# Sales and Benefits of Technology from Clean Coal Demonstration Projects

## Purpose

This report is a summary of sales data and projections that resulted from the Clean Coal Technology Demonstration Program (CCTDP). This report, and the information presented herein, has evolved over a number of years, starting out as a document intended only to allow some method of confirming the value of the CCTDP for those involved in the program. The data have been collected over the years from industry newsletters and journals websites and contacts with technology owners, users and trade associations. Some of the dollar figures are obtained from these contacts as well as from press releases announcing the various contracts that were received by the technology providers. Some were estimated based on the announced plant size and cost information contained in the Participant's final reports. Sales are included only for the demonstration technologies and those that are derived from those technologies. The final reports and other program information can be found at:

http://www.netl.doe.gov/technologies/coalpower/cctc/index.html.

## The Clean Coal Technology Demonstration Program

Congress initially authorized the CCTDP in 1985. The purpose of the program was to develop and demonstrate, at commercial scale, a family of innovative technologies that would meet strict environmental standards and so allow electric power utilities and other industries to cleanly and efficiently use coal as an energy source. The CCTDP was developed as a government/industry partnership, with the share of the United States (U.S.) Department of Energy (DOE) limited to a maximum of 50 percent of the funding for each project.

The first CCTDP projects started in 1987. These projects were selected in the first of five rounds of competition. Over the course of the program, thirty-three projects have been completed while one is still active. The total cost of these five rounds was approximately $3.3 billion with the DOE contributing approximately $1.3 billion. In 2001, a solicitation for a follow-on to the original five rounds was issued. This program was the Power Plant Improvement Initiative (PPII) and it resulted in five projects with four being finished and one still active. The total value of the PPII projects is approximately $71 million with the DOE contributing approximately $32 million.

The program that followed the PPII is the Clean Coal Power Initiative (CCPI). Solicitations issued in 2002 and 2004 resulted in a total of nine projects, all of which are still active. The value of the CCPI projects is approximately $2.7 billion with the DOE contribution set at $530 million. The CCPI as well as the earlier programs are referred to collectively as the CCTDP.

With this boost from the CCTDP assisting private industry in penetrating commercial markets, technologies associated with the program have already yielded sales totaling some $27,244,435,110. Additional sales of these and related or derivative technologies are being actively pursued, with a

pending sales value of $63,422,400,000, indicating that technologies brought to commercial readiness continue to find a robust market.

**The Technologies**

The technologies that were demonstrated under the CCTDP were established in several broad categories:

- Environmental Control Technologies,
- Advanced Power Generation,
- Industrial Technologies, and
- Coal Processing for Clean Fuels.

The paragraphs that follow provide summary information on these technologies.

Environmental Control Technologies

Advanced scrubbers for effective control of sulfur dioxide ($SO_2$) were demonstrated under the CCTDP. These scrubbers featured different state-of-the-art designs with various materials of construction (e.g., resin-lined steel, fiberglass-reinforced plastic, and tile-lined concrete). Advanced scrubber features have been widely adopted by other scrubber vendors and, more importantly, the U.S. electric utility industry. These demonstration projects have driven the scrubber market toward larger and more reliable absorber vessels, salable by-products, increased competition, and better equipment guarantees. These developments resulted in reduced Clean Air Act compliance costs, which benefit both the utilities and their customers.

Industry interest in systems to remove $SO_2$ from power plants has increased. In their online forecast report, *FGD World Markets,* the McIlvaine Company (*www.mcilvainecompany.com*) predicts that power plants will spend $168 billion for flue gas desulfurization (FGD) systems in the period 2005-2020. McIlvaine forecasts that: (1) there will be 2.2 million megawatts (MW) of coal-fired power plants operating in the world in 2020, and (2) two-thirds of these plants will be equipped with FGD. It is also predicted that most systems will utilize wet processes (such as the CT-121 and Pure Air projects), but dry lime processing will continue to maintain its presence in the market.

According to several veteran employees, work on the use of fuel/air staging during combustion processes to reduce nitrogen oxides ($NO_x$) emissions was performed at the National Energy Technology Laboratory (NETL) during the 1960s. The CCTDP continued that involvement by demonstrating a variety of $NO_x$ control technologies at commercial scale, including low-$NO_x$ burners, overfire air, selective non-catalytic reduction, and selective catalytic reduction. Low-$NO_x$ burners and overfire air, LNCFS$^{TM}$, and selective catalytic reduction have been particularly successful in penetrating the utility market. Several major U.S. suppliers have reported combined sales for all types of low-$NO_x$ burners at nearly 239,000 megawatts electric (MWe) of generating capacity. As with $SO_2$ scrubbers, demonstrations under the CCTDP are generally credited by the utility industry with reducing the costs of $NO_x$ compliance technologies — costs that must be borne by industrial, commercial, and residential consumers of electricity.

