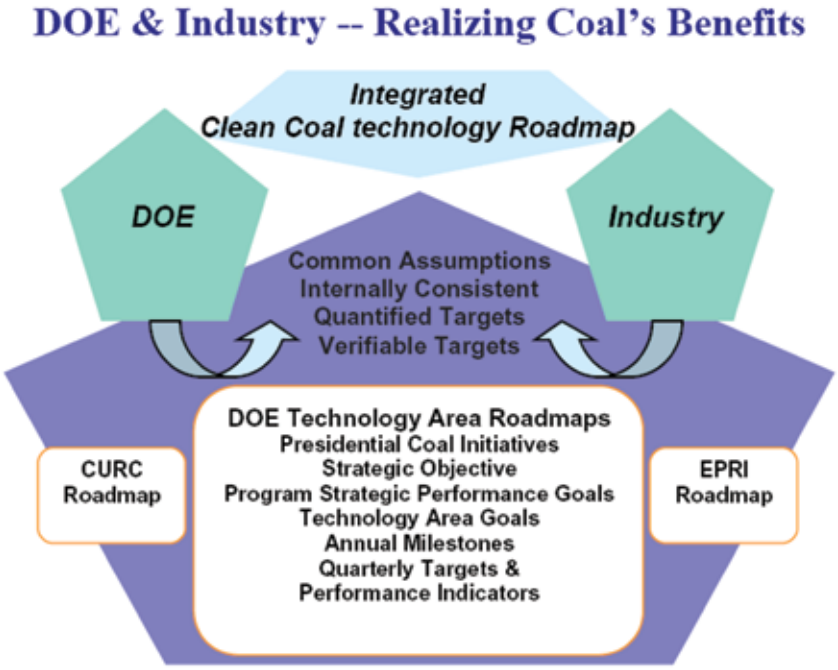
While the purposes provided by statute are broad, several priorities were established. One is to improve the performance of the existing coal-based generating fleet. Another is to construct and operate commercial-scale demonstration facilities. The statute also encourages the use of coal as a feedstock for other applications and requires that an adequate portion of OCDO funds be directed to fundamental research.

Thus, OCDO is authorized to support clean coal technology projects all along the "RD&D Continuum" (see graphic, page 14), from basic research, through the several steps of scale-up, including pilot-scale test facilities and commercial-scale demonstration units. OCDO may also co-support up to three first-of-a-kind installations in Ohio of a given technology, before it is considered "commercial" and ineligible for OCDO funding. However, it is at this point that the synergy with OAQDA's other programs comes into play.

OCDO attempts to leverage private sector and federal support into Ohio-based projects. Over its history, OCDO has leveraged an additional $3 for every $1 invested. A significant portion of these funds came from sources outside Ohio. This is accomplished by often synchronizing the release of OCDO solicitations with those of the federal government. OCDO also has written numerous letters of support for Ohio-based projects to federal agencies and to its Ohio Congressional delegation.

OCDO requires cost sharing by the participants in all of its projects. Through its public project solicitations and otherwise, OCDO strongly encourages each of its project proposers to bring to the project multiple partners and funding sources. A "typical" larger-scale project may have one key private sector research institute or technology development company, one or more participants from the private sector (especially from the user community often acting as a host site for the project), and a federal agency. There may be other participants as well.

Clean-coal technology RD&D is a huge international research endeavor undertaken by many states, the federal government, and other countries. Many of the stakeholders in this endeavor have collaborated to issue the "Clean Coal Technology Roadmap." [9] The roadmap sets forth a technology development path with specific performance objectives, and responds directly to user expectations for environmental performance and competitive economics.



Provided courtesy of the Coal Utilization Research Council

The importance of the roadmap should not be understated. The effort was led by the Coal Utilization Research Council (CURC) of which OCDO is a member; the Electric Power Research Institute (EPRI), an R&D organization serving many of the utilities in this country; and the USDOE. OCDO's solicitations specifically reference the CURC/EPRI/USDOE roadmap and how a proposed project should address the roadmap's objectives. In this way, OCDO's programmatic directions maintain continuity with the broader national and international context for CCT development.

OCDO solicitations result in numerous excellent proposals from which to choose. All proposals are subject to OCDO's standard review and approval process.

