5. CCT Projects

Introduction

CCT Program demonstrations provide a portfolio of technologies that will enable coal to continue to provide low-cost, secure energy vital to the nation's economy while satisfying energy and environmental goals well into the 21st century. This is being carried out by addressing four basic market sectors: (1) environmental control devices for existing and new power plants, (2) advanced electric power generation for repowering existing facilities and providing new generating capacity, (3) coal processing for clean fuels to convert the nation's vast coal resources to clean fuels, and (4) industrial applications dependent upon coal use.

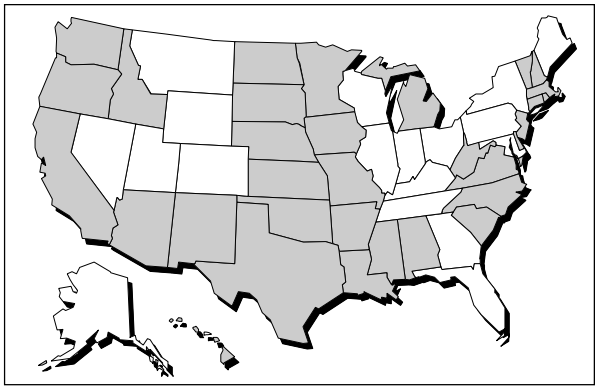
In response to the initial thrust of the CCT Program, operations have been completed for 18 of 19 projects that address SO_2 and NO_x control for coal-fired boilers. The resultant technologies provide a suite of cost-effective control options for the full range of boiler types. The 19 environmental control device projects are valued at more than $702 million. These include seven NO_x emission control systems installed in more than 1,750 MWe of utility generating capacity, five SO_2 emissions systems installed on approximately 770 MWe, and seven combined SO_2/NO_x emission control systems installed or planned on more than 665 MWe of capacity.

To respond to load growth as well as growing environmental concerns, the program provides a range of advanced electric power generation options for both repowering and new power generation. These advanced options offer greater than 20 percent reductions in greenhouse gas emissions; SO_2, NO_x, and particulate emissions far below New Source Performance Standards (NSPS); and salable solid and liquid by-products in lieu of solid wastes. Over 1,800 MWe of capacity are represented by 11 projects valued at more than $2.8 billion. These projects include five fluidized-bed combustion (FBC) systems, four integrated gasification combined-cycle (IGCC) systems, and two advanced combustion/heat engine systems. These projects will provide the demonstrated technology base necessary to meet new capacity requirements in the 21st century.

Also addressed are approaches to converting raw, run-of-mine coals to high-energy-density, low-sulfur products. These products have application domestically for compliance with the Clean Air Act Amendments of 1990 (CAAA). Internationally, both the products and processes have excellent market potential. Valued at more than $519 million, the five projects in the coal processing for clean fuels category represent a diversified portfolio of technologies. Three projects involve the production of high-energy-density solid fuels, one of which also produces a liquid product equivalent to No. 6 fuel oil. A fourth project is demonstrating a new methanol production process. A fifth effort complements the process demonstrations by providing an expert computer software system that enables a utility to assess the environmental, operational, and cost impact of utilizing coals not previously burned at a facility, including upgraded coals and coal blends.

Projects also were undertaken to address pollution problems associated with coal use in the industrial sector. These included dependence of the steel industry on coke and the inherent pollutant emissions in coke making; reliance of the cement industry on low-cost indigenous, and often high-sulfur, coal fuels; and the need for many industrial boiler operators to consider switching to coal fuels to reduce operating costs. The five industrial applications projects have a combined value of nearly $1.3 billion. Projects encompass substitution of coal for 40 percent of coke in iron making, integration of a direct iron making process with the production of electricity, reduction of cement kiln emissions and solid waste generation, and demonstrations of an industrial-scale slagging combustor and a pulse combustor system.

The remainder of this section contains a discussion of the technologies being demonstrated and fact sheets for each project.



▲ The CCT projects are spread across the nation in 18 states, indicated in white.

Technology Overview

Environmental Control Devices

Environmental control devices are those technologies retrofitted to existing facilities or installed on new facilities for the purpose of controlling SO_2 and NO_x emissions. Although boilers may be modified and combustion affected, the basic boiler configuration and function remains unchanged with these technologies.

SO_2 Control Technology. Sulfur dioxide is an acid gas formed during coal combustion, which oxidizes the inorganic, pyritic sulfur (Fe_2S), and organically-bound sulfur in the coal. Identified as a precursor to formation of acid rain, SO_2 was targeted in Title IV of the CAAA. Phase I of Title IV, effective in 1995, affected 261 coal-fired units nationwide. The required SO_2 reduction was moderate and largely met by switching to low-sulfur fuels. In year 2000, Phase II of Title IV comes into effect, impacting all fossil-fuel-fired units, but most of all, the approximately 700 pre-NSPS coal-fired facilities. Under the stricter Phase II requirements, compliance by fuel switching alone is unlikely. The CAAA provides utilities flexibility in control strategies through SO_2 allowance trading. This permits a range of control options to be applied by a utility, as well as allowance purchasing. Recognizing this, the CCT Program has sought to provide a portfolio of SO_2 control technologies.

Sulfur dioxide control devices embody those technologies that condition and act upon the flue gas resulting from combustion, not the combustion itself, for the purpose of removing only SO_2. Three basic approaches evolved, driven primarily by different conditions that exist within the pre-NSPS boiler population impacted by the CAAA. There is a tremendous range in critical factors, *e.g.*, size, type, age, and space availability.

On one end of the spectrum are the smaller, older boilers with limited space for adding equipment. For these, sorbent injection techniques hold promise. Sorbent is injected into the boiler or the ductwork, and humidification is incorporated in some fashion to properly condition the flue gas for efficient SO_2 capture. Equipment size and complexity are held to a minimum to keep capital costs and space requirements low. Both limestone and lime sorbents are used. Limestone costs are about one-third that of hydrated lime; but limestone must be conditioned (calcined), and even then, it is less effective in SO_2 capture (under simple sorbent injection conditions) than hydrated lime. Where limestone is used, it is injected in the boiler to produce calcium oxide, which reacts with SO_2 to form solid compounds of calcium sulfite and calcium sulfate. Both limestone and lime injection require the presence of water (humidification) and a calcium-to-sulfur (Ca/S) molar ratio of about 2.0 for sulfur capture efficiencies of 50 to 70 percent.

In the mid-range of the spectrum are 100- to 300-MWe boilers less than 30 years old and somewhat space constrained. For many of these, an increase in higher equipment cost is justified by enhanced performance. The approach involves introduction of a reactor vessel in the flue gas stream to create conditions to enhance SO_2 capture beyond that achievable with the simpler sorbent injection systems. Lime, as opposed to limestone, is used and sulfur capture efficiencies up to 90 percent can be achieved at Ca/S molar ratios of 1.3 to 2.0. This category of control device is called a spray dryer (because the solid by-product from the reaction is dry).

▲ Unique CT-121 SO_2 scrubber at Plant Yates combined a number of functions and eliminated process steps.