Advanced Power Generation

Several advanced electric power generation concepts have been demonstrated under the CCTDP. These include atmospheric-circulating and pressurized fluidized-bed combustion. Atmospheric-Circulating Fluidized-Bed Combustion (AFBC) has gained widespread commercial acceptance. While Pressurized Fluidized-Bed Combustion (PFBC) is still working to gain a market foothold, DOE's Tidd PFBC Demonstration Project served to provide valuable operating data and experience for this emerging technology. The Tidd project is one of six CCTDP projects — including Pure Air, CT-121, Wabash River, Tampa Integrated Gasification Combined Cycle (IGCC), and JEA — that won prestigious Power Plant of the Year Award from *Power* magazine. Circulating Fluidized-Bed combustors were successfully demonstrated during the Nucla project and, at a larger scale, during the JEA project. Both units have continued to operate beyond the demonstration period and this technology is being considered for a number of projects now under development. The latest (2005) EIA-767 indicates that six units are being planned for startup in 2009 and that nine have come online since 2000.

The other type of advanced power generation that was demonstrated is Integrated Gasification Combined Cycle (IGCC). Gasification has long been used commercially, primarily to manufacture chemicals. Under the CCTDP, coal gasification technology has been extended to a new application – U.S. electric power production. IGCC technology also has been used in other countries. Two gasifier types have been demonstrated successfully for U.S. IGCC applications – the E-Gas and Texaco gasifiers, at Wabash River, in Indiana, and Tampa, in Florida, respectively. These two commercial facilities provide a solid platform for further IGCC technology advancement. The Wabash River demonstration project is complete and the Tampa IGCC demonstration project completed operations in October 2001. Since the Tampa project was completed, the technology was acquired by General Electric, which, according to its website and ads in the literature, is actively marketing the technology. Both projects continue to operate commercially. Projects using both gasifiers are also in development according to corporate websites and industry newsletters such as McIlvaine. A third demonstration, the air-blown KRW process, by KRW Energy Systems (formerly Kellogg-Rust-Westinghouse), achieved operation of the gasifier for short periods, but was unable to achieve integrated operation of the gasifier and combined cycle. Information on past, current, and planned gasification installations can be found at:

http://www.netl.doe.gov/technologies/coalpower/gasification/database/database.html

Information on all coal-fired generation activities can be found at:

http://www.netl.doe.gov/coal/refshelf/ncp.pdf

Industrial Technologies

Industrial applications for clean coal technology projects address environmental pollution problems associated with the use of coal in the industrial sector. The technologies involve either the continuing use of coal or its introduction into various industrial processes. This category includes such diverse technologies as small-scale combustion systems, replacing metallurgical coke with granular coal in a blast furnace, and an innovative scrubber for cement kiln flue gas.

Coal Processing for Clean Fuels

Several clean fuel technologies were demonstrated under the CCTDP. One such project resulted in the development of software that can assist coal-burning utilities in selecting the optimum quality of coal for a specific boiler based on operational efficiency, cost, and environmental emissions. According to EPRI, the software was issued to twenty-two U.S. organizations and three overseas organizations. Other projects demonstrated technologies designed for upgrading low-quality coal and for converting coal to clean liquids. The technology demonstrated by Western SynCoal has been acquired by another company that is working to commercialize the technology.

**The Benefits**

In addition to maintaining an adequate supply of affordable electricity, the CCTDP has resulted in several types of benefits to industry participants and the general public. These include:

- Technology Sales,
- Employment,
- Improved Health, and
- Cleaner Air.

Technology Sales

The CCTDP has resulted in substantial sales for the private sector participants. Past and pending sales, using the method described earlier, are presented in Table 1. If no reliable sales prices or estimates could be obtained, the value of the sales was not included in the table.

**Table 1 – Sales and Pending Sales as of June 30, 2006**

| Technology Type | Estimated Sales, $ | Pending Sales, $ |
|---|---|---|
| Environmental Technologies | 11,936,955,110 | 56,940,000,000 |
| Advanced Power Generation | 15,306,954,000 | 6,482,400,000 |
| Other Technologies | 526,000 | -- |
| **Total** | 27,244,435,110 | 63,422,400,000 |

Employment

The CCTDP has resulted in creation of many jobs. Temporary jobs were created during the construction phase of the demonstration projects and permanent jobs were created for those projects that continue to operate as commercial facilities. If actual data were not available the number was estimated using a method suggested in a personal communication with a participant. They assume half the plant cost is due to labor and that one man-year equals $200,000. Jobs resulting directly from the projects also resulted in indirectly induced jobs, which the Bureau of Labor Estimate Calculation Factors sets at 1.2 induced jobs for each direct job. In addition, a large number of jobs have been created and will continue to be created as the result of sales of the technologies. The jobs estimates are presented in Table 2.

