CRTD-80

National Energy Technology Laboratory

Final Report
Carbon Sequestration
Project Review Meeting

Greater Pittsburgh International Airport Hyatt Hotel
September 26-29, 2005

Volume I:
Meeting Summary and Recommendations

José D. Figueroa
NETL Project Manager and Meeting Coordinator

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NETL Project Manager and Meeting Coordinator
412/386-4966

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EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE), under the Carbon Sequestration Program administered by the National Energy Technology Laboratory [NETL] of the Office of Fossil Energy, is seeking a better scientific understanding of the capture and storage of Carbon Dioxide (CO_2). One of the goals of this program is to develop cost-effective and environmentally sound technologies which will reduce greenhouse gas emissions and help to stabilize overall atmospheric concentrations of CO_2.

In compliance with the President's Management Agenda for "Better R&D Investment Criteria" and subsequent requirements from the Office of Management and Budget (OMB), DOE and NETL are fully committed to improving the quality of research projects in their programs. With regard to the Carbon Sequestration Program, DOE and NETL have initiated a series of Project Review meetings with outside experts to assess ongoing research projects and to make recommendations for improvement, if necessary.

In cooperation with the National Research Center for Coal and Energy at West Virginia University, on September 26, 2005, the American Society of Mechanical Engineers [ASME] convened a panel of nine leading government, academic, and industry experts to conduct a two and one-half day review of selected carbon sequestration research projects supported under the NETL program.

A Brief Overview of Carbon Sequestration Research Categories

The Review Panel completed evaluations regarding projects reviewed in the following six carbon sequestration research categories:

- Economics
- Sequestration—Geologic
- Sequestration—Terrestrial
- Capture of CO_2
- Non-Greenhouse Gas Concepts
- Breakthrough Concepts

Overview of Project Reviews

NETL requested that ASME implement a project review panel that would gather expert recommendations on how to improve the performance and research knowledge necessary to fully understand the issues being addressed by the individual projects. These recommendations and/or action items would then be considered by the respective DOE project manager for project incorporation.

Eighteen projects (22%) – out of 83 in the total sequestration project portfolio – were reviewed in a total of 14 presentation sessions during this review process. Selected projects were combined for presentation purposes. Each project team prepared an 11-page summary of work completed to date for review by the ASME Panel prior to the meeting. These summaries were sent to the Review Panel prior to the meeting for comment. This two-step review procedure was implemented for the 2005 reviews. Under this procedure, reviewers were encouraged to respond with questions, which were subsequently forwarded to the respective PIs, to be addressed during their presentations at the review meeting. At the meeting, each research team made a 30-minute presentation (or 45 to 60-minute presentations for larger or joint projects) that was followed by a 10-minute question and answer session with the reviewers. Each reviewer, using a predetermined set of review criteria, evaluated all 18 projects and provided written review comments following the group discussion of each project.

Projects were evaluated against 10 criteria described in the tabular section shown below. Reviewers evaluated the progress of the projects against these criteria under one of the following:

- Project accomplishments do not meet expectations
- Project accomplishments meet expectations
- Project accomplishments exceed expectations

As shown in the table, the Review Panel as a whole considered that the projects reviewed either met or exceeded expectations for each of the evaluation criteria. The Review Panel provided comments on Strengths, Weaknesses, Recommendations, Action Items, and General Comments. NETL uses the Review Panel recommendations in providing feedback and guidance to the principal investigators.

Average Evaluations for All 18 Projects

	Tech Merit	Benefits	Approach	Progress	Other Res	Economics	Utilization	Commercial	AdvEffects	Concerns
Does Not Meet	3.5%	3.5%	1.7%	5.0%	11%	26%	6.2%	7.6%	12%	5.1%
Meets	54%	59%	67%	63%	61%	67%	72%	66%	85%	88%
Exceeds	43%	37%	32%	32%	29%	6.9%	22%	26%	3.4%	6.7%

Tech Merit – Scientific and Technical Merit
Benefits – Anticipated Benefits if Successful
Approach – Technical Approach
Progress – Rate of Progress
Other Res – Knowledge of Related Research
Economics – Economic Analysis
Utilization – Utilization of Government Resources
Commercial – Commercialization Potential
AdvEffects – Possible Adverse Effects Considered
Concerns – Attention to Constituent's Concerns

