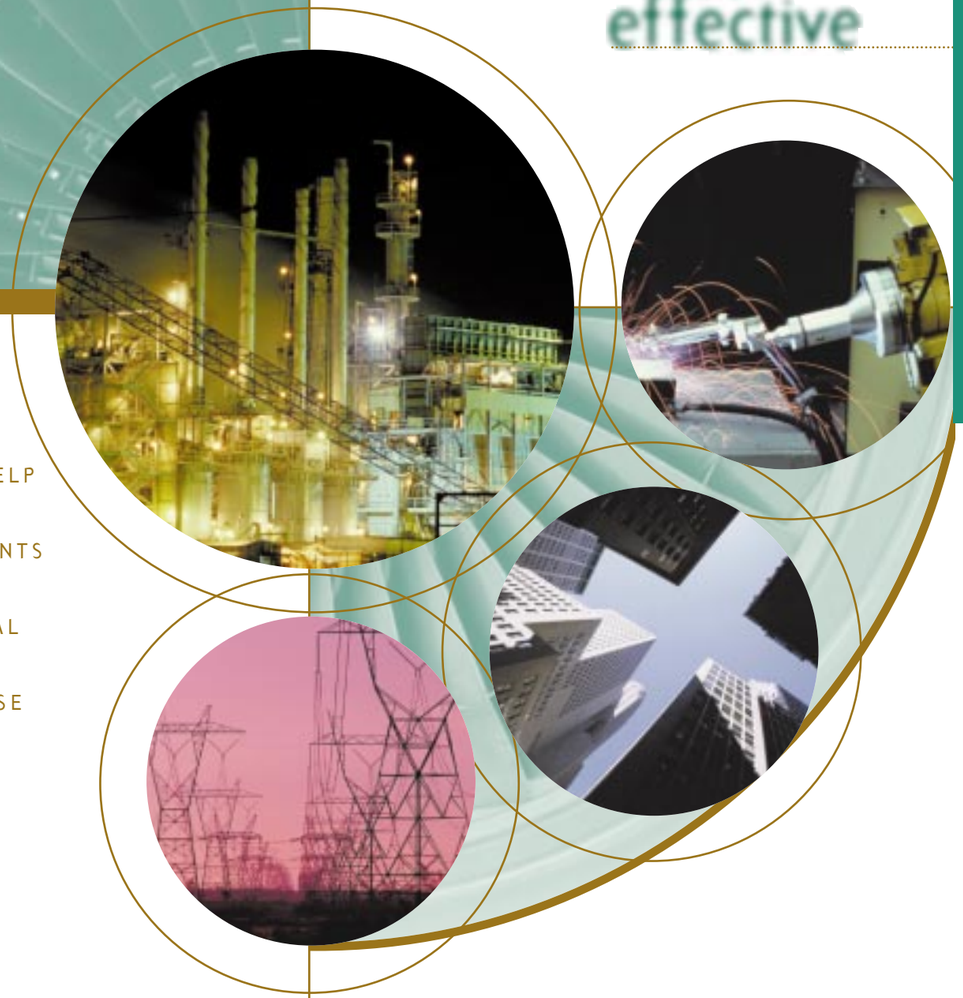
TECHNOLOGIES FOR EXISTING PLANTS

COST-EFFECTIVE SOLUTIONS FOR TODAY'S FLEET

cost-effective



solutions

DOE IS DEVELOPING TECHNOLOGIES TO HELP EXISTING POWERPLANTS MEET ENVIRONMENTAL STANDARDS, INCREASE EFFICIENCY, AND IMPROVE OVERALL PERFORMANCE.

PROGRAM AREAS

Advanced Environmental-Compliance Technologies

- Advanced Control Systems
- Ambient Air Quality Monitoring
- Air Toxics
- Combustion By-Products Utilization

Improved Plant Efficiencies and Performance

- Repowering
- Advanced Computer-Based Controls

INTRODUCTION

ENVIRONMENTAL CONCERNS ARE THE DRIVING FORCE

The environmental drivers influencing the operation of existing coal-fired powerplants over the next decade are being defined today. Key environmental regulations have been proposed or promulgated over the past year establishing a basis for new technology needed to comply with them:

- Revised National Ambient Air Quality Standards (NAAQS) for fine particulate matter and ozone.
- Instructions to revise State Implementation Plans to address ozone concerns in the eastern U.S.
- Petitions by northeastern States for the Environmental Protection Agency (EPA) to require upwind States to reduce emissions of nitrogen oxides (NO_X) from powerplants.
- Requirements for States to address regional haze.
- Proposals to regulate mercury emissions from powerplants.