At the other end of the spectrum are the larger (300-MWe and more) boilers with some latitude in space availability, as well as new capacity additions. For these boilers, advanced flue gas desulfurization (AFGD) wet scrubbers, with higher capital cost but higher sulfur capture efficiency than other approaches, become cost effective. These systems apply larger and somewhat more complex reactors that drive up the capital cost. However, the sorbent is limestone, and SO_2 removal efficiencies greater than 90 percent are achieved at a Ca/S molar ratio of about 1.0, making operating costs significantly lower than those of the other two approaches. Furthermore, although the initial AFGD solid by-product is in slurry form, it is dewatered to produce gypsum—a salable product.

Under the CCT Program, two sorbent injection systems, one spray dryer, and two AFGD processes, were successfully demonstrated. All have completed testing. Exhibit 5-1 briefly summarizes the characteristics and performance of the technologies that are described in more detail in the project fact sheets.

NO_x Control Technology. Nitrogen oxides (NO_x) are formed from oxidation of nitrogen contained within

Exhibit 5-1
CCT Program SO_2 Control Technology Characteristics

Project	Process	Coal Sulfur Content	SO_2 Reduction	Fact Sheet
Confined Zone Dispersion Flue Gas Desulfurization Demonstration	Sorbent injection—in-duct lime sorbent injection and humidification	1.5–2.5%	50%	5-24
LIFAC Sorbent Injection Desulfurization Demonstration Project	Sorbent injection—furnace sorbent injection (limestone) with vertical humidification vessel and sorbent recycle	2.0–2.9%	70%	5-28
10-MWe Demonstration of Gas Suspension Absorption	Spray dryer—vertical, single-nozzle reactor with integrated sorbent particulate recycle (lime sorbent)	2.7–3.5%	60–90%	5-20
Advanced Flue Gas Desulfurization Demonstration Project	AFGD—cocurrent flow, integrated quench absorber tower, and reaction tank with combined agitation/oxidation (gypsum by-product)	2.25–4.7%	94%	5-32
Demonstration of Innovative Applications of Technology for the CT-121 FGD Process	AFGD—forced flue gas injection into reaction tank (Jet Bubbling Reactor®) for combined SO_2 and particulate capture (gypsum by-product)	1.2–3%	90+%	5-36

▼ Pictured here, the 10-MWe AirPol gas suspension absorption demonstration unit.

▼ Shown is the water inlet connections to the Pure Air absorber module.

the coal (*i.e.*, "fuel-bound NO_x") and oxidation of the nitrogen in the air at high temperatures of combustion (*i.e.*, "thermal NO_x"). To control fuel-bound NO_x formation, it is important to limit oxygen at the early stages of combustion. To control thermal NO_x, it is important to limit peak temperatures.

Nitrogen oxides were identified both as a precursor to acid rain (targeted under Title IV of the CAAA) and as a contributor to ozone formation (targeted under Title I). Phase I of Title IV, effective in 1995, required 265 wall- and tangentially-fired coal units to reduce emissions to 0.50 and 0.45 lb/10^6 Btu, respectively. In 2000, Phase II of Title IV will come into effect, impacting all fossil-fueled units, but most of all, the balance of the pre-NSPS coal-fired units (see Exhibit 5-2). Ozone nonattainment prompted the EPA to issue a NO_x transport State Implementation Plan (SIP) call for 22 states and the District of Columbia to cut NO_x emissions 85 percent below 1990 rates or achieve a 0.15 lb/10^6 Btu emission rate by May 2003.

The CCT Program has sought to provide a number of NO_x control options to cover the range of boiler types and emission reduction requirements. Control of NO_x emissions can be accomplished by either modifying the combustion process or acting upon the products of combustion (or combinations thereof). Combustion modification technologies include low-NO_x burners (LNBs), advanced overfire air (AOFA), and reburning processes using either natural gas or coal. Post-combustion processes used to act upon flue gas include selective catalytic reduction (SCR) and selective noncatalytic reduction (SNCR).

Exhibit 5-2
Group I and 2 Boiler Statistics and Phase II NO_x Emission Limits

Boiler Types	Number of Boilers	Phase II NO_x Emission Limits (lb/10^6 Btu)
Group 1		
Tangentially-fired	299	0.40
Dry-bottom, wall-fired	308	0.46
Group 2		
Cell burner	36	0.68
Cyclone >155 MWe	55	0.86
Wet-bottom, wall-fired >65 MWe	26	0.84
Vertically fired	28	0.80

Source: Environmental Protection Agency, Nitrogen Oxides Emission Reduction Program, Final Rule for Phase II, Group 1 and Group 2 Boilers (http://www.epa.gov/docs/acidrain/noxfs3.html).

LNBs regulate the initial fuel-air mixture, velocities, and turbulence to create a fuel-rich flame core and control the rate at which additional air required to complete combustion is mixed. This staging of combustion avoids a highly oxidized environment and hot spots conducive to fuel-bound NO_x and thermal NO_x formation. LNBs alone typically can achieve 40 to 50 percent NO_x reduction.

AOFA involves injection of air above the primary combustion zone to allow the primary combustion to occur without the amount of oxygen needed for complete combustion. This oxygen deficiency mitigates fuel-bound NO_x formation. AOFA injected at high velocity creates turbulent mixing to complete the combustion in a gradual fashion at lower temperatures to mitigate thermal NO_x formation. Usually, AOFA is used in combination with LNBs; but alone, AOFA can achieve 10 to 25 percent NO_x emission reductions. The LNB/AOFA systems generally can achieve NO_x emission reductions of 37 to 68 percent, depending upon boiler type.

▲ Shown are The Babcock & Wilcox Company DRB-XCL® burners installed on a down-fired boiler.

Advanced control systems using artificial intelligence are also becoming an integral part of NO_x control systems. These systems can handle the numerous parameters and optimize performance to reduce NO_x while enhancing boiler performance.

In reburning, a percentage of the fuel input to the boiler is diverted to injection ports above the primary combustion zone. Either gas or coal is typically used as the reburning fuel to provide 10 to 30 percent of the heat input to the boiler. The reburning fuel is injected to create a fuel-rich zone deficient in oxygen (a reducing rather than oxidizing zone). NO_x entering this zone is stripped of oxygen, resulting in elemental nitrogen. Combustion is completed in a burnout zone where air is injected by an AOFA system. Reburning has application to all boiler types, including cyclone boilers, and can achieve NO_x emission reductions of 50 to 67 percent.

SCR and SNCR can be used alone or in combination with combustion modification. These processes use ammonia or urea in a reducing reaction with NO_x to form elemental nitrogen and water. SNCR can only be used at high temperatures (1,600 to 2,200 ºF) where a catalyst is not needed. SCR is typically applied at temperatures between 600 to 800 ºF. Generally, SNCR and SCR systems alone can achieve NO_x emission reductions of 30 to 50 percent and 80 to 90+ percent, respectively.

Under the CCT Program, seven NO_x control technologies were assessed encompassing LNBs, AOFA, reburning, SNCR, SCR, and combinations thereof. Six of the seven of the projects have completed operations. One project has been extended.

Exhibit 5-3 briefly summarizes the characteristics and performance of the technologies that are described in more detail in the project fact sheets.

