

Title:

AN EVALUATION OF COMMERCIALIZATION MECHANISMS FOR THE  
CLEAN COAL TECHNOLOGY PROGRAM

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## I. Executive Summary

The Clean Coal Technology (CCT) Program is an exemplary model of a successful collaboration between industry and government to develop advanced clean coal technologies that will both sustain and expand coal usage for electrical power production and materials manufacturing. Begun in 1985, the program has included five national competitive solicitations over a period of nine years. These solicitations have resulted in forty-five projects covering twenty-one states with a total capital investment of almost \$7 billion.<sup>1</sup> The goal of the program has been to demonstrate the next generation of advanced coal based technologies and to transfer these technologies to individual companies in the domestic and international market place.

This study was commissioned by the CCT Program to evaluate technology transfer mechanisms used in other programs that can be used to stimulate the commercialization of the CCT Program's technologies. Los Alamos National Laboratory (LANL) was selected for this task because of its involvement in the Natural Gas and Oil Technology Partnership, which is sponsored by the DOE Office of Fossil Energy. The mission of the Partnership is to coordinate the development and transfer of technologies developed at DOE national laboratories to the U.S. petroleum industry. The intent of this study is to examine the structure of the Partnership and evaluate the applicability of this structure to the CCT Program.

Examination of the structure of the Partnership revealed many similarities and some significant differences. One difference, for example, is that the Partnership links non-regulated industries, such as the oil industry, with the national laboratories to transfer and commercialize technologies developed by the laboratories. Oil companies are primarily interested in increasing competitiveness by lowering costs and risks. On the other hand, the CCT Program deals primarily with the utilities, a regulated industry which is driven by environmental compliance. Utilities seek to minimize cost and risk. The most appropriate application that can be obtained from the Partnership is the concept of the industry review panels. The focus of the review panels is on technology development and commercialization. These panels, which are made-up of both technology suppliers and their customers, assess technology needs of the industry. One major benefit of the industry review panels is that they are industry driven and the

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<sup>1</sup>"The Clean Coal Technology Program -- Lessons Learned," U.S. Department of Energy, Assistant Secretary for Fossil Energy, Office of Clean Coal Technology, July 1994.

mechanisms for technology selection and commercialization are customer-based.

While this report was commissioned primarily to evaluate the applicability of the Partnership model to the CCT Program, several other mechanisms regarding the commercialization of CCT technologies have been developed. These findings are summarized in the following paragraphs.

Because of the CCT Program's breadth a variety of technologies have been developed. DOE should encourage companies to commercialize component parts or subsets of the technologies they have developed and/or encourage them to seek other applications of their technologies in other industries. This approach would magnify the impact of the CCT Program technologies over a wider range of environmental problems.

Regarding communication, marketing and incentives for technology implementation, DOE should become active to the extent limited by law. DOE should begin a formal information dissemination program among industry, DOE and other applicable organizations. This would enhance the already existing "Executive Seminar Series" and provide a means for analyzing the value of specific technologies. DOE should provide marketing assistance to companies who wish to commercialize their technologies, especially small, entrepreneurial companies. Lastly in this area DOE should work with other government agencies to provide utilities with an incentive to incorporate clean coal technologies.

There are significant opportunities in the international marketplace for the commercialization of clean coal technologies. While many of these opportunities involve the application of retrofit technologies to remedy short term environmental problems, there is considerable interest abroad in advanced coal technologies that will improve efficiency and minimize environmental impact. The opinion of many industry representatives is that proof of government assistance is the single most important element required to establish foreign contracts. Without a good working knowledge of local industry practices, local contacts and the DOE "stamp of approval", it is very difficult for United States' companies to expand into foreign markets. Also, the commercialization of clean coal technologies on an international scale might be more practical if the technologies can be marketed as a total package, including a practical financing package, breakdown of business units and an integrated team that would assist with start-up operations.