Each proposal is reviewed by OCDO staff and several members of OCDO's Proposal Review Team (PRT), a group of independent technical experts retained by OCDO under contract. Their evaluations are compiled into a master evaluation, which is sent to the proposer and to OCDO's statutorily-created Technical Advisory Committee (TAC). During a public meeting, proposers present before the TAC, which queries the proposers and then votes whether or not to recommend the project to the OCDO.

At a subsequent public meeting, the project is presented to the OAQDA with the TAC and OCDO Director's recommendations. Should the OAQDA approve a project, a legal agreement is entered into with the proposer to conduct the project according to a specific statement of work, timeline and budget. Projects that were on-line or approved during the period of this report are discussed elsewhere in this document; abstracts of each are also available on the agency's website, www.ohioairquality.org/coal.

A major change. In July 2003, OCDO was transferred from the Ohio Department of Development to the Ohio Air Quality Development Authority. OCDO's charter is to foster the research, demonstration, and deployment of technologies that can economically and cleanly use Ohio coal, support the economy by holding the line on electric energy costs, improve the environment, and support the jobs associated with coal's production and use. Although OCDO cannot fund projects involving readily or commercially available technologies, OAQDA can assist in the financing of commercial projects that will benefit Ohio's air quality.

Combining the OCDO program with OAQDA's other resources creates a clear, progressive path for clean coal technologies in Ohio, from concept through commercial application.

The Ohio Coal Development Agenda

In December of 2003, a joint retreat was held by the seven OAQDA members and OCDO's 14-member Technical Advisory Committee (TAC) to better acquaint each group with their respective activities. Several national experts in the field of coal R&D addressed the group on coal and environmental issues nationally and regionally and how these matters pertain to Ohio's coal R&D efforts.

At that time, OCDO had been in existence for 19 years. OAQDA commissioned the first-ever third-party review of OCDO's efforts to highlight successes, identify challenges and assess its ability to adapt to a rapidly changing landscape. The full report, entitled "Third Party Review of the Ohio Coal Development Office," is now completed and posted on the OAQDA website, www.ohioairquality.org. Its key recommendation was that OCDO needed to develop, implement and follow a clearly defined strategic planning process. That process is now under construction.

Appendix II: List of all projects (in 2003-2005 timeframe)

NEAR-TERM TECHNOLOGIES

- Long-wall mining machine modification for improved quality [D-01-19]
    - Technology-head positioning device and sensor
    - Goal-selective mining for higher coal quality
    - Status-seeking integration of sensor into machine
- 50-MW demonstration of multi-pollutant process [D-01-20]
    - Technology-ECO (electro-catalytic reduction) process
    - Goal-Simultaneous removal of SO2, NOx, fine particulate, and mercury with fertilizer production
    - Status-high removal efficiencies, reliability demonstrated
- Enhancement to ECO process for more valuable fertilizer product [D-05-01]
    - Technology-crystallizer test loop added to ECO demo
    - Goal-convert liquid fertilizer product into more valuable solid
    - Status-testing on-going
- Corrosion management in coal-fired utility boilers [D-01-15]
    - Technology-real-time corrosion monitoring device
    - Goal-avoid outages from boiler tube failures caused by corrosion
    - Status-ready for commercial application
- Advanced materials for higher-temperature boilers [D-97-2]
    - Technology-advanced boiler tube alloys
    - Goal-more corrosion-resistant coal-fired boilers
    - Status-final analyses of test samples from operating boiler being conducted
- Assessment of materials for ultra-supercritical (USC) boiler [D-00-20]
    - Technology-new alloys for USC boiler conditions
    - Goal-higher efficiency coal-fired boilers
    - Status-numerous sub-tasks on-going
- Weldability of USC materials [D-02-04]
    - Technology-Inconel 740 boiler tube materials
    - Goal-maintaining post-weld strength of alloys
    - Status-Numerous sub-tasks on-going
- USC compatible steam turbine [D-05-02]
    - Technology-steam-turbine metallurgy, O2 enhanced boiler
    - Goal-smaller boilers producing CO2-rich gas streams for sequestration
    - Status-on-going
- Coal Combustion Extension Program [D-99-4, D-05-07, D-05-10]
    - Technologies-multiple
    - Goal-competitive, environmentally safe recycle of CCPs
    - Status-CCPs use increased in Ohio through multiple on-going programs
- Testing of pavement systems using coal combustion products [D-00-5]
    - Technology-CCP-enhanced asphalt and concrete paving materials
    - Goal-high-volume recycle of CCP
    - Status-testing indicates enhanced performance, durability; Ohio DOT to evaluate results.
- Midwest Regional Carbon Sequestration Partnership-phase 1 [D-02-17]
    - Purpose-characterization of CO2 sources and sinks
    - Goal-mitigate CO2 impact on global climate change
    - Status-Sources characterized, sequestration sites identified and evaluated
- Midwest Regional Carbon Sequestration Partnership-phase 2 [D-05-13]
    - Purpose-continue characterization of CO2 “sinks,” initial demos
    - Goal-mitigate CO2 impact on global climate change
    - Status-two CO2 recovery demonstrations on-going, leveraging of oil/gas drilling for core samples indicative of sequestration potential