Combined SO_2/NO_x Control Technology. Combined SO_2/NO_x control systems encompass those technologies that combine previously described control methods and those that apply other synergistic techniques. Three of the projects combine either LNBs or gas reburning with sorbent injection. In one of these, SNCR is used with LNBs to enhance performance. Another project combines a number of techniques to improve overall system performance, such as LNBs with SNCR, unique space-saving and durable wet-scrubber design, sorbent additive, and artificial intelligence controls. The balance of the seven projects use synergistic methods not previously described.

SO_x-NO_x-Rox Box™ incorporates an SCR catalyst in a high-temperature filter bag for NO_x control and applies sorbent injection for SO_2 control. The high-temperature filter bag, operated in a standard pulsed-jet baghouse, protects the SCR catalyst, allows operation at optimal NO_x control temperatures, forms a sorbent cake on the surface to enhance SO_2 capture, and provides high-efficiency particulate capture.

Exhibit 5-3
CCT Program NO_x Control Technology Characteristics

Project	Process	Boiler Size/ Type	NO_x Reduction	Fact Sheet
Demonstration of Coal Reburning for Cyclone Boiler NO_x Control	Coal reburning—30% heat input	100-MWe/cyclone	52–62%	5-46
Evaluation of Gas Reburning and Low-NO_x Burners on a Wall-Fired Boiler	LNB/gas reburning/AOFA—13–18% gas heat input	172-MWe/wall	37–65%	5-54
Micronized Coal Reburning Demonstration for NO_x Control	Coal reburning—14% heat input (tangentially-fired) and 17% heat input (cyclone)	148-MWe/tangential 50-MWe/cyclone	28% 59%	5-58
Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit	LNB—separation of coal and air ports on plug-in unit	605-MWe/cell burner	48–58%	5-50
Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler	LNB/AOFA—advanced LNB with separated AOFA and artificial intelligence controls	500-MWe/wall	68%	5-42
180 MWe Demonstration of Advanced Tangentially-Fired Combustion Techniques for the Reduction of NO_x Emissions from Coal-Fired Boilers	LNB/AOFA—advanced LNB with close-coupled and separated overfire air	180-MWe/tangential	37–45%	5-66
Demonstration of Selective Catalytic Reduction Technology for the Control of NO_x Emissions from High-Sulfur, Coal-Fired Boilers	SCR—eight catalysts with different shapes and chemical compositions	8.7-MWe/various	80%	5-62

SNOX™ uses SCR followed by catalytic oxidation of SO_2 to SO_3 with condensation of the SO_3 in the presence of water to produce sulfuric acid. Following the SCR with the catalytic oxidation allows the SCR to operate at optimal ammonia concentration without worry of ammonia slip (ammonia passing to the second catalyst is broken down into water vapor, nitrogen, and a small amount of NO_x). Furthermore, most particulates passing through the upstream baghouse are captured in the sulfuric acid condensing unit. The system produces no solid waste.

NOXSO uses a single, regenerable adsorber (spherical alumina beads impregnated with sodium carbonate) to capture both SO_2 and NO_x. The adsorber is used in a fluidized bed to achieve effective mixing with the flue gas. The adsorber is then processed through a regenerator system to release the NO_x and SO_2 before return to the fluidized bed. The flue gas passes through a baghouse to remove particulates.

Six of the seven combined SO_2/NO_x control technology projects have completed operations and one is on hold. Exhibit 5-4 briefly summarizes the characteristics and performance of the technologies that are described in more detail in the project fact sheets.

▲ The SNOX™ SCR catalyst and the catalytic oxidation system has been retained as a permanent part of the Niles Station.

Exhibit 5-4
CCT Program Combined SO_2/NO_x Control Technology Characteristics

Project	Process	Coal Sulfur Content	SO_2/NO_x Reduction	Fact Sheet
LIMB Demonstration Project Extension and Coolside Demonstration	LNB/sorbent injection—furnace and duct injection, calcium-based sorbents	1.6–3.8%	60–70%/40–50%	5-86
Integrated Dry NO_x/SO_2 Emissions Control System	LNB/SNCR/sorbent injection—calcium- and sodium-based sorbents used in duct injection	0.4%	70%/62–80%	5-94
Enhancing the Use of Coals by Gas Reburning and Sorbent Injection	Gas reburning/sorbent injection—calcium-based sorbents used in duct injection	3.0%	50–60%/67%	5-82
Milliken Clean Coal Technology Demonstration Project	LNB/SNCR/wet scrubber—sorbent additive and space-saving, durable scrubber design	1.5–4.0%	98%/53–58%	5-90
SO_x-NO_x-Rox Box™ Flue Gas Cleanup Demonstration Project	SCR/high temperature baghouse/sorbent injection—SCR in high-temperature filter bag and calcium-based sorbent injection	3.4%	80–90%/90%	5-78
SNOX™ Flue Gas Cleaning Demonstration Project	SCR/oxidation catalyst/sulfuric acid condenser—synergistic catalyst effect and no solid waste	3.4%	95%/94%	5-74
Commercial Demonstration of the NOXSO SO_2/NO_x Removal Flue Gas Cleanup System	Regenerable adsorbent—spherical alumina beads impregnated with sodium carbonate in fluidized-bed adsorber	3.4% (planned)	98% (goal)/75% (goal)	5-72

Advanced Electric Power Generation Technology

Advanced electric power generation technologies enable the efficient and environmentally superior generation of electricity. The advanced electric power generation projects selected under the CCT Program are responsive to capacity expansion needs requisite to meeting long-term demand, off setting nuclear retirements, and meeting stringent CAAA emission limits effective in 2000. These technologies are characterized by high thermal efficiency, very low pollutant emissions, reduced CO_2 emissions, few solid waste problems, and enhanced economics. Advanced electric power generation technologies may be deployed in modules, allowing phased construction to better match demand growth, and to meet the smaller capacity requirements of municipal, rural, and nonutility generators.

There are five generic advanced electric power generation technologies demonstrated in the CCT Program. The characteristics of these five technologies are outlined here, and the specific projects and technologies are presented in more detail in the fact sheets.

Fluidized-Bed Combustion. Fluidized-bed combustion (FBC) reduces emissions of SO_2 and NO_x by controlling combustion parameters and by injecting a sorbent (such as crushed limestone) into the combustion chamber along with the coal. Pulverized coal mixed with the limestone is fluidized on jets of air in the combustion chamber. Sulfur released from the coal as SO_2 is captured by the sorbent in the bed to form a solid calcium compound that is removed with the ash. The resultant waste is a dry, benign solid that can be disposed of easily or used in agricultural and construction applications. More than 90 percent of the SO_2 can be captured this way.

At combustion temperatures of 1,400 to 1,600 ºF, the fluidized mixing of the fuel and sorbent enhances both combustion and sulfur capture. The operating temperature range is about half that of a conventional pulverized-coal boiler and below the temperature at which thermal NO_x is formed. In fact, fluidized-bed NO_x emissions are about 70 to 80 percent lower than those for conventional pulverized-coal boilers. Thus, fluidized-bed combustors substantially reduce both SO_2 and NO_x emissions. Also, fluidized-bed combustion has the capability of using high-ash coal, whereas conventional pulverized-coal units must limit ash content in the coal to relatively low levels.