## II. Introduction

The Clean Coal Technology Demonstration Program (CCT Program) is a joint effort between the United States Department of Energy (DOE) and industry to develop technologies that can be used to reduce the environmental impacts of coal-based energy production. The Program was funded jointly by both DOE and industry groups and has been a model of government and industry collaboration in technology development. Its goal is to demonstrate a new generation of advanced coal-based technologies and select the most promising technologies for transfer into the domestic and international marketplace. The success of the Program can be attributed to the innovations used by both the public and private sectors to overcome procedural issues, create new management systems and controls and move toward accomplishing shared objectives.<sup>2</sup>

The CCT Program was begun in 1985 and expanded in 1987. It consisted of five nationwide competitive solicitations conducted over a period of 9 years. These solicitations have resulted in 45 projects covering 21 states with a total capital investment of almost \$7 billion.<sup>3</sup> Since its implementation, the Program has progressed rapidly through the project selection, negotiation and implementation phases. Approximately 9 projects have been completed and 36 projects are in various stages of implementation. Now the focus has turned to the issue of technology commercialization. This issue was one of the key congressional initiatives assigned to the CCT Program.

### A. Statement of Problem

After nine years of successful operation, the solicitation phase of the CCT Program is nearing its end, marking the true beginning of the technology commercialization phase of the Program. The success of this phase is dependent upon both the national demand for additional power generating facilities and the ability of the utility industry to tailor the technologies to suit their current operations. Unfortunately, this is untimely for the utility industry, which does not foresee a short-term need for advanced clean coal technologies. Utilities are currently in a state of great flux, as a result of significant restructuring within the industry, the likelihood of upcoming stringent environmental regulations and the prospect of industry deregulation.

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<sup>2</sup> Ibid.

<sup>3</sup> Ibid.

In addition, energy analysts have already determined that a base load increase in coal generation capabilities will not be required until the middle of the next decade. These technologies will, however, be needed in the future, as stricter environmental regulations dictate the use of more efficient technologies; as national reserves of natural gas are exhausted; and as the US attempts to decrease its dependence on foreign oil sources for domestic energy production. Moreover, coal has been predicted as the fuel of choice for electricity generation in the future.<sup>4</sup> As a result, it is likely that there will be a need for advanced clean coal technologies in the next decade. If the industry is deregulated, utilities will need to focus on increasing their competitiveness and decreasing costs and risk. Adapting advanced coal technologies could play a significant role in furthering this goal.

If there is to be an increase in the use of advanced clean coal technologies, they must be proven to have minimum environmental impact and be cost-effective. In addition, the societal cost/benefit of clean coal technologies must be competitive with technically viable alternate technologies. Therefore, to prepare for the expected future demand of coal-fueled electricity generation, it is necessary now to develop a successful mechanism within which to accomplish the goals of commercialization of the CCT Program technologies and their subsequent deployment to the marketplace. LANL has been asked to evaluate one of the potential mechanisms that can be applied to the CCT Program for this purpose. This mechanism is the technology transfer initiative outlined in the Natural Gas and Oil Technology Partnership.

The Technology Partnership is a DOE initiative to identify, develop and introduce new technology concepts for the petroleum industry. This initiative emphasizes the direct transfer of existing and developing technologies from the national laboratories to the domestic petroleum industry. This partnership has been very successful thus far, resulting in numerous collaborative projects between Los Alamos and Sandia National Laboratories and petroleum industry partners. The mechanisms used in the partnership appear to have the potential to become the basis of an effective way to achieve one of the major goals of the CCT Program -- technology transfer and commercialization of the concepts, processes and technologies being developed.

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<sup>4</sup> Personal communication with Jacqueline Bird, Coal Director for the Coal Development Office of the Ohio Department of Development, September 7, 1994.