Increased Visibility of Project Review Process

NETL recognizes the importance of having greater visibility on this annual review process for its sequestration projects and, consequently, has recently launched a

website to provide more information to interested parties. The website can be accessed at:

http://www.netl.doe.gov/coal/Carbon%20Sequestration/index.html

Click on Analysis

Click on Peer Review

Search for 2005 Carbon Sequestration Project Review Volume 1

For More Information

For more information concerning the contents of this report, contact the Project Manager, José D. Figueroa at the National Energy Technology Laboratory (412) 386-4966 or Jose.Figueroa@netl.doe.gov.

A copy of the Carbon Sequestration Technology Roadmap and Program Plan can be accessed at:

http://www.netl.gov/coalpower/sequestration

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Volume I. Meeting Summary and Recommendations

I. Introduction

For the fourth consecutive year, the American Society of Mechanical Engineers (ASME) has been invited to provide an independent, unbiased, and timely review of selected projects within the Carbon Sequestration Program of the U.S. Department of Energy, Office of Fossil Energy. This report contains a summary of the findings from that review.

Compliance with OMB Requirements

The Carbon Sequestration Project Review process has been designed to comply with requirements from the Office of Management and Budget (OMB) concerning the President's Management Agenda, and specifically to address the requirement for "Better R&D Investment Criteria." The U.S. Department of Energy, the Office of Fossil Energy, and the National Energy Technology Laboratory (NETL) are fully committed to improving the quality and results of projects in the Carbon Sequestration Program.

ASME was selected as the independent contractor to review 18 projects in 14 presentation sessions. The projects reviewed were selected by NETL. Principal Investigators (PIs) for each selected project were asked to submit an 11-page written summary of the status of their project, receive questions from reviewers prior to the review meeting, and then to make an oral presentation to a panel of Project Reviewers selected by and convened by ASME. ASME conducted the review meeting including an evaluation of each project against predefined criteria. Results of the review by ASME are summarized and presented to NETL in two volumes. The present volume (Volume I) prepared by ASME provides a general overview of findings from the Project Review and is available to the public. The second volume (Volume II), prepared by ASME, contains evaluations and reviewer comments concerning each project reviewed. Volume II is not distributed publicly due to the nature of this document. A third volume (Volume III), prepared by NETL, summarizes the responses of the Principal Investigators to the "Action Items" proposed by the ASME review panel.

ASME Center for Research and Technology Development (CRTD)

All requests for project reviews are organized by ASME's Center for Research and Technology Development (CRTD) under the following procedure. Director of Research, Dr. Michael Tinkleman, with advice from ASME's Vice President for Research, selects an Executive Committee of senior ASME members that is responsible for reviewing and selecting all Review Panel members and ensuring there are no conflicts of interest within the panel or the review process. In consultation with NETL managers, ASME is responsible for organizing the review meeting agenda, advising the Principal Investigators and their colleagues on how to prepare for the review, facilitating the review session, and preparing a summary of results. A more extensive discussion of the ASME Project Review Methodology used for this project is provided in Appendix A. A copy of the Meeting Agenda is provided in Appendix B and an introduction to the Project Review Panel Members for this project is provided in Appendix C.

Review Criteria and Reviewer Evaluation Sheets

In cooperation with the West Virginia University (WVU) National Research Center for Coal and Energy (NRCCE), the ASME team developed a set of agreed upon evaluation criteria to be applied to the projects under review at this meeting and then prepared an evaluation sheet, based on these criteria, for use by the Review Panel. Written reviewer comments were also collected and the Review Panel spent time in executive sessions assessing the strengths and weaknesses of each project before providing both recommendations and action items to NETL managers. A more detailed explanation of this process and a sample Reviewer Evaluation Sheet are provided in Appendix D.

The following sections of this report summarize findings from the Project Review Meeting and are organized as follows:

II. General Reviewer Comments on the DOE Carbon Sequestration Roadmap
A summary of general comments from reviewers about the overall DOE Carbon Sequestration Technology Roadmap.