▲ The 110-MWe Nucla ACFB demonstration enabled Pyropower Corporation (now owned by Foster Wheeler) to save almost 3 years in establishing a commercial line of ACFB units.

Two parallel paths were pursued in fluidized-bed development—bubbling and circulating beds. Bubbling beds use a dense fluid bed and low fluidization velocity to effect good heat transfer and mitigate erosion of an in-bed heat exchanger. Circulating fluidized-beds use a relatively high fluidization velocity that entrains the bed material, in conjunction with hot cyclones to separate and recirculate the bed material from the flue gas before it passes to a heat exchanger. Hybrid systems have also evolved from these two basic approaches.

Fluidized-bed combustion can be either atmospheric (AFBC) or pressurized (PFBC). AFBC operates at atmospheric pressure while PFBC operates at pressure 6 to 16 times higher. PFBC offers higher efficiency by using both a gas turbine and steam turbine. Consequently, operating costs and waste are reduced relative to AFBC, as well as boiler size per unit of power output.

Second-generation PFBC integrates the combustor with a pyrolyzer (coal gasifier) to fuel a gas turbine (topping cycle), the waste heat from which is used to generate steam for a steam turbine (bottoming cycle). The inherent efficiency of the gas turbine and waste heat recovery in this combined-cycle mode significantly increases overall efficiency. Such advanced PFBC systems have the potential for efficiencies over 50 percent.

Of the five fluidized-bed combustion projects, two have successfully completed demonstration (one PFBC and one AFBC), and the other three are in the project definition and design phase.

Integrated Gasification Combined-Cycle. The integrated coal gasification combined-cycle process has four basic steps: (1) fuel gas is generated from coal reacting with high-temperature steam and an oxidant

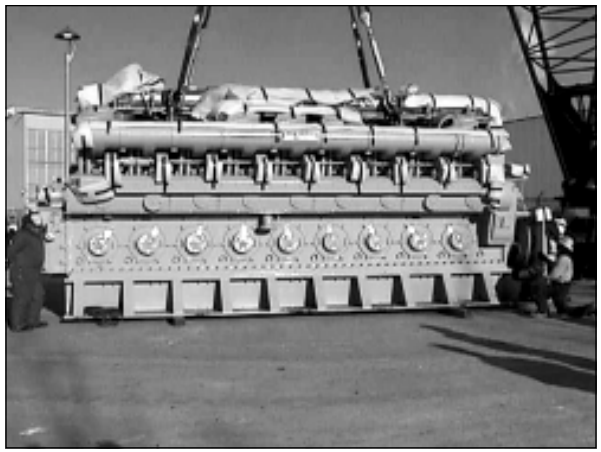
(oxygen or air) in a reducing atmosphere; (2) the fuel gas is either passed directly to a hot-gas cleanup system to remove particulates, sulfur, and nitrogen compounds or first cooled to produce steam and then cleaned conventionally; (3) the clean fuel gas is combusted in a gas turbine generator to produce electricity; and (4) the residual heat in the hot exhaust gas from the gas turbine is recovered in a heat recovery steam generator, and the steam is used to produce additional electricity in a steam turbine generator.

Integrated gasification combined-cycle systems are among the cleanest and most efficient of the emerging clean coal technologies. Sulfur, nitrogen compounds, and particulates are removed before the fuel is burned in the gas turbine, that is, before combustion air is added. For this reason, there is a much lower volume of gas to be treated than in a postcombustion scrubber. The chemical composition of the gas requires that the gas stream must be cleaned to a high degree, not only to achieve low emissions, but to protect downstream components, such as the gas turbine, from erosion and corrosion.

In a coal gasifier, the sulfur in the coal is released in the form of hydrogen sulfide (H_2S) rather than as SO_2. In some IGCC systems, much of the sulfur-containing gas is captured by a sorbent injected into the gasifier. Others use existing proven commercial hydrogen sulfide removal processes, which remove more than 99 percent of the sulfur, but require the fuel to be cooled, which is an efficiency penalty. Therefore, hot-gas cleanup systems are now being demonstrated. In these cleanup systems, the hot coal gas is passed through a bed of metal oxide particles, such as zinc oxides. Zinc oxide can absorb sulfur contaminants at temperatures in excess of 1,000 ºF, and the compound can be regenerated and reused with little loss of effectiveness. Produced during the regeneration stage are salable sulfur, sulfuric acid, or sulfur-containing compounds that may be used to produce useful by-products. The technique is capable of removing more than 99.9 percent of the sulfur in the gas stream. With hot-gas cleanup, IGCC systems have the potential for efficiencies of over 50 percent.

High levels of nitrogen removal are also possible. Some of the coal's nitrogen is converted to ammonia, which can be almost totally removed by commercially available chemical processes. NO_x formed in the gas turbine can be held to well within allowable levels by staged combustion in the gas turbine or by adding moisture to control flame temperature.

Integrated Gasification Fuel Cell. A typical fuel cell system using coal as fuel includes a coal gasifier with a gas cleanup system, a fuel cell to use the coal gas to generate electricity (direct current) and heat, an inverter to convert direct current to alternating current, and a heat-recovery system. The heat-recovery system would be used to produce additional electric power in a bottoming steam cycle.



▲ Shown is the Coltec coal-fired diesel being installed at the University of Alaska.

Energy conversion in fuel cells is more efficient than traditional energy conversion devices (up to 60 percent, depending on fuel and type of fuel cell). Fuel cells directly transform the chemical energy of a fuel and an oxidant (air or oxygen) into electrical energy instead of going through an intermediate step, *i.e.*, burner, boiler, turbines, and generators. Each fuel cell includes an anode and a cathode separated by an electrolyte layer. In a coal gasification/fuel cell application, coal gas is supplied to the anode and air is supplied to the cathode to produce electricity and heat.

Of the four IGCC projects, three are in operation and one is in the project definition and design phase.

Coal-Fired Diesel. Coal-fired diesels use either a coal-oil or coal-water slurry fuel to drive an electric generation system. The hot exhaust from the diesel engine is routed through a heat-recovery unit to produce steam for a steam-turbine electric generating system (combined cycle). Environmental control systems for SO_2, NO_x, and particulate removal treat the cooled exhaust before release to the atmosphere. The diesel system is expected to achieve 41 to 48 percent thermal efficiencies. The 5- to 20-MWe capacity range of the technology is most amenable to distributed power applications. The CCT coal-fired diesel project is in construction.

Slagging Combustor. Many new coal burning technologies are designed to remove the coal ash as molten slag in the combustor rather than the furnace. Most of these slagging combustors are based on a cyclone concept. In a cyclone combustor, coal is burned in a separate chamber outside the furnace cavity. The hot combustion gases then pass into the boiler where the actual heat exchange takes place.

An advantage of a cyclone combustor is that the ash is kept out of the furnace cavity where it could

collect on boiler tubes and lower heat transfer efficiency. To keep ash from being blown into the furnace, the combustion temperature is kept so hot that mineral impurities melt and form slag, hence the name slagging combustor. A vortex of air (the cyclone) forces the slag to the outer walls of the combustor where it can be removed as waste.