## B. The Natural Gas and Oil Technology Partnership

The Technology Partnership was begun in the fall of 1988. A Partnership Office was established, consisting of one representative each from Los Alamos and Sandia National Laboratories. An implementation plan was established to create a management structure within the existing DOE Fossil Energy framework and a link with industry through the concepts of a Partnership Steering Committee, an Industry Review Panel and the Crosswell Seismic Forum.<sup>5</sup> The initial emphasis of the project was focused on two areas that were considered high priorities for the industry. Consistent with these priorities, four collaborative research projects were undertaken during FY 1989-90. The nature of the projects typified the production problems that were being encountered by major and independent oil producers at the time. The advanced technologies being developed at the national laboratories were applied to solve these complex problems. Funding for these projects came from both Federal and industry sources. Federal funds were used to support the national laboratories and individual companies financed their own efforts.

In addition to these collaborative projects, there was also a mechanism established for rapid response to industry needs. This allowed the national laboratories to respond quickly to specific industry requests, that were either too small for a full-fledged collaborative effort or had a time constraint. Much of the success of the Program is due to the well-established structure within which industry was empowered to guide the direction of the research projects. For example, the Partnership Steering Committee was an executive level committee, consisting of six to nine industry members and three DOE/national laboratory members. The primary responsibility of this group was the overall review, direction and oversight of the Partnership. This committee provided the Partnership with a high-level support framework under which to develop projects.

The Industry Review Panel is a technical-level committee that provided both an industry perspective and review of Partnership activities to form a cohesive direction for the national laboratories. The panel also ensured that there was a balance between available funding and technical priorities. Lastly, the Crosswell Seismic Forum was established to focus DOE and industry efforts in crosswell seismology, which could contribute

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<sup>5</sup> The Crosswell Seismic Forum was established as a mechanism to focus on technologies that were particularly appealing to industry. The first focus technology was crosswell seismology. Robert J. Hanold and David A. Northrop, "Oil Recovery Technology Partnership -- The First Two Years: Biennial Report for Fiscal Years 1989-1990," Los Alamos National Laboratory and Sandia National Laboratories, #LA-12283-SR Status Report, UC-122, April 1992.



significantly to reservoir characterization and production, and was therefore very important to the industry.

The Partnership has played a key role in stimulating new ideas, technology developments and collaborative activities in the oil industry. The well-established industry based infrastructure has proven to be a very useful mechanism for developing projects that are most valuable to the industry.

### C. Program Comparison

This section outlines several similarities and differences between the Partnership and the CCT Program. The following table, Table 1.

Comparison of Partnership and CCT Program, summarizes the comparison of these two programs. While there are many commonalties between these programs, such as industry/government cost sharing; stakeholder involvement meetings; and mechanisms for idea exchange and joint research, it is the differences between the two programs that are perhaps most insightful. One major difference between the programs

is that the Partnership deals with the transfer of technologies from the national laboratories to industry, whereas the CCT Program involves the transfer of commercially developed technologies to industry for use domestically and internationally. In the case of the Partnership, the technologies developed by the national laboratories are in the public domain, whereas in the case of the CCT Program, the companies who develop the technologies own the intellectual property.

Additionally, the programs are in many ways aimed at two different industrial sectors: in the case of the petroleum partnership the focus is narrowed to the unregulated petroleum industry versus the CCT Program, which includes regulated utilities, Independent Power Producers (IPP's) and other coal based industries. Lower costs and risks are the main driver for the petroleum industry, while the power generation industry is primarily driven by compliance. Compliance as a driver for technological change creates an atmosphere where minimization of cost and risk, along with little near term need for new capacity, become preeminent concerns and deterrents to commercialization. This concept was described in a report by the Clean Coal Technology Coalition.<sup>6</sup> If this idea is correct, it will be difficult to change the posture of the power generating industry, unless one of two things occur. The first is the development of advanced

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<sup>6</sup> "Recommendation Made by the Clean Coal Technology Coalition to the Department of Energy on the Future of the CCT Program", October 6, 1993.