- Feasibility of geologic sequestration [D-99-16]
    - Technology-geologic CO2 sequestration with injection from power plant
    - Goal-mitigate CO2 impact on global climate change
    - Status-simulations completed, pilot CO2 control facility being developed
- Oxygen enhanced combustion [D-05-05]
    - Technology-O2-based combustion (instead of air) and subsequent boiler design
    - Goal-Concentrate CO2, evaluate boiler characteristics
    - Status-initial evaluations complete, design phase on-going
- Monitoring of PM2.5 and co-pollutants [D-98-2]
    - Purpose-indoor, outdoor monitoring for epidemiological and long-range transport studies
    - Goal-comprehensive database
    - Status-on-going
- Development of a compact dry sorbent injection system
    - Technology-perlite-enhanced lime sorbent injected into flue gas duct
    - Goal-high SO2 removal, low-cost process for small coal-fired boilers; displace natural gas by coal for small boilers
    - Status-full-scale testing on 2.7-million lb/hr coal-fired boiler to begin soon
- Design, installation, operation of multi-pollutant removal process
    - Technology-Gas Suspension Absorber
    - Goal-demonstrate GSA on a 50 MW unit for improved sorbent utilization and mercury removal
    - Status-performance goals achieved, process ready for commercial application
- Pilot testing of Ohio State Carbonization and Ash Reactivation Process [D-98-18]
    - Technology-novel sorbent made from spray dryer FGD material
    - Goal-demonstrate sorbent ability to remove SO2 and arsenic
    - Status-sorbent proved effective, licensing and commercial arrangements under discussion

Appendix

Summary of Grants Awarded in Response to RFP 2002

	OCDO ID#	Title	Proposer	Location	Duration	OCDO $	Proposer $	Federal $	Other $	Total $
7	D-02-04	Welding Process Development of Inconel® 740 for USC Boilers	Energy Industries of Ohio	Alliance and Columbus, OH	60 months	$112,296		$449,183	$92,085	$653,564
7	D-02-17	Midwest Regional Carbon Sequestration Project	Battelle	Columbus, OH	24 months	$100,000	$23,750	$1,600,000	$694,718	$2,418,468
6	D-02-19	Improved Soil Quality and Increased Carbon Credits Through the Use of FGD Gypsum to Enhance No-tillage Crop Production	The Ohio State University Research Foundation	Bucyrus, OH	24 months	$170,051	$267,378	$73,000		$510,429
5	D-01-15	Field Test of a Corrosion Advisor System	AEP	Cheshire, OH	24 months	$240,368	$100,000	$140,000	$80,000	$560,368
8	D-04-01	Commercialization of Fly Ash in Expendable Tool Applications	Energy Industries of Ohio	Defiance and Independence, OH	24 months	$213,036	$37,460		$225,000	$475,496
Total for proposals approved (Categories 5, 6, and 7)						$835,751	$428,588	$2,262,183	$1,091,803	$4,618,325

Key: 5. Proposal approved on January 27, 2003.
6. Proposal approved on March 31, 2003.
7. Proposal approved on August 12, 2003
8. Proposal approved on December 14, 2004

D-02-04 -- In this project, a consortium of boiler manufactures will attempt to demonstrate methods for welding of metals that are suitable for applications in ultra-supercritical (USC) boilers. This is a key component of designs of boilers suitable for the high temperatures and pressures of USC boilers. USC boilers are more efficient then conventional boilers in conversion of the energy of coal into electricity.

D-02-17 -- In this project a consortium of seven eastern and mid-western states and twenty two industrial partners are assessing the technical, economic, and social feasibility of carbon sequestration in our region. This is a phase one USDOE program. The project will make recommendations to USDOE regarding small-scale field test opportunities in a second phase of the program which will include terrestrial and deep well carbon sequestration.