Results to date show that by positioning air injection ports so that coal is combusted in stages, NO_x emissions can be reduced by 70 to 80 percent. Injecting limestone into the combustion chamber has the potential to reduce sulfur emissions by 90 percent in combination with a spray dryer absorber. Advanced slagging combustors could replace oil-fired units in both utility and industrial applications or be used to retrofit older, conventional cyclone boilers. The CCT advanced slagging combustor project is in operation.

Exhibit 5-5 summarizes the process characteristics and size of the advanced electric power generating technologies presented in more detail in the project fact sheets.

Exhibit 5-5
CCT Program Advanced Electric Power Generation Technology Characteristics

Project	Process	Size	Fact Sheet
Fluidized-Bed Combustion			
McIntosh Unit 4A PCFB Demonstration Project	Pressurized circulating fluidized-bed combustion	137-MWe (net)	5-100
McIntosh Unit 4B Topped PCFB Demonstration Project	McIntosh 4A with pyrolyzer and topping combustor	240-MWe (net)	5-102
Tidd PFBC Demonstration Project	Pressurized bubbling fluidized-bed combustion	70-MWe	5-106
JEA Large-Scale CFB Combustion Demonstration Project	Atmospheric circulating fluidized-bed combustion	297.5-MWe (gross) 265-MWe (net)	5-104
Nucla CFB Demonstration Project	Atmospheric circulating fluidized-bed combustion	100-MWe	5-110
Integrated Gasification Combined Cycle			
Kentucky Pioneer Energy IGCC Demonstration Project	Oxygen-blown, slagging fixed-bed gasifier with cold gas cleanup, fuel cell slipstream	400-MWe (net) 2.0 MWe MCFC	5-116
Piñon Pine IGCC Power Project	Air-blown, fluidized-bed gasifier with hot gas cleanup	107 MWe (gross) 99-MWe (net)	5-118
Tampa Electric Integrated Gasification Combined-Cycle Project	Oxygen-blown, entrained-flow gasifier with hot and cold gas cleanup and molten carbonate fuel cell (MCFC)	313 MWe (gross) 250-MWe (net)	5-120
Wabash River Coal Gasification Repowering Project	Oxygen-blown, two-stage entrained-flow gasifier with cold gas cleanup	296-MWe (gross); 262-MWe (net)	5-122
Advanced Combustion/Heat Engines			
Healy Clean Coal Project	Advanced slagging combustor, spray dryer with sorbent recycle	50-MWe (nominal)	5-126
Clean Coal Diesel Demonstration Project	Coal-fueled diesel engine	6.4-MWe (net)	5-128

Coal Processing for Clean Fuels Technology

The coal processing category includes a range of technologies designed to produce high-energy-density, low-sulfur solid and clean liquid fuels, as well as systems to assist users in evaluating impacts of coal quality on boiler performance.

In the case of the Custom Coals International project, advanced physical-cleaning techniques are applied to bituminous coal with an already high Btu content to remove the ash, which contains sulfur in the form of pyrite, an inorganic iron compound. A dense-medium cyclone using finely sized magnetite effectively separates 90 percent of the pyritic sulfur. But, because physical methods cannot remove the organically bound sulfur, dense-medium-cyclone processed coals can only be considered compliance coals (meeting CAAA SO_2 requirements) if the organic sulfur content is very low. This processed compliance coal is called Carefree Coal™. For coals with significant organic sulfur content, sorbents and other additives must be added to capture the sulfur released upon combustion and bring the coal into compliance. This second product is called Self-Scrubbing Coal™. The project is on hold.

The Western SynCoal LLC's advanced coal conversion process applies mostly physical-cleaning methods to low-Btu, low-sulfur subbituminous coals, primarily to remove moisture and secondarily to remove ash. The objective is to enhance the energy density of the already low-sulfur coal. Some conversion of the properties of the coal is required, however, to provide stability (prevent spontaneous combustion) in transport and handling. In the process, coal with 5,500 to 9,000 Btu/lb, 25 to 40 percent moisture content, and 0.5 to 1.5 percent sulfur is converted to a 12,000 Btu/lb product with 1.0 percent moisture and as low as 0.3 percent sulfur. The SynCoal® product is used at utility and industrial facilities. Project operation was extended through 2001.

The ENCOAL project, which completed operational testing in July 1997, used mild gasification to convert low-Btu, low-sulfur subbituminous coal to a high-energy-density, low-sulfur solid product and a clean liquid fuel comparable to No. 6 fuel oil. Mild gasification is a pyrolysis process (heating in the absence of oxygen) performed at moderate temperatures and pressures. It produces condensable volatile hydrocarbons in addition to solids and gas. The condensable fraction is drawn off as a liquid product. Most of the gas is used to provide on-site energy requirements. The process solid is significantly beneficiated to produce an 11,000 Btu/lb low-sulfur solid fuel. The demonstration plant processed 500 tons per day of subbituminous coal, and produced 250 tons per day of solid Process-Derived Fuel (PDF®) and 250 barrels per day of Coal-Derived Liquids (CDL®). Both the solid and liquid fuels have undergone test burns at utility and industrial sites. The project was successfully completed.

The liquid phase methanol (LPMEOH™) process being demonstrated is an 80,000 gallon/day indirect liquefaction process using synthesis gas from a coal gasifier. The unique aspect of the process is the use of an inert liquid to suspend the conversion catalyst. This removes the heat of reaction and eliminates the need for an intermediate water-gas shift conversion. Also addressed in the project are the load-following capability of the process by simulating application in an IGCC system, and fuel characteristics of the unrefined product. Since operations began in April 1997, approximately 43 million gallons of methanol have been produced and plant availability has exceeded 97 percent. Plant availability in 1998 and 1999 has exceeded 99.7 percent.

ABB Combustion Engineering, Inc. and CQ Inc. have developed a personal computer software package that will serve as a predictive tool to assist utilities in selecting optimal quality coal for a specific boiler based on operational efficiency, cost, and environmental considerations. Algorithms were developed and verified through comparative testing at bench, pilot, and utility scale. Six large-scale field tests were conducted at five separate utilities. The software has been released for commercial use.

Exhibit 5-6 summarizes the process characteristics and size of the coal processing for clean fuels technologies presented in more detail in the project fact sheets.

Industrial Applications Technology

Technologies applicable to the industrial sector address significant environmental issues and barriers associated with coal use in industrial processes. These technologies are directed at both continued coal use and introduction of coal use in various industrial sectors.