III. Summary of Projects Reviewed in 2005
A summary description of the fourteen presentations from the 18 projects reviewed this year.

IV. An Overview of the Evaluation Process Followed in 2005
A brief overview of evaluations along with analysis and recommendations.

V. Process Considerations for Future Project Reviews
A few “lessons learned” in this review that could be applied to future reviews.

II. General Reviewer Comments on the DOE Carbon Sequestration Technology Roadmap

The Review Panel at this meeting focused only on the evaluation of the projects selected by DOE for review. This meeting was not intended to be a review of the entire DOE Carbon Sequestration Program. However, the DOE Carbon Sequestration Technology Roadmap and Program Plan was provided to the reviewers in advance of the meeting and they were given a briefing on the document as both background and context for the specific projects that they were to review. At the conclusion of the meeting, reviewers were asked to reflect on the meeting in general. Following is a summary of reviewer comments about the Sequestration Roadmap. These comments are not intended to go beyond the limited scope of the Project Review. They are provided by the reviewers, in good faith, that they might be useful to DOE managers.

The Roadmap as a Strategic Plan

The challenge of reducing CO_2 emissions and sequestering carbon is a very large problem to be solved over the long term. It is a century-scale problem. Even reducing U.S. CO_2 emissions by one third, at the cost targets proposed, would be a $10-30 billion policy issue. The research being conducted in this Program will drive the policy options that will be considered for decades to come. Within this context, the managers of this Program must support solid scientific research and not cut off that research too quickly, while at the same time looking for the economic drivers and the commercialization potential that will make sequestration practical. The Review Panel gave the Program and its managers high marks for "big picture" thinking and drafting a Roadmap that had a favorable long-term potential for a successful program.

The Roadmap as a "Portfolio" of Projects

The "portfolio" of projects presented at this review meeting and the cross-section of projects reviewed over the past three years covers an impressive range of potential carbon sequestration options and yet is well balanced. The projects presented are consistent with the goals of the Roadmap. Reviewers who have participated in this review over all four years commented that the quality of projects has been steadily increasing and that the group of projects reviewed this year was the best to date. The quality of the presentations has been increasing and the number of flaws upon which to comment has been decreasing.

Projects are being Managed Well against the Roadmap

To be successful, research must be effectively managed to address technical challenges, economic considerations, schedule targets, and commercialization objectives. Managers in this Program have performed well in helping project researchers to learn from mistakes or "blind alleys" while continuing to redirect projects toward Roadmap goals.

The Program Needs to be Publicized Better

The Carbon Sequestration Program in general needs to do a better job of presenting its scope, objectives, and its successes to date in both technical and general media publications. Individual PIs should be encouraged to present more papers and articles.

III. Summary of Projects Reviewed in 2005

The projects that were reviewed by the ASME review panel represent a sample of the total number of projects within each of six Carbon Sequestration Program categories. Twelve months was considered by NETL to be the minimum amount of performance needed before a project would have enough information to evaluate. The evaluation also provided valuable insight on the technology developed and the project methodology for a nearly-completed project so that lessons learned could be available for future or ongoing similar projects.

During the 2005 Project Review – as well as the annual reviews conducted in 2003 and 2004 – NETL selected a number of projects for review that had been reviewed in prior years. Specifically, 55% (10) of the 18 projects in 2005 had been reviewed in one of the three prior years. During both 2003 and 2004, three projects (18%) were selected each year that had been reviewed in a prior year. This approach enables NETL to constantly monitor the research progress made in its sequestration projects and to evaluate how well the Principal Investigators are addressing recommendations/action items proposed by the annual Review Panels for improving those projects.