D-02-19 -- This project will demonstrate on Ohio farms that the application of flue gas desulfurization gypsum to poorly drained clay soils will enhance soil drainage sufficiently for adoption of non-tillage methods of production of corn and soybeans. Non-tillage reduces the overall cost of production of these crops and also enables soils to sequester carbon as soil humus. As long as these soils are cultivated by non-tillage methods the soil humus concentration will increase to a higher steady equilibrium level retaining carbon in the soil.

D-01-15 -- This project will demonstrate a method to monitor and manage the waterwall corrosion in coal-fired utility boilers. The goal was to develop a methodology for combining predicted and measured data into corrosion management guidelines. This enabled avoidance of boiler conditions which are excessively corrosive and reduction of maintenance costs. The cost of prevention of corrosion is much less than cost of repair of corrosion.

D-04-01 -- The goal of this project is demonstration of the use of fly ash for molds for casting of auto parts and use of fly ash in other auto parts applications. In earlier work it was demonstrated that auto parts cast with fly ash molds require considerable less machining after casting then do parts made using foundry sand molds. In this project fly ash molds will be evaluated in an actual commercial foundry process for production of auto parts.

Summary of Grants Awarded in Response to RFP 2005

	OCDO ID#	Title	Proposer	Location	Duration	OCDO $	Proposer $	Federal $	Other $	Total $
1	D-05-01	50 MW_e Commercial Demonstration of Electro-Catalytic Oxidation Technology for NO_x, SO_2, PM Hg Removal Project Supplement	FirstEnergy Corp.	Dilles Bottom, OH	13 months	$1,000,000	$3,099,000		$1,265,000	$5,364,000
1	D-05-02	Advanced Materials for Ultrasupercritical Coal Power Plants	Energy Industries of Ohio	Independence, OH	36 months	$2,000,000		$7,298,712	$2,196,219	$11,494,931
1	D-05-04	Research and Demonstration of Beneficial Agricultural Uses of FGD-Products in Ohio	The Ohio State University	Wooster, Columbus, Bucycrus, OARDC NW (Wood County)	24 months	$170,362	$180,361	$15,000	$163,777	$529,500
1	D-05-05	Demonstration of the Oxy-Combustion Process for CO_2 Control at the City of Hamilton, OH	Babcock & Wilcox	Alliance, Barberton, Hamilton, OH and Countryside, IL	24 months	$484,382	$284,382	$400,000	$284,382	$1,453,146
5	D-05-06	Demonstration of Reactive CO_2 Separation Process using Tailored Nanoporous Calcium Sorbent	The Ohio State University	Columbus, OH	36 months	$1,249,999	$730,163		$549,300	$2,529,462
1	D-05-07	Coal Combustion Products Extension Program	The Ohio State University	Columbus, OH	36 months	$248,719	$277,342		$137,616	$663,677

Summary of Grants Awarded in Response to RFP 2005 (Continued)

	OCDO ID#	Title	Proposer	Location	Duration	OCDO $	Proposer $	Federal $	Other $	Total $
2	D-05-08	Use of Lime-Activated High-Carbon Class F Fly Ash in Full-Depth Reclamation of Asphalt Pavements-Delaware County	The Ohio State University	Delaware County, OH	36 months	$459,994	$338,737		$540,582	$1,339,313
2	D-05-09	Use of Lime-Activated High-Carbon Class F Fly Ash in Full-Depth Reclamation of Asphalt Pavements-Warren County	The Ohio State University	Warren County, OH	36 months	$223,561	$326,775		$103,192	$653,528
4	D-05-10	Development of a Database and an Analytical Tool for the Management and Visualization of Ohio Flue Gas Desulfurization (FGD) and Other Coal Combustion Products (CCPs)	Ohio University	Athens, OH	12 months	$24,581	$50,533			$75,114
4	D-05-12	Pilot-Testing of Sieving Electrostatic Precipitator	Ohio University	Athens, OH	14 months	$204,532	$204,532		$204,532	$613,596
1	D-05-13	Regional Carbon Partnerships-Phase II-Midwest Region	Battelle	Columbus, OH	48 months	$750,000		$14,299,996	$3,017,381	$18,067,377
		Total Approved				$6,816,130	$5,491,825	$22,013,708	$8,461,981	$42,783,644

Categories: 1. Approved by the OAQDA on June 14, 2005.
2. Approved by the OAQDA on June 14 as a single combined project.
4. Approved by the OAQDA on July 12, 2005.
5. Approved by the OAQDA on November 8, 2005.