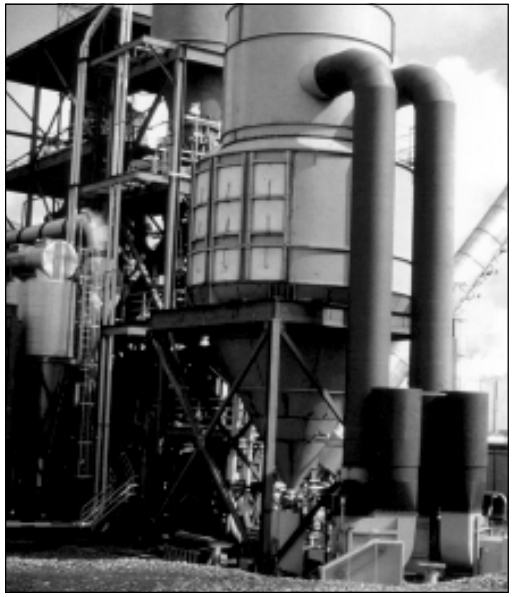
One of the critical environmental concerns has to do with pollutant emissions resulting from producing coke from coal for use in steel making. Two approaches to mitigate or eliminate this problem are being demonstrated. In one, about 40 percent of the coke is displaced through direct injection of granular coal into a blast furnace system. The coal is essentially burned in the blast furnace where the pollutant emissions are readily controlled (as opposed to first coking the coal). The other approach eliminates the need for coke making by using a direct iron-making process. In this

Exhibit 5-6
CCT Program Coal Processing for Clean Fuels Technology Characteristics

Project	Process	Size	Fact Sheet
Development of the Coal Quality Expert™	Coal Quality Expert™ computer software	Tested at 250–880-MWe	5-138
Advanced Coal Conversion Process Demonstration	Advanced coal conversion process for upgrading low-rank coals	45 tons/hr	5-136
ENCOAL® Mild Coal Gasification Project	Liquids-from-coal (LFC®) mild gasification to produce solid and liquid fuels	1,000 tons/day*	5-142
Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process	Liquid phase process for methanol production from coal-derived syngas	80,000 gal/day	5-132
Self-Scrubbing Coal™: An Integrated Approach to Clean Air	Dense-medium cyclones with finely sized magnetic and sorbent addition for bituminous coals	500 tons/hr	5-134

*Operated at 500 tons/day

▼ Western SynCoal Partnership's advanced coal conversion process plant in Colstrip, MT has produced over 1.5 million tons of SynCoal® products.



▼ The ENCOAL mild gasification plant near Gillette, WY has operated 12,800 hours and processed approximately 260,000 tons of raw coal and produced over 120,000 tons of PDF® and 121,000 barrels of CDL®.

▼ The LPMEOH™ process produces over 80,000 gal/day of methanol, all of which is used by the Eastman Chemical Company in Kingsport, TN.

process, raw coal is introduced into a reactor to produce reducing gas and heat for a unique reduction furnace; no coke is required. Excess reducing gas is cleaned and used to fuel a boiler for electric power generation.

Because production costs are largely driven by fuel cost, coal is often the fuel of choice in cement production. Faced with the need to control SO_2 emissions and also to address growing solid waste management problems, industry sponsored the demonstration of an innovative SO_2 scrubber. The successfully demonstrated Passamaquoddy Technology Recovery Scrubber™ uses cement kiln dust, otherwise discarded as waste, to control SO_2 emissions, convert the sulfur and chloride acid gases to fertilizer, return the solid by-product as cement kiln feedstock, and produce distilled water. No new wastes are generated and cement kiln dust waste is converted to feedstock. This technology also has application for controlling pollutant emissions in paper production and waste-to-energy applications.

In many industrial boiler applications, the relatively low, stable price of coal makes it an attractive substitute for oil and gas feedstock. However, drawbacks to conversion of oil- and gas-fired units to coal include addition of SO_2 and NO_x controls, tube fouling, and the need for a coolant water circuit for the combustor. Oil- and gas-fired units are not high SO_2 or NO_x emitters, use relatively tight tube spacing in the absence of potential ash fouling, and the flow of oil or gas cools the combustor, precluding the need for water cooling. For these reasons, the CCT Program demonstrated an advanced air-cooled, slagging combustor that could avoid these potential problems. The cyclone combustor stages introduction of air to control NO_x, injects sorbent to control SO_2, slags the ash in the combustor to prevent tube fouling, and uses air cooling to preclude the need for water circuitry.

The pulse combustor to be demonstrated by ThermoChem has a wide range of applications. The technology can be used in many coal processes, including coal gasification and waste-to-energy applications.

The cement kiln, slagging combustor projects, and granular-coal injection into a blast furnace projects are completed. The CPICOR™ and the ThermoChem projects are in the project definition and design phase, and construction phase, respectively.

Exhibit 5-7 summarizes process characteristics and size for the industrial applications technologies presented in more detail in the project fact sheets.

Project Fact Sheets

The remainder of this document contains fact sheets for all 40 projects. Two types of facts sheets are provided: (1) a brief, two page overview for ongoing projects; and (2) an expanded four page summary for projects that have successfully completed operational testing. The expanded fact sheets for completed projects contain a summary of the major results from the demonstration as well as sources for obtaining further information, specifically, contact persons and key references. Information provided in the fact sheets includes the project participant and team members, project objectives, significant project features, process description, major milestones, progress (if ongoing) or summary of results (if completed), and commercial applications. A key to interpreting the milestone charts is provided in Exhibit 5-8. To prevent the release of project-specific information of a proprietary nature, process flow diagrams contained in the fact sheets are highly simplified, and are presented only as illustrations of the concepts involved in the demonstrations. The portion of the process or facility central to the demonstration is demarcated by the shaded area.

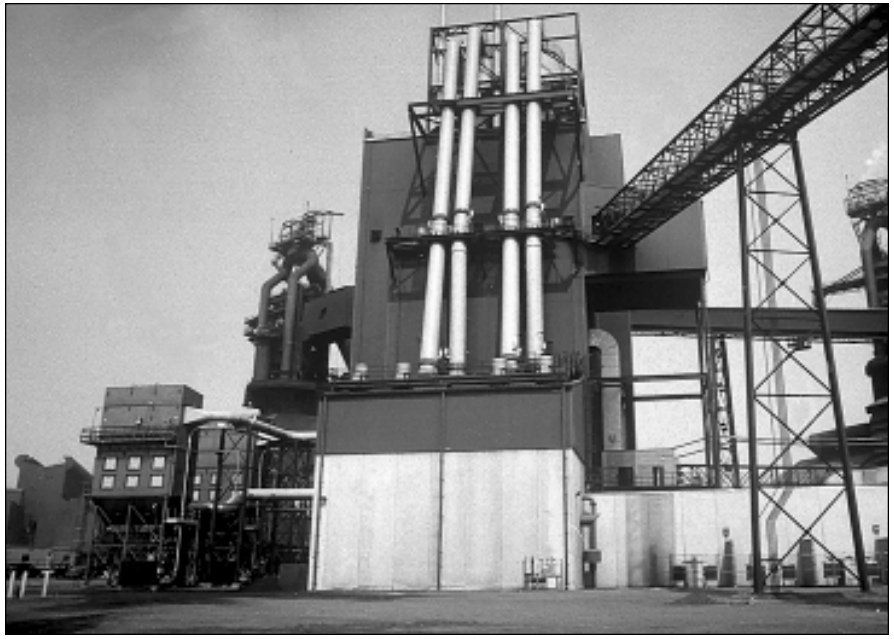
An index to project fact sheets is provided in Exhibit 5-9. Projects are listed by application category. Ongoing projects in each category appear first followed by projects having completed operations. A shaded area distinguishes projects having completed operations from ongoing projects. Within these breakdowns, projects are listed alphabetically by participant. In addition, Exhibit 5-9 indicates the solicitation under which the project was selected; its status as of September 30, 1999; and the page number for each Fact Sheet. Exhibit 5-10 lists the projects alphabetically by participant and provides project, location, and page numbers.