Table 1. Comparison of Partnership and CCT Program.

<b>Oil Recovery Technology Partnership</b>	<b>Clean Coal Technology Program</b>
• Joint industry/government program	• Same as Partnership
• Support of technology development	• Same as Partnership
• Private sector commercialization -- domestic only	• Private sector commercialization -- domestic and international
• Industry working groups used to define industrial direction and definition of need	• Program is driven by the private sector; DOE only evaluates proposal; private sector responsible for project definition
• Industry working groups used to select projects	• Project selection is by the source evaluation board (DOE)
• N/A	• Industrial direction governed through Executive Seminar Series <sup>7</sup>
• Technologies developed at national laboratories	• Technologies developed by individual companies
• Technologies modified for implementation into commercial sector	• N/A (Note: This may become important for commercialization of CCT technologies.)
• Usually, technologies developed by national laboratories are public domain, although CRADA's can be used to protect intellectual property	• Technologies that are developed normally become the intellectual property of the company that developed it
• Industry is unregulated	• A mix of regulated and non-regulated industries
• Projects implemented to increase competitiveness and reduce costs and risks	• Projects implemented mainly for compliance with regulations (utilities)
• Addresses narrow scope of technologies/ projects	• Addresses broad scope of industries/ projects

coal technologies that are both inexpensive and proven; the second is an increased need for new capacity in the near future.

<sup>7</sup> The Executive Seminar Series is a program designed to bring together senior industry managers and senior DOE managers to exchange experiences and ideas.

An important common thread between the two programs is industrial direction. Each technology that is being developed by these two programs meets a need of industry, whether that need is compliance or cost driven. It is critical that industry remain both the driver for, and filter of, new technology development and, ultimately, commercialization.

### III. Information Review

This section contains a review of several reports that have recently been written about the future directions of the CCT Program. Contributions from industry trade groups, such as the Clean Coal Technology Coalition and the National Coal Council, and the Department of Energy are included. In addition, a summary of meeting and interview highlights is incorporated.

#### A. Clean Coal Technology Coalition

The Clean Coal Technology Coalition is an ad hoc organization formed to seek continued research, development, and eventual commercialization of advanced coal technologies. In a report to DOE on the future of the CCT Program, the Coalition discussed several obstacles and supporting reasons that confront the widespread commercialization of technologies from the Program.<sup>8</sup> Among these obstacles, several major issues were identified in this report, as follows:

- High costs to demonstrate previously unproved technologies, coupled with a significant risk.
- A unique and heavily regulated environment into which these technologies must be accepted.
- Initial demonstrations that do not adequately address all operating, maintenance, and performance costs.
- Competition from non-utility generators poised to provide capacity based on mature technology that use natural gas or pulverized coal.
- Limited base-load capacity additions expected in the near-term.

These issues raise some valid concerns about the difficulties associated with demonstrating new technologies. There are significant risks and

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<sup>8</sup> "Recommendation Made by the Clean Coal Technology Coalition to the Department of Energy on the Future of the CCT Program", October 6, 1993.

costs. However, the major success of the Program has thus far been the forty-five demonstration projects that are a direct result of financial support from DOE. Without this support from DOE, most of these companies would not have been able to pilot their technologies. Through the Program, DOE has given many entrepreneurial companies the chance to succeed. When demand for base capacity arrives in the middle of the next decade, these companies and their technologies will be prepared for implementation.

The Coalition report also contained several recommendations that may overcome the obstacles to commercialization outlined above:<sup>9</sup>

- From excess and unobligated CCT Program appropriations, initiate an industry cost-shared "Commercial Demonstration Program" directed at specific clean coal technologies (including retrofit technologies) that have already been demonstrated.
- Demonstrate the economics and operational performances of clean coal technologies by bridging the existing "risk gap" (measured in capital and operating costs) between these technologies and currently-available technologies.
- Require that new concepts for clean coal technologies use federal R&D support from DOE's Fossil Energy budget, rather than from the CCT Program's unobligated funds.
- Implement the Innovative CCT Transfer Program which is authorized by section 1332 of the Energy Policy Act of 1992.