D-05-01 -- This project is a continuation of a very successful demonstration of a process for control of NOx, SO_2, PM and Hg emissions from coal-fired utilities. A longer column will be built to demonstrate optimization of the NOx control to 90 percent or more. Also, a crystallizer will be demonstrated for separation of ammonium by-sulfide crystals from the waste water stream. The ammonium bi-sulfate crystals are can be sold as a commercial fertilizer. The remainder of the waste water will be recycled through the process.

D-05-02 -- In this project, a consortium of boiler and turbine manufactures will evaluate materials suitable for applications in ultra-supercritical (USC) boilers. This is a key component of designs of boilers suitable for the high temperatures and pressures of USC boilers. USC boilers are more efficient then conventional boilers in conversion of the energy of coal into electricity.

D-05-04 -- This project will demonstrate on Ohio farms that the application of flue gas desulfurization gypsum to poorly drained clay soils will enhance soil drainage sufficiently for adoption of non-tillage methods of production of corn and soybeans. Non-tillage reduces the overall cost of production of these crops and also

enables soils to sequester carbon as soil humus. As long as these soils are cultivated by non-tillage methods the soil humus concentration will increase to a higher steady equilibrium level retaining carbon in the soil. This project is a necessary continuation of project D-02-19 and will provide the additional data required for a statistically valid demonstration.

D-05-05 -- This project is the first phase of a demonstration of retro-fitting existing coal-fired utility boilers for use of oxygen in place of air or oxy-combustion. Oxy-combustion yields a flue gas stream of CO_2 suitable for sequestration in geologic formations. The objective of this phase of the work is to define equipment required for retro-fitting existing boilers and the cost of such retro-fitting. The proposed phase two, which would be another project would actually build and demonstrate an oxy-combustion boiler.

D-05-06 -- This project is a scale up of laboratory studies conducted at Ohio State University for a novel process for separation of CO_2 from flue gas. The project is to demonstrate at the bench scale level a method of CO_2 capture that is suitable for both retro-fitting of existing coal-fired boilers and for new coal-fired boilers. The project would also demonstrate capture of SO2 and a reduction of total energy required for CO_2 capture as compared with alternative methods for CO_2 capture.

D-05-07 -- This project provides technical expertise, through the Ohio State University Cooperative Extension Program, to users of coal combustion products (CCPs). Some examples would include consultations with county engineers and/or ODOT engineers regarding usage of CCPs in highway maintenance and construction, construction contractors in use of CCPs in concrete formulations, farmers in use of CCPs for feedlot pads, use of CCPs for soil amendments, etc. This program also provides comments and supporting data on US-EPA and/or Ohio EPA proposed regulations for beneficial usage of CCPs.

D-05-08/09 -- These projects were combined into one. The Ohio State University, in cooperation with the Warren and Delaware County Engineer Offices, will demonstrate the usage of CCPs in reclamation of asphalt pavements. In full depth reclamation, the asphalt and sub-road layers are removed, mixed with CCPs and additional additives and replaced as new pavements. The goal of the project is to demonstrate that usage of CCPs is less costly and equal to or better then alternative full depth reclamation treatments.

D-05-10 -- This project is to develop a data base on locations and availability of CCPs for beneficial recycling in highway construction, concrete formulas, etc. This will be one of the tools to be used by project D-05-07 in promotion of CCPs usage.

D-05-12 -- This project is a scale up of bench scale studies at Ohio University to a pilot scale demonstration at a power plant of a novel method for capture of particulate emissions from coal-fired utilities. The project will demonstrate a novel ESP design which is much less expensive then conventional ESP designs. The project will demonstrate methods for fine particulate capture. Also will be demonstrated the separation of carbon from fly ash during the capture process. The carbon captured can be re-burned in the power plant. The remaining low carbon fly ash is very suitable for blending in concrete formulations.

D-05-13 -- This is phase II of a DOE project for demonstration of methods for CO_2 sequestration. In this project a consortium of seven eastern and mid-western states and twenty two industrial partners will demonstrate CO_2 sequestration in Ohio as well as other states in agricultural and forest lands and also by injection into deep geologic formations.

Appendix

Summary of Ohio Coal Research Consortium Projects
The program grant agreement was between Ohio University and the Ohio Coal Development Office. The University then entered into sub-grant agreements with other participating Ohio colleges and universities.