The cost to comply with these regulations is expected to be several billion dollars per year; the research challenge is to find improved technologies that dramatically reduce these costs and fill technology gaps.

STRATEGIES AND TIMING

It is imperative that needed technologies be developed through cost-shared collaboration between government and industry quickly enough to allow for demonstration and deployment prior to regulatory deadlines. Some of these regulations are already promulgated and their requirements must be met soon. For example, instructions to revise State Implementation Plans to address ozone concerns in the eastern U.S. will lead to State requirements for most eastern U.S. coal-fired powerplants to significantly reduce NO_X emissions (to 0.15 pound per million Btu) by 2003. Utilities are already ordering hardware for compliance. On the other hand, western U.S. powerplants are not subject to these regulations, but may need similar reductions to meet future regional haze or fine particulate matter ($PM_{2.5}$) standards in the 2007 to 2015 time frame. Because most of these regulations on the horizon are not yet finalized, and because the timing of implementation of the regulations has not yet been clearly articulated, judgment must be used in estimating the effectiveness and timing of needed technologies. Objectives being pursued in this program element are:

- Develop and demonstrate extremely low NO_X burner technologies (augmented by advanced computer-based controls) intended to provide the lowest-cost option for use on dry-bottom boilers, by October 2000.
- Further refine high-efficiency NO_X reduction technologies, such as selective catalytic reduction (SCR), to reduce compliance costs for wet-bottom boilers, by October 2000.
- Develop and demonstrate technologies to address mercury emissions by 2004.
- Develop a database in partnership with other public- and private-sector organizations on the sources and receptors of ambient fine particulate matter in support of NAAQS attainment/non-attainment determinations and State implementation strategies.
- Develop and transfer to industry the technology base for the cost-effective and environmentally acceptable utilization of coal-combustion by-products.

BENEFITS TO THE NATION

Environmental and economic security. Advanced technologies for improved plant performance and environmental compliance will yield benefits to human health as well as to the environment, and will result in cheaper, more efficient electric power.

Essential reductions in emissions. Specific benefits to the U.S. by 2010 will include reduction of emissions of SO_2, NO_X, and primary particulate matter from coal-based power systems to levels determined necessary to address human health and environmental concerns. Such concerns include ozone, $PM_{2.5}$, visibility impairment, acidification, and eutrophication.

Energy security. Electric power from indigenous coal resources will continue to be an integral component of the Nation's overall energy mix, thereby ensuring that the U.S. maintains a position of energy independence and security.

Continued value of investments. The existing infrastructure at older fossil-energy powerplants will be maintained using repowering and cofiring technologies.

Lower-cost electricity. Improvements in the efficiency and environmental and operating performance of existing powerplants will result in a lower cost of electricity. In fact, the U.S. could save up to $7 billion per year because of lower-cost environmental-control technologies to meet new standards.

- Develop and transfer to industry operational, performance, and cost information on advanced repowering, cofiring, and advanced computer-based control systems.

ACHIEVEMENTS TO DATE AND IN THE FUTURE

The U.S. electric utility industry has made major strides in reducing emissions of SO_2, NO_X, and particulates since passage of the 1970 Clean Air Act and its subsequent amendments. Emissions of SO_2 have been reduced from 1980 levels of 10.9 million to 5.3 million tons. NO_X emission rates from utility boilers are 40% below 1990 levels, from an average of 0.65 lb/mm Btu to an average of 0.39 lb/mm Btu. Particulate emissions from the utility sector have decreased by nearly one-third since 1988.

DOE-industry partnerships developing technologies needed for existing plants are expected to accomplish these goals:

- Postcombustion NO_X control technology that is capable of meeting NO_X emission standards for ozone mitigation at a cost 25% to 50% less than stand-alone SCR will be available by 2003.
- Postcombustion control technology that is capable of increasing the overall collection efficiency of primary fine particulates to 99.9%, especially for small particles in the 0.1 to 1.0 micron range, will be developed and demonstrated by 2005.
- Technologies that increase the utilization of high-volume coal-combustion by-products (fly ash and scrubber sludge) as well as create high-value uses of solid materials generated from advanced coal combustion systems will be available by 2000. Effective use of the solid by-products from coal combustion will be considered to be a "common business practice."