#### B. National Coal Council

The National Coal Council is a private, non-profit advisory group whose primary interests are coal production and advanced coal technologies. The Council published a series of recommendations to DOE on the future direction of the Program and increasing domestic and foreign technology commercialization<sup>10</sup>. These recommendations are summarized as follows:

- DOE should not issue any further solicitations under the existing CCT Demonstration Program.

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<sup>9</sup> Ibid.

<sup>10</sup> "Clean Coal Technology for Sustainable Development", The National Coal Council report to United States Department of Energy, February 1994.

- Clean coal technologies should be recognized broadly as environmental technologies in current and future Administration environmental technology programs, providing opportunities not only for preventing pollution, but also for improving the global environment.
- DOE should foster the establishment of a new federal-level Clean Coal Technology Incentive Program to stimulate initial and sustainable commercial deployment of clean coal technologies.
- DOE's market assessment and communications program should be continued and expanded to include, in addition to electric utilities, representatives of regulatory bodies, non-utility generators, industrial coal users, insurance carriers, investment bankers, equipment suppliers, coal suppliers, and environmental groups.
- DOE, in cooperation with individual utilities and state and local agencies, should evaluate the potential for converting existing but non-compliant plant sites to new sites employing CCT and develop policies to minimize site re-licensing requirements and delays.
- DOE, in conjunction with its industrial participants, should disseminate commercial cost information as it becomes available to facilitate assessment of each technology's total economic viability.
- Where unused CCT Program funds exist, DOE should continue some operating demonstrations to gain more experience which would facilitate commercial deployment.
- DOE should continue to monitor policies which could affect the domestic or international competitive position of technologies developed through the CCT Demonstration Program and assist in developing policies to minimize barriers to commercial deployment.

This environmentally based program is entering its commercialization phase. This shift in program emphasis, will require more emphasis on late stage technology demonstration, an increased communication network which includes a broader segment of industry, incentives to implement technologies, and marketing of the developed technologies both within the US and abroad.

### C. DOE Office of Clean Coal Technology

In a report to Congress concerning the future direction of the Program, the DOE presented an excellent discussion on the state of the Program and what is needed to "Complete the Mission".<sup>11</sup> The following recommendations by the DOE are related to technology commercialization:

- It is not necessary to initiate a sixth round of the CCT Program; the first five rounds have already accomplished the major program goals.
- The new Outreach/Technology Transfer initiative will be immediately implemented.
- On a funds available basis, implement the International Technology Transfer Initiative.
- Within the context of guidance received from program participants and stakeholders, analyze the merits of commercial incentives (e.g., financial, tax, buy down) as a means for transferring clean coal technologies to the domestic and international marketplaces.

Based on the completion of the solicitation phase of the Program, these recommendations reflect preparation for the next phases, such as technology transfer and commercialization. DOE will begin to implement other aspects of the Program.

### B. Interview and Meeting Results

Interviews and/or meetings were conducted with the following organizations: Morgantown Energy Technology Center (METC); Pittsburgh Energy Technology Center (PETC); New York State Electric and Gas Corporation (operating Milliken Station, New York); Southern Company Services, Inc. (operating Plant Crist, Florida); Energy and Environmental Research Corporation (operating Lakeside Station, Illinois); and the DOE Office of Clean Coal Technology. The following observations have been compiled as a result of these discussions.

- Many utilities are not interested in switching to clean coal technologies because there is no regulatory incentive. Reduction of

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<sup>11</sup> Comprehensive Report to Congress, "Clean Coal Technology Program - Completing the Mission", U.S. Department of Energy, Assistant Secretary for Fossil Energy, Office of Clean Coal Technology, July 1994.

environmental impact is not a priority unless there is a regulation that requires it.