The projects reviewed in the 2005 Carbon Sequestration Project Review Meeting, within the six different categories, are as follows:

Section I: Economics

E-1: DE-AC21-92MC29094
Development of an Integrated Environmental Control Model, Carbon Sequestration Version (IECM-cs)
Edward S. Rubin—Carnegie Mellon University

Section II: Sequestration—Geologic

G-1: NT42209
Investigation of Integrated Subsurface Processing of Landfill Gas And Carbon Sequestration, Johnson County, Kansas
K. David Newell—Kansas Geological Society

G-2: OST-44-04
Modeling CO_2 Sequestration in Coal Seams
Duane H. Smith—National Energy Technology Laboratory

G-3: FEW34895 and FWP0402-34895
Sequestration of CO_2 in a Depleted Oil Reservoir
Rajesh Pawar—Los Alamos National Laboratory

Section III: Sequestration—Terrestrial

T-1: NT41151
Application and Development of Appropriate Tools and Technologies for Cost Effective Carbon Sequestration
Bill Stanley—The Nature Conservancy

T-2: NT42208
Assessing Fossil and Recent Carbon Pools in Reclaimed Mine Soils
Rattan Lal—Ohio State University

T-3: FWP02FE18
Applied Terrestrial Sequestration and Carbon Management
Michael H. Ebinger—Los Alamos National Laboratory

Section IV: Capture of CO_2

C-1: NT40248 and FWPA24C
Syngas Upgrading—A Low Temperature Approach
Gordon Deppe—Nexant, Inc.

C-2: FWP5A402 and 02FE19AC03
CO_2 Separation Using a Thermally Optimized Membrane
Kathryn A. Berchtold—Los Alamos National Laboratory

C-3: OST-07-04
Solid Sorbents for CO_2 Removal from Pre-Combustion and Post-Combustion Gas Streams
Ranjani Siriwardane—National Energy Technology Laboratory

C-4: OST-O3-04
Ammonia-Based Process for Multi-Component Removal
James T. Yeh—National Energy Technology Laboratory

Section V: Non-Greenhouse Gas Concepts

Non-1: FWP-AE-FY05-19 and FWP-FY-05-08
Geological Sequestration--Enhancement of Natural Seals
William K. O'Connor—Albany Research Center

Section VI: Breakthrough Concepts

BC-1: NT42121

CO_2 Separation with Novel Microporous Metal Organic Frameworks (MOFs)
Robert Bedard—UOP

BC-2: NT42123

CO2 Sequestration in Carbonate Sediments Below the Sea Floor
Daniel P. Schrag—Harvard University

A short summary of each of the above projects is presented in Appendix E. In addition, a compact disk containing electronic files of presentation material used by the Principal Investigators at the review meeting is included in hard-copy versions of this report. The presentation materials and Volume I will be available electronically at the NETL web site:

http://www.netl.doe.gov/coal/Carbon%20Sequestration/index.html

Click on Analysis

Click on Peer Review

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IV. An Overview of Evaluations in 2005

The ASME team, in cooperation with NETL and with input from the Project Review panel, continues to enhance and improve the process used for evaluating the projects selected for the 2005 Project Peer Review Meeting. Please refer to Appendix D for expanded discussion of the Reviewer Evaluation Sheet and an explanation of the review process.

This section presents a brief overview of evaluations from the 2005 Project Review Meeting along with an analysis and recommendations for action. The criteria against which the projects scored well are not discussed since the focus of this section is to highlight the areas that need improvement.

The following table shows, on average, how the composite set of projects reviewed faired against the ten review criteria. Each cell represents the average across all reviewers. For example, in regard to "Technical Merit" the reviewers found that the majority of projects (54%) met expectations. Impressively, 43% of the projects exceeded expectations. And only 3.5% did not meet expectations. In addition, seven of the ten criteria were ranked by the panel with 90% or greater evaluations as having "met or exceeded expectations" for the collective group of projects.

Summary of All Project Evaluations

	Tech Merit	Benefits	Approach	Progress	Other Res	Economics	Utilization	Commercial	AdvEffects	Concerns
Does Not Meet	3.5%	3.5%	1.7%	5.0%	11%	26%	6.2%	7.6%	12%	5.1%
Meets	54%	59%	67%	63%	61%	67%	72%	66%	85%	88%
Exceeds	43%	37%	32%	32%	29%	6.9%	22%	26%	3.4%	6.7%

Tech Merit – Scientific and Technical Merit
Benefits – Anticipated Benefits if Successful
Approach – Technical Approach
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Other Res – Knowledge of Related Research
Economics – Economic Analysis
Utilization – Utilization of Government Resources
Commercial – Commercialization Potential
AdvEffects – Possible Adverse Effects Considered
Concerns – Attention to Constituent's Concerns

Criteria where Projects Need Significant Improvement

There was one review criterion where a significant number of 2005 sequestration projects did not meet expectations:

- #6 Economic Analysis.