An appendix containing contact information for all of the projects is provided as Appendix D. A list of acronyms used in this document is provided as Appendix E.

Exhibit 5-7
CCT Program Industrial Applications Technology Characteristics

Project	Process	Size	Fact Sheet
Blast Furnace Granular-Coal Injection System Demonstration Project	Blast furnace granular-coal injection for reduction of coke use	7,000 net tons/day of hot metal/furnace	5-152
Advanced Cyclone Combustor with Internal Sulfur, Nitrogen, and Ash Control	Advanced slagging combustor with staged combustion and sorbent injection	23 x 10^6 Btu/hr	5-156
Clean Power from Integrated Coal/Ore Reduction (CPICOR™)	Direct reduction iron-making process to eliminate coke; combined-cycle power generation	170-MWe 3,300 tons/day of hot metal	5-148
Cement Kiln Flue Gas Recovery Scrubber	Cement kiln dust used to capture SO_2; dust converted to feedstock; and fertilizer and distilled water produced	1,450 tons/day of cement	5-160
Pulse Combustor Design Qualification Test	Advanced combustion using Manufacturing and Technology Conversion International's pulse combustor/gasifier	To be determined	5-150

▼ Shown here is the Bethlehem Steel Corporation facility, which demonstrated the injection of granulated coal directly into two blast furnaces at Burns Harbor, IN.



▼ Shown here is the Cement Kiln Flue Gas Recovery Scrubber project's crystallizer and condensor in foreground and flue gas condensor in background.

Exhibit 5-8
Key to Milestone Charts in Fact Sheets

Each fact sheet contains a bar chart that highlights major milestones—past and planned. The bar chart shows a project's duration and indicates the time period for three general categories of project activities—preaward, design and construction, and operation. The key provided below explains what is included in each of these categories.

Preaward

Includes preaward briefings, negotiations, and other activities conducted during the period between DOE's selection of the project and award of the cooperative agreement.

Design and Construction

Includes the NEPA process, permitting, design, procurement, construction, preoperational testing, and other activities conducted prior to the beginning of operation of the demonstration.

MTF Memo-to-file

CX Categorical exclusion

EA Environmental assessment

EIS Environmental impact statement

Operation

Begins with start-up of operation and includes operational testing, data collection, analysis, evaluation, reporting, and other activities to complete the demonstration project.

Exhibit 5-9
Project Fact Sheets by Application Category

Project	Participant	Solicitation/Status	Page
Environmental Control Devices			
SO_2 Control Technologies			
10-MWe Demonstration of Gas Suspension Absorption	AirPol, Inc.	CCT-III/completed 3/94	5-20
Confined Zone Dispersion Flue Gas Desulfurization Demonstration	Bechtel Corporation	CCT-III/completed 6/93	5-24
LIFAC Sorbent Injection Desulfurization Demonstration Project	LIFAC-North America	CCT-III/completed 6/94	5-28
Advanced Flue Gas Desulfurization Demonstration Project	Pure Air on the Lake, L.P.	CCT-II/completed 6/95	5-32
Demonstration of Innovative Applications of Technology for the CT-121 FGD Process	Southern Company Services, Inc.	CCT-II/completed 12/94	5-36
NO_x Control Technologies			
Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler	Southern Company Services, Inc.	CCT-II/extended	5-42
Demonstration of Coal Reburning for Cyclone Boiler NO_x Control	The Babcock & Wilcox Company	CCT-II/completed 12/92	5-46
Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit	The Babcock & Wilcox Company	CCT-III/completed 4/93	5-50
Evaluation of Gas Reburning and Low-NO_x Burners on a Wall-Fired Boiler	Energy and Environmental Research Corporation	CCT-III/completed 1/95	5-54
Micronized Coal Reburning Demonstration for NO_x Control	New York State Electric & Gas Corporation	CCT-IV/completed 9/99	5-58
Demonstration of Selective Catalytic Reduction Technology for the Control of NO_x Emissions from High-Sulfur, Coal-Fired Boilers	Southern Company Services, Inc.	CCT-II/completed 7/95	5-62
180-MWe Demonstration of Advanced Tangentially-Fired Combustion Techniques for the Reduction of NO_x Emissions from Coal-Fired Boilers	Southern Company Services, Inc.	CCT-II/completed 12/92	5-66
Combined SO_2/NO_x Control Technologies			
Commercial Demonstration of the NOXSO SO_2/NO_x Removal Flue Gas Cleanup System	NOXSO Corporation	CCT-III/on hold	5-72
SNOX™ Flue Gas Cleaning Demonstration Project	ABB Environmental Systems	CCT-II/completed 12/94	5-74
SO_x-NO_x-Rox Box™ Flue Gas Cleanup Demonstration Project	The Babcock & Wilcox Company	CCT-II/completed 5/93	5-78
Enhancing the Use of Coals by Gas Reburning and Sorbent Injection	Energy and Environmental Research Corporation	CCT-I/completed 10/94	5-82
LIMB Demonstration Project Extension and Coolside Demonstration	McDermott Technology, Inc.	CCT-I/completed 8/91	5-86
Milliken Clean Coal Technology Demonstration Project	New York State Electric & Gas Corporation	CCT-IV/completed 6/98	5-90
Integrated Dry NO_x/SO_2 Emissions Control System	Public Service Company of Colorado	CCT-III/completed 12/96	5-94
Advanced Electric Power Generation			
Fluidized-Bed Combustion			
McIntosh Unit 4A PCFB Demonstration Project	Lakeland, City of, Lakeland Electric	CCT-III/design	5-100
McIntosh Unit 4B Topped PCFB Demonstration Project	Lakeland, City of, Lakeland Electric	CCT-V/design	5-102
JEA Large-Scale CFB Combustion Demonstration Project	JEA	CCT-I/design	5-104

Shaded area indicates projects having completed operations.