- The most significant issues that must be dealt with now are risk, demand for power and high deployment costs.
- Decisions are now being made based on return on investment calculations.
- Many companies have used the CCT Program to develop a strategic environmental plan, by leveraging their own internal funds with DOE funds. This has allowed companies the flexibility to examine a suite of emission control technologies and plan accordingly.
- Small entrepreneurial companies are often faced with marketing problems that they may not be equipped to handle.
- The technology demonstrations are a very effective way to learn more about the limitations of the technology and isolate problems.
- Japan and Europe often have more stringent regulations for NO<sub>x</sub> emissions than in the US. This must be taken into account in locating appropriate foreign markets for technology transfer.
- Buy-in from management and workers is critical.
- Lastly, one should not forget the direct benefit that the DOE Coal Research and Development Program has had on the CCT Program, through initial technology definition and development. Typically, this has occurred at the DOE Energy Technology Centers in Morgantown and Pittsburgh.

Interactions with representatives of host utilities, industry and trade associations has been very positive. The CCT Program has opened the door for many entrepreneurial companies and has shown utilities how they can increase efficiency, reduce emissions and lower costs. In addition, it has provided the financial support necessary for these companies which has allowed them the opportunity to test their technologies.

#### IV. Conclusions

In conclusion, there are several lessons to be learned from the successful technology transfer efforts of the Natural Gas and Oil Technology Partnership. These lessons include:

- Focus on projects that have the highest industry priority.
- Maintenance of a broad focus and selective implementation of projects.
- Frequent and detailed interaction between DOE and industry to guide the project.
- Intellectual property developed within DOE boundaries (national laboratories) in the public domain; occasionally shared with industry through Cooperative Research and Development Agreements (CRADA's).
- Impetus for project prioritization and implementation from industry.
- Industry involvement in the CCT Program initiated by industry.

Because of the differences between the structure of the Partnership and that of the CCT Program, some of the concepts that were used in the Partnership will not be applicable. For instance, it will not be possible to narrow the scope of the CCT Program. The clean coal technologies have been mostly developed by individual companies. However, it is possible to focus on increasing interaction between DOE and industry, ensuring that companies and host utilities both have complete management and worker buy-in and encourage companies to develop projects for the Program of their own initiative.

The CCT Program has the potential to commercialize its technologies successfully. To date, the Program has already performed demonstrations of technologies that will make substantial improvements in the prolonged use of coal for electrical energy production and other materials manufacturing applications. Such improvements will continue to be made as the remaining projects in the Program are completed.

It should also be remembered that the technologies developed under this program are broad in scope and that the individual unit operations that



make up the processes have commercial potential in their own right. Spin-offs of this type offer additional new opportunities for the CCT Program's technologies. Additionally, these technologies provide solutions to other environmental problems outside coal based industries. As such, these versatile technologies can be of value to industries such as the chemical, petroleum and metals industries, which are interested in the reduction of sulfur dioxide and nitrous oxide emissions.

Another important conclusion regarding the success of the CCT Program lies in the structure of the partnership between host utility and industrial partner. This relationship is key to the success of the demonstration. It is critical to have a strong relationship between the utility where the technology is being demonstrated and the organization sponsoring the demonstration (i.e., technology developer, utility or IPP). In addition, companies that are large are at an advantage because they are better able to finance technology demonstration projects than small entrepreneurial companies and, as a result, often have more success. There must be full support and interest in the technology being demonstrated for success to occur. If many technical problems are uncovered during the demonstration, it may be necessary to have strong financial backing to ensure success.