In the case of "Economic Analysis" the Review Panel was looking for at least some evidence of a rudimentary economic analysis that the project team had completed to examine possible costs of implementing the technology studied or commercializing the technology, if their project was ultimately successful. The Review Panel wanted to

confirm that even modest consideration had been given to reaching the Carbon Sequestration Technology Roadmap economic targets for future technologies.

Again this year, only a small number of projects provided a compelling economic analysis. In fairness to the project teams, the scope of work for many projects either:

- Did not require an economic analysis, or,
- The analysis was to be performed at the end of the project performance period, or,
- The technical teams did not currently have the expertise to conduct such an analysis.

The presentation by Edward Rubin from CMU:

> E-1: DE-AC21-92MC29094
> Development of an Integrated Environmental Control Model,
> Carbon Sequestration Version (IECM-cs)
> Edward S. Rubin—Carnegie Mellon University

demonstrated that significant work was being done for the program in this regard. Several reviewers felt this contribution was one of the "highlights" of this year's review meeting. The work of Rubin et.al. received good comments concerning its framework and its open documentation. Other principal investigators and NETL program managers are beginning to understand that this analysis tool is now available and are beginning to use it. However, most project investigators still give this criterion only a mention and have yet to present any rigorous analysis or compelling economic conclusions. Developing reasonable economic assessments remains one of the largest challenges for the projects in this program.

Criteria Where Projects Need Modest Improvement

There were three other review criteria where projects also showed need for improvement:

- #9 Possible Adverse Effects Considered
- #5 Knowledge of Related Resources
- #8 Commercialization Potential

In the case of "Possible Adverse Effects Considered," the Review Panel was looking for some indication from the project team that they had carefully reviewed both the materials and systems used in their project against an array of concerns including safety, public health, environmental degradation, or pollution. In some cases, the review panel had specific concerns that were not addressed in the presentation. Reviewers did not require a complete solution in order to give a positive score in this case. Reviewers wanted to see that potential issues of concern had been addressed.

In the case of 'Knowledge of Related Resources," reviewers faulted a few projects for not sufficiently reviewing the available literature in their field. This finding is easily remedied and specific guidance was given to the PIs where necessary.

In the case of "Commercialization Potential," the reviewers were first looking for some indication that the project team had thought about how their concept or technology might eventually be commercialized. If the team did present commercialization concepts or scenarios, they were judged favorably but if there was no analysis or thought concerning the commercial viability of the technology proposed or the evaluation panel considered the technology commercially unviable, then an unfavorable evaluation was given.

V. Process Considerations for Future Project Reviews

Both Review Panel members and the DOE managers involved in the Project Review offered constructive comments about how this review process has worked to date and how it might be modified for the future. Following is a brief summary of ideas recommended for use when planning future project review sessions.

General Process Comments

Reviewers continue to comment that the Project Review meeting is well organized and focused. It is well run so that the time of both presenters and reviewers is respected. Process details have largely been worked out over the previous years and seem to be working well. All reviewers agreed that this was the best of the review meetings to date. The academic members of the panel commented that autumn is the worst time to be away from school in order to attend this review meeting. Some suggested a mid-year timeframe for the next annual review.

Selecting Projects for Review

Reviewers continue to agree that the best time to review a project is after it has had sufficient time to get started but well before its end so that the comments of reviewers can help to improve the project. Unless there are special circumstances, each project should be reviewed only after a year or so of activity and a year or more before its conclusion.

Most reviewers agreed that it is good to see a representation of all program categories at each review session. This year was another good mix. It is hoped that over the course of several years, all projects will have the benefit of this review. Reviewers noted that there were significantly more “in house” NETL projects reviewed this time and they were impressed with the overall quality of the NETL projects.