Exhibit 5-9 (continued)
Project Fact Sheets by Application Category

Project	Participant	Solicitation/Status	Page
Tidd PFBC Demonstration Project	The Ohio Power Company	CT-I/completed 3/95	5-106
Nucla CFB Demonstration Project	Tri-State Generation and Transmission Association, Inc.	CCT-I/completed 1/91	5-110
Integrated Gasification Combined-Cycle			
Kentucky Pioneer Energy IGCC Demonstration Project	Kentucky Pioneer Energy, L.L.C.	CCT-V/design	5-116
Piñon Pine IGCC Power Project	Sierra Pacific Power Company	CCT-IV/operational	5-118
Tampa Electric Integrated Gasification Combined-Cycle Project	Tampa Electric Company	CCT-III/operational	5-120
Wabash River Coal Gasification Repowering Project	Wabash River Coal Gasification Repowering Project Joint Venture	CCT-IV/operational	5-122
Advanced Combustion/Heat Engines			
Healy Clean Coal Project	Alaska Industrial Development and Export Authority	CCT-III/operational	5-126
Clean Coal Diesel Demonstration Project	Arthur D. Little, Inc.	CCT-V/construction	5-128
Coal Processing for Clean Fuels			
Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process	Air Products Liquid Phase Conversion Company, L.P	CCT-III/operational	5-132
Self-Scrubbing Coal™: An Integrated Approach to Clean Air	Custom Coals International	CCT-IV/on hold	5-134
Advanced Coal Conversion Process Demonstration	Western SynCoal LLC	CT-I/operational	5-136
Development of the Coal Quality Expert™	ABB Combustion Engineering, Inc. and CQ Inc.	CCT-I/completed 12/95	5-138
ENCOAL® Mild Coal Gasification Project	ENCOAL Corporation	CCT-III/completed 7/97	5-142
Industrial Applications			
Clean Power from Integrated Coal/Ore Reduction (CPICOR™)	CPICOR™ Management Company L.L.C.	CCT-V/design	5-148
Pulse Combustor Design Qualification Test	ThermoChem, Inc.	CCT-IV/design	5-150
Blast Furnace Granular-Coal Injection System Demonstration Project	Bethlehem Steel Corporation	CCT-III/completed 9/99	5-152
Advanced Cyclone Combustor with Internal Sulfur, Nitrogen, and Ash Control	Coal Tech Corporation	CCT-I/completed 5/90	5-156
Cement Kiln Flue Gas Recovery Scrubber	Passamaquoddy Tribe	CCT-II/completed 9/93	5-160

Shaded area indicates projects having completed operations.

Exhibit 5-10
Project Fact Sheets by Participant

Participant	Project	Location	Page
ABB Combustion Engineering, Inc. and CQ Inc.	Development of the Coal Quality Expert™	Homer City, PA	5-138
ABB Environmental Systems	SNOX™ Flue Gas Cleaning Demonstration Project	Niles, OH	5-74
Air Products Liquid Phase Conversion Company, L.P.	Commercial-Scale Demonstration of the Liquid-Phase Methanol (LPMEOH™) Process	Kingsport, TN	5-132
AirPol, Inc.	10-MWe Demonstration of Gas Suspension Absorption	West Paducah, KY	5-20
Alaska Industrial Development and Export Authority	Healy Clean Coal Project	Healy, AK	5-126
Arthur D. Little, Inc.	Clean Coal Diesel Demonstration Project	Fairbanks, AK	5-128
Babcock & Wilcox Company, The	Demonstration of Coal Reburning for Cyclone Boiler NO_x Control	Cassville, WI	5-46
Babcock & Wilcox Company, The	Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit	Aberdeen, OH	5-50
Babcock & Wilcox Company, The	SO_x-NO_x-Rox Box™ Flue Gas Cleanup Demonstration Project	Dilles Bottom, OH	5-78
Bechtel Corporation	Confined Zone Dispersion Flue Gas Desulfurization Demonstration	Seward, PA	5-24
Bethlehem Steel Corporation	Blast Furnace Granular-Coal Injection System Demonstration Project	Burns Harbor, IN	5-152
Coal Tech Corporation	Advanced Cyclone Combustor with Internal Sulfur, Nitrogen, and Ash Control	Williamsport, PA	5-156
CPICOR™ Management Company L.L.C.	Clean Power from Integrated Coal/Ore Reduction (CPICOR™)	Vineyard, UT	5-148
CQ Inc. (see ABB Combustion Engineering and CQ Inc.)			
Custom Coals International	Self-Scrubbing Coal™: An Integrated Approach to Clean Air	Central City, PA	5-134
ENCOAL Corporation	ENCOAL® Mild Coal Gasification Project	Gillette, WY	5-142
Energy and Environmental Research Corporation	Enhancing the Use of Coals by Gas Reburning and Sorbent Injection	Hennepin, IL Springfield, IL	5-82
Energy and Environmental Research Corporation	Evaluation of Gas Reburning and Low-NO_x Burners on a Wall-Fired Boiler	Denver, CO	5-54
JEA	JEA Large-Scale CFB Combustion Demonstration Project	Jacksonville, FL	5-104
Kentucky Pioneer Energy, L.L.C.	Kentucky Pioneer Energy IGCC Demonstration Project	Trapp, KY	5-116
Lakeland, City of, Lakeland Electric	McIntosh Unit 4A PCFB Demonstration Project	Lakeland, FL	5-100
Lakeland, City of, Lakeland Electric	McIntosh Unit 4B Topped PCFB Demonstration Project	Lakeland, FL	5-102
LIFAC-North America	LIFAC Sorbent Injection Desulfurization Demonstration Project	Richmond, IN	5-28
McDermott Technology, Inc.	LIMB Demonstration Project Extension and Coolside Demonstration	Loraine, OH	5-86
New York State Electric & Gas Corporation	Micronized Coal Reburning Demonstration for NO_x Control	Lansing, NY	5-58

Exhibit 5-10 (continued)
Project Fact Sheets by Participant

Participant	Project	Location	Page
New York State Electric & Gas Corporation	Milliken Clean Coal Technology Demonstration Project	Lansing, NY	5-90
NOXSO Corporation	Commercial Demonstration of the NOXSO SO_2/NO_x Removal Flue Gas Cleanup System	On hold	5-72
Ohio Power Company, The	Tidd PFBC Demonstration Project	Brilliant, OH	5-106
Passamaquoddy Tribe	Cement Kiln Flue Gas Recovery Scrubber	Thomaston, ME	5-160
Public Service Company of Colorado	Integrated Dry NO_x/SO_2 Emissions Control System	Denver, CO	5-94
Pure Air on the Lake, L.P.	Advanced Flue Gas Desulfurization Demonstration Project	Chesterton, IN	5-32
Sierra Pacific Power Company	Piñon Pine IGCC Power Project	Reno, NV	5-118
Southern Company Services, Inc.	Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler	Coosa, GA	5-42
Southern Company Services, Inc.	Demonstration of Innovative Applications of Technology for the CT-121 FGD Process	Newnan, GA	5-36
Southern Company Services, Inc.	Demonstration of Selective Catalytic Reduction Technology for the Control of NO_x Emissions from High-Sulfur, Coal-Fired Boilers	Pensacola, FL	5-62
Southern Company Services, Inc.	180-MWe Demonstration of Advanced Tangentially-Fired Combustion Techniques for the Reduction of NO_x Emissions from Coal-Fired Boilers	Lynn Haven, FL	5-66
Tampa Electric Company	Tampa Electric Integrated Gasification Combined-Cycle Project	Mulberry, FL	5-120
ThermoChem, Inc.	Pulse Combustor Design Qualification Test	Baltimore, MD	5-150
Tri-State Generation and Transmission Association, Inc.	Nucla CFB Demonstration Project	Nucla, CO	5-110
Wabash River Coal Gasification Repowering Project Joint Venture	Wabash River Coal Gasification Repowering Project	West Terre Haute, IN	5-122
Western SynCoal LLC	Advanced Coal Conversion Process Demonstration	Colstrip, MT	5-136