Coal combustion by-products are proving useful for such applications as the construction of this cattle lot.

TECHNOLOGIES FOR EXISTING PLANTS

- A suite of mercury-control technologies that remove all forms of mercury from coal-combustion flue gas will be developed and demonstrated by 2005.
- Technologies for repowering steam powerplants will be viewed as a preferred way to utilize existing powerplant assets by 2010.

ADVANCED ENVIRONMENTAL-COMPLIANCE TECHNOLOGIES

ADVANCED CONTROL SYSTEMS

The Advanced Environmental Control Systems subprogram focuses on the development of cost-effective environmental control technologies and systems that are able to meet current and future restrictions on the emissions of SO_X, NO_X, and particulate matter (PM) from the electric utility sector. It provides the scientific underpinning necessary to identify control technology needs and research priorities and to foster informed decision making. This part of the Coal and Power Systems Program helps to ensure that our indigenous coal resources are utilized in an environmentally sound manner, so that they can continue to be an integral component of the Nation's overall energy mix.

Areas of focus are:

- Developing postcombustion control technology—such as SCR, SNCR, and advanced reburning—capable of achieving significant NO_X reductions in response to environmental issues such as ozone transport, ambient fine particulates, acid rain, and eutrophication.
- Determining the formation, transport, and chemical composition of ambient fine particulate matter in order to better understand the relationship between anthropogenic emissions of SO_X, NO_X, and PM and ambient air quality.
- Improving the collection efficiency of particulate-control technology, especially fine particles in the submicron-size range, including both retrofits to conventional emissions-control hardware, such as electrostatic precipitators (ESPs), and the development of advanced systems.

Projects in Advanced Environmental Control Systems involve DOE-industry collaborations. Working with American Electric Power, several other utilities, and the Electric Power Research Institute (EPRI), DOE is field-testing an SNCR NO_X-control system on a 640-megawatt (MW) coal-fired unit located at the Cardinal power station in Ohio. This is a first-of-a-kind demonstration of this technology on an electric-utility boiler of this size. Utilities are considering SNCR systems to meet the emission reductions that will be required under the proposed NO_X emission regulations to address summertime ozone.

AMBIENT AIR QUALITY MONITORING

In response to the $PM_{2.5}$ National Ambient Air Quality Standards, DOE is also collaborating with EPA, EPRI, and the utility industry in the operation of several ambient monitoring sites to collect information critical to understanding the impact of coal-based power systems on air quality.

In DOE's Upper Ohio River Valley Project, an air sampler in Greene County, Pennsylvania, verifies that $PM_{2.5}$ standards are met and collects representative samples for detailed information on the chemical composition of fine particulate matter in outdoor air.

In the Upper Ohio River Valley Project, four monitoring sites will be located in the tri-state area around Pittsburgh, Pennsylvania. These sites will offer a comparison of ambient $PM_{2.5}$ in rural and urban settings, providing an understanding of local and regional pollutant transport issues. DOE is also participating in ambient $PM_{2.5}$ monitoring and characterization studies with the Tennessee Valley Authority in Great Smoky Mountain National Park and with Southern Company Services in the Atlanta, Georgia, area.

AIR TOXICS

Air toxics research promotes the development of postcombustion control options for mercury, particularly vapor-phase mercury. The emphasis is on augmenting the effectiveness of existing control technologies to enable capture of all chemical forms of mercury. The control approaches being investigated include sorbent injection upstream of a particulate-control device, such as an ESP or baghouse, enhanced removal across a lime- or limestone-based wet scrubber, and novel, stand-alone technology.