This raises an important point for technology transfer on an international scale. Companies who wish to enter overseas markets must first be financially solvent and large enough to undertake such an endeavor. These companies must also be able to identify local partners and assess the market to develop a potentially successful strategy before attempting to transfer the technology. Companies that do not currently have international ties will be at a serious disadvantage to those companies with existing relationships abroad.<sup>12</sup>

There is a lack of incentive for utilities to invest significant funds and incorporate advanced clean coal technologies into current operations. The state of regulations do not yet require such stringent emission reductions and additional base capacity is not needed at this time. Utilities, IPP's and other power generators will not switch technologies unless there is a significant driver to do so. There must be a need for the product -- additional power or clean air incentives -- first. Niches must be created. Currently, utilities are limited to provide power in specific regions only. An opportunity will be created if these regions are expanded or if the

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<sup>12</sup> Personal Communication with Paul M. Ashline, Air Products - Pure Air, Sept. 7, 1994.

power grid is opened to the market. Otherwise, it will be difficult to provide an incentive to build more facilities.

The perception of the public and political figures will have an impact on the success of the CCT Program and its future. It is important that the Program accomplish its goals for several reasons:

- Protect the environment and ensure the continued use of coal through clean technologies.
- Achieve a high return on the \$7 billion invested so far in the Program.
- Increase the efficiency of our power generation and reduce dependence on foreign fuel sources.
- Assist domestic companies in marketing technologies abroad and thus, help protect the global environment.

Because of this shift in program emphasis, it appears that DOE needs to become more involved with support directly related to commercialization.

## V. Recommendations

The following recommendations were compiled from the assessment of the Technology Partnership and the interviews and meetings conducted by LANL over the past few months. A comparison of the Partnership to the CCT Program is located in Section II-C of this report, "Program Comparison." A summary of the interview and meeting highlights can be found in Section III-D of this report, "Interview and Meeting Results." The conclusions contain a synopsis of the most important points revealed from this research. Each recommendation is focused on a general concept and supported by possible implementation mechanisms.

1. Establish a system of working groups based on specific technologies that will be dynamic and responsive to accommodate the flux within industry.
  - Initiate user groups with carefully selected invitees and initiation fees.
  - Prioritize decisions jointly, with industry, DOE and trade associations.

- Provide a forum for industry to target areas of interest, both domestically and internationally. This effort would complement the ongoing Executive Seminar Series and add a vital link between technology producers and consumers.
- Fund research groups to evaluate market and regulatory trends that might impact future technology commercialization.
- Offer recommendations to DOE for further funding of projects.
- Evaluate and address the needs of the customer more efficiently.

2. Encourage companies to commercialize parts of the technologies they have developed and/or encourage them to seek other applications of their technologies in other industries.

- Promote the development and marketing of spin-off technologies.
- DOE should assist companies in commercializing spin-off technologies and identifying appropriate opportunities of Clean Coal Technologies in other industries. For example, controls and neural networks have previously been used on boilers and can be used in other applications.
- Encourage companies to apply for several patents for individual parts of the technology and commercialize parts of the technology, instead of the whole technology.
- Utilize the full capabilities and range of a technology to include other industries.
- Develop a business mechanism to sell useful by-products, such as fly-ash, gypsum and sulfuric acid.

3. Begin a formal information dissemination program among industry, DOE and other applicable organizations.

- Include trade associations in discussions.
- Develop mechanisms to better evaluate technologies, company needs and the marketplace.
- Begin a newsletter or electronic bulletin board.