**Table 2 – Jobs Resulting From the CCTDP**

| Job Source | Direct Jobs | Induced Jobs | Man Years |
|---|---|---|---|
| Project Construction | 1,871 | 2,245 | |
| Continued Operation | 439 | 526 | |
| Technology Sales | | | 66,799 |
| Pending Sales | | | 400,281 |

Improved Health

Monetized health benefits due to improved air quality have been estimated in a number of reports including, "Estimating the Public Health Benefits of Proposed Air Pollution Regulations," by the *Board on Environmental Studies and Toxicology* in 2002. It was estimated that by 2010, compliance with the 1990 Clean Air Act Amendments (CAAA) will account for $107.9 billion in annual medical cost savings. The CCTDP has been instrumental in gaining compliance with many of the 1990 CAAA requirements with regard to $NO_x$, $SO_2$, and ozone. The monetized health benefits from reductions in those pollutants alone will amount to $1.96 billion annually. Applying this figure to the nine-year period from 1995 (Phase I compliance under the CAAA of 1990) to 2004 yields a monetized health benefit of $17.6 billion.

In March 2005, the U.S. Environmental Protection Agency (EPA) announced stringent new limits on air pollution in 28 states that should lead to cleaner air for millions of Americans living in the central and eastern United States. EPA Air Pollution Chief Jeffrey Holmstead was quoted as saying that, "by 2015, the new rule should prevent about 17,000 premature deaths each year," as reported in USA Today on March 11, 2005. Those deaths, mostly from heart and lung disease, are more than the annual number from drownings, fires, and work accidents combined. The reduction in emissions for the CCTDP projects only is substantial as shown in Table 3. These projects proved the feasibility/commercial readiness of a number of environmental control technologies and technology types that would lead to cleaner air, and hence improved health benefits.

Cleaner Air

A report entitled, "Ambient Air Quality Trends: An Analysis of Data Collected by the U.S. Environmental Protection Agency," dated September 1, 2004, by Meszler Engineering Services for the Foundation for Clean Air Progress, presented its finding related to air quality trends resulting from EPA's Clean Air Act of 1970. The study noted that, year after year since the adoption of the Clean Air Act, America's air quality has become dramatically cleaner and healthier. The environmental technologies obviously contribute to cleaner air. In addition, the advanced power generation technologies also contribute, as do the industrial technologies. In some cases the benefits are real, although not obvious. For example, injecting granulated coal into a blast furnace not only saves money, but also avoids the copious emissions associated with metallurgical coke manufacturing. The system continued to operate beyond the demonstration at the Burns Harbor blast furnaces. Some form of coal injection is used in nearly half of U.S. blast furnaces today. The emissions reductions presented in Table 3 for VOCs, particulates, CO, and ammonia are due entirely to the coke displaced at the Burns Harbor Blast furnaces. Estimates of the total emission reductions through 2004 from the CCTDP projects only are presented in Table 3. The numbers include emission reductions for those projects that continue to operate commercially.

**Table 3 – Emission Reductions through 2004 by the CCTDP Projects**

| **Pollutant** | **$SO_2$ *** | **$NO_x$ *** | **VOCs*** | **Particulates** | **CO*** | **Ammonia** |
|---|---|---|---|---|---|---|
| Tons Captured/Avoided | 1,585,814 | 382,700 | 19,234 | 21,384 | 7,581 | 1,810 |

*Key:
$SO_2$: Sulfur Dioxide
$NO_x$: Nitrous Oxides
VOCs: Volatile Organic Compounds
CO: Carbon Monoxide

**Summary**

"***…this program [the CCTDP] serves as an example to other cost-share programs in demonstrating how the government and the private sector can work effectively together to develop and demonstrate new technologies.***" – Jim Wells, Director of Natural Resources and Environment, U.S. General Accounting Office (GAO), Congressional testimony on June 12, 2001. The CCTDP program has successfully met the DOE mission of fostering a secure and reliable energy system that is environmentally and economically sustainable. Sales results and projections show by every measure that the CCTDP has yielded — and continues to yield — clean coal technologies that are capable of meeting existing and emerging environmental regulations while competing in a deregulated electric power marketplace.