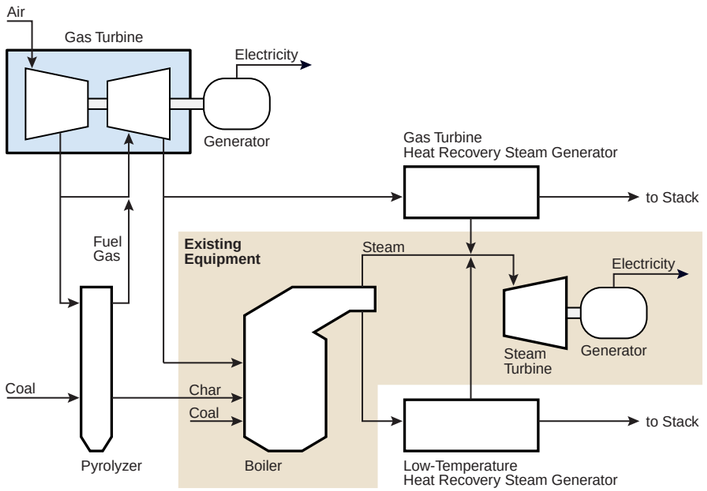
For example, the Advanced Emissions-Control Development Project is focused on evaluating and developing cost-effective strategies for controlling mercury from electric-utility boilers and making maximum use of existing emissions-control systems such as wet scrubbers, ESPs, and fabric filters. Under the Carbon-Based Sorbent Injection for Mercury Control Project, jointly funded by DOE and EPRI, Public Service Company of Colorado is evaluating the mercury-capture effectiveness of various carbon-based sorbents.

COMBUSTION BY-PRODUCTS UTILIZATION

Combustion by-products utilization focuses on developing new technologies and improving existing technologies for environmentally beneficial utilization of coal-combustion by-products from power systems. The emphasis is on by-products whose supply has traditionally far outpaced utilization capacity (flue-gas desulfurization [FGD] sludge and high-carbon fly ash) and the by-products from advanced power systems developed under DOE's Clean Coal Technology Program.

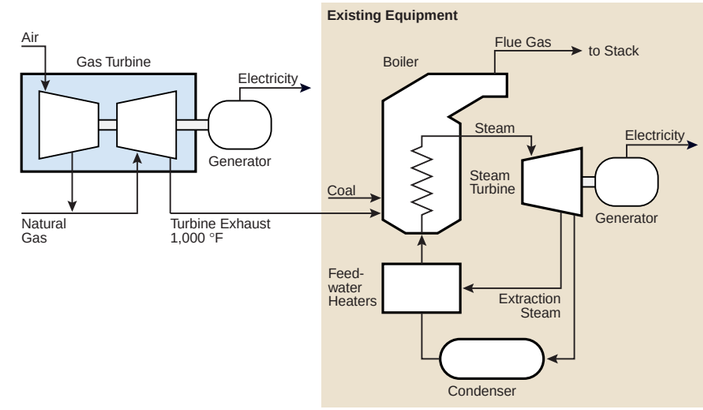
This issue is addressed through outreach activities that include facilitating technology transfer of data from DOE-sponsored coal combustion by-product (CCB) utilization projects to State regulators and CCB users. Field-scale demonstrations are under way that use large volumes of FGD material and fly ash to reduce surface subsidence and acid mine drainage and produce aggregate for transportation and other construction materials. The subprogram also includes product development for fly ash that contains large amounts of carbon.

REPOWERING



Repowering with a high-efficiency clean coal power system leads to an increase in net power capacity and net relative plant efficiency.

HOT WINDBOX REPOWERING



The hot windbox repowering approach, where hot turbine exhaust replaces the air entering the boiler, increases generating capacity up to 25%, and increases efficiency by as much as 15%.

DOE is implementing a CCB consortium managed by West Virginia University to form partnerships with the utility industry, other Federal and State agencies, universities, and special-interest groups to enhance the use of CCBs. The consortium will leverage Federal funds to initiate research projects, from feasibility studies through demonstration field tests, that have the potential to increase the options available to coal producers and users for disposition of CCBs.

IMPROVED PLANT EFFICIENCIES AND PERFORMANCE

Improving the efficiency and performance of the existing fleet of over 300 gigawatts of coal-fired powerplants with new equipment and technology could be one of the most cost-effective means of transforming older, underperforming plants into cleaner, lower-cost producers of electricity.