- Sponsor more specific conferences, based on technologies.
4. Provide utilities with an incentive to incorporate clean coal technologies.
    - Work with Federal and/or state regulators to define consistent emission requirements.
    - Promote technologies that have already been proven and are relatively low risk.
    - Consider subsidizing utilities, IPP's and other power generators who implement new technologies.
    - Consider developing, in support of EPA, an emissions trading program; a system of NO<sub>x</sub> credits; a series of tax incentives; or a semi-permanent government cost-sharing plan.
  5. Market the CCT Program to foreign investors specifically interested in clean coal technologies.
    - Focus on the stringent requirements of the solicitation phase; advertise this as the DOE "stamp of approval".
    - Encourage companies to develop agreements with foreign countries for multiple facilities, at a reduced, but still profitable, fee.
    - Work as a mediator to bring companies and countries together.
  6. Provide marketing assistance to companies who wish to commercialize their technologies, especially small, entrepreneurial companies.
    - Establish a list of foreign contacts with international marketing experience who would be available to work with individual companies.
    - Set up seminars to teach companies how to develop full-fledged marketing plans and be able to transfer an integrated technology package to other utilities that would include the technology itself, a practical financing package, the appropriate business units and an integrated team that would assist in the initial operations.

- Assist companies in evaluating foreign markets and developing a plan, based on the country's major environmental conditions, size, coal supply, energy needs, finances, history and customs. In fact, financial concerns may play a large role in determining the extent of technology transfer in foreign countries.<sup>13</sup>
- Help expedite the identification of qualified foreign participants for U.S. companies.
- Conduct case studies of technology transfer in specific countries.

These recommendations all point to specific areas where assistance could enable increased commercial acceptance of the CCT Program's technologies. Lastly, thought has been given to the integration and implementation of the specific recommendations and how this might be best enabled. As the Program moves to its commercialization phase, emphasis will shift to final technology demonstration, dissemination of technology evaluations, marketing of the technologies and continued monitoring of evolving environmental regulations.

This study was commissioned to evaluate the Natural Gas and Oil Technology Partnership as a model for aiding in commercialization of the technologies of the CCT Program. It has, however, become apparent during the course of this study that this model is not appropriate and that another mechanism seems far more viable for commercializing the technology. This model uses a nonprofit center as a mechanism for commercialization.<sup>14</sup> Such a model should be fully evaluated and customized to the CCT program. The Center should be thought of as a vehicle for direct commercialization of Clean Coal Technologies as well as a mechanism to spin-off technologies to other industries. The latter would involve evaluation, and if necessary modification, of the technologies to make them attractive to other industrial sectors. It is along these lines the last major recommendation of this study is made.

7. This "Center" concept should be fully developed as a vehicle to assist commercialization of technology developed within the CCT Program.

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<sup>13</sup> Representative of the National Coal Council remarked that the focus of technology interests is changing to that of coal preparation technologies, instead of coal combustion and environmental impact reduction technologies, in response to financial concerns. Personal Communication with James F. McAvoy, National Coal Council, May 23, 1994.

<sup>14</sup>P.G. Apen, B.C. Benicewicz, and J.R. Laia, "A New Model for Public - Private Partnerships", *Technology in Society*, Vol. 16, No. 4, pp. 389-402, 1994.

- Such a center might be called the Center for Clean Coal and Environmental Technologies, and would serve as a technology broker. The Center would market technologies within its current industrial sectors and also assist in spinning off technologies to other industrial sectors, where appropriate.
- The Center could assist in modification of technologies, and/or adaptation of these technologies to other industrial sectors. These technology modifications could be done through coordinated technical agreements with Industry, the Energy Centers (PETC, METC), National Laboratories, and Universities.
- The Center could be administered through the DOE-Fossil Energy - Office of Clean Coal Technology under a cost sharing agreement between DOE and Industry. A board of directors could be envisioned which would be composed of senior members of DOE-FE, Industry, the Energy Centers (PETC, METC), National Laboratories and Universities.
- The Center's mission would be to facilitate communication, assess market opportunities for CCT technologies, monitor and help develop environmental regulations and, ultimately, commercialize the CCT Program technologies.
- Similar centers already exist and routinely match technologies with interested customers.<sup>15</sup>

## VI. Acknowledgments

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<sup>15</sup> The National Center for Manufacturing Sciences is located in Ann Arbor, Michigan. This center works with manufacturing companies and research institutions to bring technology to the market place. This center has both federal and industrial support.