Academic Year	Number of Grants	Universities Involved	OCDO $	University $	Totals $
2003-2004	Administration & 13 Research Projects	The Ohio State University, Ohio University, University of Akron, University of Cincinnati, Case Western Reserve University, University of Dayton	$1,102,513	$484,838	$1,587,351
2004-2005	Administration & 13 Research Projects	The Ohio State University, Ohio University, University of Akron, University of Cincinnati, Case Western Reserve University, University of Dayton	$1,162,085	$451,877	$1,613,962
2005-2006	Administration & 15 Research Projects	The Ohio State University, Ohio University, University of Akron, University of Cincinnati, Case Western Reserve University, University of Dayton	$1,189,428	$448,387	$1,647,575

Appendix III: Source Notes

1. Ernie R. Slucher, Ohio Division of Geological Survey, Summary of Coal in Ohio for Ohio Coal Development Office, August 2005 [for section 1551.34]
2. Ohio Department of Natural Resources, Division of Geological Survey, Report on Ohio Mineral Industries 2003
3. Ohio Coal Development Office, Ohio Coal Research Consortium-III: Year 4 Proposals Solicitation
4. Ohio Coal Development Office Request for Proposals, Clean Energy Production Technologies Projects Solicitation, 2002, 2005
5. Dr. John Topper, IEA Clean Coal Centre, International Clean Coal Initiatives (obtained from http://www.iea-coal.org.uk)
6. Department of Energy, Electric Power Research Institute, and Coal Utilization Research Council, Clean Coal Technology Roadmap ("CURC/EPRI/DOE Consensus Roadmap"), available from various websites.
7. John S. Mead, Director, Coal Research Center, Southern Illinois University Carbondale, Clean Coal Technology: The Illinois Experience, Testimony submitted on energy of the Committee on Science, US House of Representatives (www.house.gov/science/energy/jun12/mead.htm)
8. Information obtained from the New Energy and Industrial Technology Development Organization (NEDO) and Center for Coal Utilization, Japan (CCUJ).
9. Larry Boyd, Energy Industries of Ohio, "Energy Consumption in the Industries of the Future Sectors,"
10. Michael L Williams, Chairman, Governor's Clean Coal Technology Council of Texas, Clean Coal: The Key to Affordable Electricity in Texas, report to the Honorable Rick Perry, Governor, March 2005.
11. Information available from the National Energy Technology Laboratory website on the Clean Coal Technology Demonstration Program.
12. Jason Makansi, Analysis of The Energy Policy Act of 2005, Document developed for clients of Pearl Street Inc
13. Jason Makansi, Opportunities and Perils in the Next Phase of Electricity Market Development, Document developed for clients of Pearl Street Inc.

Appendix IV: News release announcing public comment period for Ohio Coal Development Agenda

FOR IMMEDIATE RELEASE
October 14, 2005

CONTACT: Mark R. Shanahan, OAQDA – (614) 224-3383
Jacqueline F. Bird, OCDO --- (614) 466-6799

Ohio Coal Agenda Available for Public Comment
Statutorily mandated report covers years 2003 through 2005

(Columbus, OH) The Ohio Air Quality Development Authority (OAQDA) today announced that the Ohio Coal Agenda, covering the years 2003 through 2005, has been posted on its website for public comment, effective today through October 31, 2005.

The Ohio General Assembly previously mandated the publishing of a bi-annual Coal Agenda to update interested citizens and organizations on the specific activities of the Ohio Coal Development Office (OCDO), and on the broader status of Ohio coal. OCDO was transferred to OAQDA in July 2003.

Individuals interested in offering public comment on the Coal Agenda are asked to do so in specific fashion, referring to particular paragraphs on identified page numbers. The Coal Agenda, in final form, will be issued by December 31, 2005. It can be found in its current draft status on the OAQDA website, at www.ohioairquality.org. Responses should be directed to Jacqueline F. Bird, Director, Ohio Coal Development Office.

Responses may be submitted, by close of business November 1, 2005, in writing or electronically to the following addresses:

Ohio Coal Development Office
50 W. Broad St., Ste. 1718
Columbus, OH 43215

Or, to: jbird@aqda.state.oh.us

Ohio Air Quality Development Authority
50 West Broad St., Suite 1718
Columbus, Ohio 43215

Phone: (614) 224-3383
Fax: (614) 752-9188
www.ohioairquality.org