REPOWERING

The in-place fleet of fossil electric-generating plants continues to wear and age, with many units reaching 40 and 50 years of service. The U.S. power industry is being restructured and deregulated into a competitive market, with electricity being sold as a bulk commodity. Demand is for the lowest cost of electricity. Many existing plants will reach a point where they are worn out, are too inefficient to compete, face significant costs to upgrade emission controls, or must contend with any combination of these factors. Options include extensive refurbishment to extend the life of these units, retirement of aging units, replacing them with new capacity, or repowering them. Repowering uses existing equipment in the plant while integrating new technology, such as gas turbines, to allow the plant to produce more electricity than the original design.

The cost of new generating capacity, combined with the difficulty in obtaining permits and developing new plant sites, makes repowering an attractive option. Repowering existing coal-fired steam-generating units can boost generating capacity, improve efficiency, and reduce CO_2, SO_2, NO_X, and particulate emissions—all at competitive costs. The additional capacity and the typically low production cost of a highly efficient, coal-fired, advanced power system translates into high-capacity factors and a steady revenue stream. By comparison, life extension provides no major improvements in generating capacity or production cost.

One common option is hot windbox repowering. In this approach, hot exhaust from a gas turbine replaces the air entering an existing boiler, eliminating the need for forced-draft fans, increasing generating capacity up to 25%, and increasing efficiency by as much as 15%. Generally suitable for newer units larger than 300 MW, hot windbox repowering can be a low-cost option.

AN ENVIRONMENTAL SUCCESS STORY: LOW-NO_X BURNERS

A quarter of the coal-fired capacity in the U.S. today uses low-NO_X burners developed through DOE investment, significantly reducing emissions of one of the chief pollutants responsible for smog and ozone buildup.

A portfolio of cost-effective NO_X-control technologies suitable for the full range of existing boilers is now available. Three major new low-NO_X burners are now widely marketed, and sales of these will reach $4 billion in the next couple of years. Gas reburning has also been successfully demonstrated on a number of different boilers, reducing NO_X by over 65%. This process breaks down NO_X into environmentally benign gases by using natural gas or finely ground micronized coal to reburn the residues of coal-firing. The Generic NO_X Control Intelligent System is the latest innovation to lead the way to the zero-NO_X plants of the future.

The costs of reducing NO_X emissions by retrofitting powerplants are now up to 90% lower than they would have been without the Federal government's research investment.

Feedwater heating is another low-cost repowering option. In this approach, heat from the exhaust of a gas turbine is used to heat feedwater for the existing boiler. The benefits are a capacity increase of up to 30% and an efficiency improvement of 5% to 10%.

Repowering is made even more attractive because a suite of flexible advanced power system technologies developed through DOE sponsorship are available, allowing an optimum repowering strategy to be developed for site-specific situations. By repowering with clean, efficient power systems, such as a pressurized fluidized-bed combustor, integrated gasification combined cycle, or high-performance power system, net power capacity increases from 20% to 175% and net relative plant efficiency increases of over 30% can be achieved.

ADVANCED COMPUTER-BASED CONTROLS

Improving the way that existing plants are operated is an effective way to improve their environmental performance, reduce cost, and increase efficiency.

Modern control systems have significantly improved the operating performance—in terms of both cost and environmental performance—of coal-fired powerplants. However, the complexity of the optimization problem has limited the benefits achieved by conventional systems. This complexity can be overcome by embedding artificial intelligence or other advanced computer-based approaches in a powerplant's digital control system.

One of these artificial intelligence systems—the Generic NO_X Control Intelligent System (GNOCIS™)—was demonstrated at Georgia Power Company's Plant Hammond Unit 4 (a 550-MW opposed wall-fired unit), where it is fully operational and has achieved an efficiency improvement of 0.5%, a 3% reduction in the unburned carbon content of the unit's fly ash, and a 15% reduction in NO_X emissions at full load. This performance would allow a typical eastern U.S. powerplant rated at 1,000 MW to reduce its coal consumption by up to 25,000 tons per year. GNOCIS™, developed jointly by DOE, EPRI, PowerGen, Radian International, Southern Company, and the U.K. Department of Trade and Industry, is designed to operate on units burning gas, oil, or coal and is available for all combustion firing geometries. To date, 20 coal-fired plants have installed GNOCIS™. Adding these plants to the 15 powerplants that are in preliminary stages of applying this system of advanced computer-based controls suggests that by 2000 there will be 20,000 MW of power-generating capacity garnering the benefits of GNOCIS™.