Pre-Meeting Documentation

The 11-page, pre-meeting project summaries have become a critical part of the review process. The first three standardized pages continue to be well received and were commended by several of the reviewers. For the general reader, the 11-page limit was viewed as being optimal. Reviewers liked the new requirement for a bibliography but asked that it be kept within the prescribed limits.

Pre-Review Questions Back to the PIs

This year, for the first time, under the two-step process, Reviewers were given the opportunity to send questions back to the PIs after having read the 11-page summaries and before attending the Review Meeting. This process appears to have helped PIs focus their presentations and it clearly helped Reviewers understand more about the complex projects quickly. This new two-step process will likely become a part of future reviews.

Both reviewers and PIs commented that it would be helpful if the turn-around time could be extended.

Meeting Agenda

This year, larger projects, with multiple participants or very large scopes of work, were given 15 to 30 minutes extra for presentation and a few additional minutes for questions and answers. Although this time extension reduces the total number of projects that can be reviewed at each Review Meeting, it was judged by both PIs and reviewers to be fairer. The general format of presentation, Q&A, and executive session discussion by the Reviewers after each project is working well and should remain as the standard format for the meeting.

Presentations

The Reviewers were highly complimentary of most presentations this year and judged them as a group to be the best of the four years so far. It is clear that PIs are taking this review process seriously and are making an effort to present their projects well.

One criticism leveled at several projects (and reflected in the evaluations) is that the PI did not really make clear the overall objectives of the research and its position in the Program. It is not enough to simply state where a project sits in the Program organizational chart. It is important to present the logic of where the project is going, how it might hope to meet the commercialization goals of the program or, for smaller projects, at least explain how the project might fit into the context of a larger project or goal.

Also, it would be a great help to reviewers if the presenter could make a stronger effort to use comparable units of measure for CO_2 or carbon sequestration. Perhaps it would be helpful for DOE to provide some guidance in this regard to all projects (as is being done for economic analysis). Without comparable units it is difficult for the Reviewers to quickly get the context for each project.

Project Discussions

The format of discussing each project individually after its presentation was confirmed again this year as the best approach. It would always be preferable to have more time for Q&A but the current time allocations appear to be at least sufficient. It is important to have both the group discussion of each project and individual written comments from Reviewers. Several Reviewers commented that the group discussion did change his or her perceptions of selected projects, sometimes substantially. The written reviewer comments are also very useful in preparing review comments for each project. There is not enough time at the meeting for all Reviewers to discuss all of their written comments.

Appendices

A. ASME Project Review Methodology

B. Meeting Agenda

C. Project Review Panel Members

D. Reviewer Evaluation Sheet

E. Project Summaries

Appendix A
ASME Project Review Methodology

The American Society of Mechanical Engineers (ASME) has been involved in conducting research since 1909 when it started work on steam boiler safety valves. Since then, the Society has expanded its research activities to a broad range of topics of interest to mechanical engineers. ASME draws on the impressive breadth and depth of technical knowledge among its members and, when necessary, experts from other disciplines for participation in ASME related research programs. In 1985, ASME created the Center for Research and Technology Development (CRTD) to coordinate ASME's research programs.

As a result of ASME's technical depth within its membership and its long commitment to supporting research programs, the Society has often been asked to provide independent, unbiased, and timely reviews of technically related research by others, including the Federal government. After long years of experience, the Society has developed a standardized approach to review research projects. The purpose of this section is to give a brief overview of the review procedure established for the DOE/NETL Carbon Sequestration Project Review.

ASME Knowledge and Community (K&C) Sector

One of the five sectors responsible for the activities of ASME's 125,000 members worldwide, the Knowledge and Community Sector is charged with the dissemination of technical information, providing forums for discussions to advance the profession, and managing the Society's research activities.

Center for Research and Technology Development (CRTD)

The mission of the CRTD is to effectively plan and manage the collaborative research activities of ASME to meet the needs of the mechanical engineering profession as defined by the ASME members. The Center is governed by the Board on Research and Technology Development (BRTD). The BRTD has organized over a dozen research committees in specific technical areas. Day-to-day operations of the CRTD are handled by a Director of Research and his staff. The Director of Research serves as staff to the Project Review Executive Committee, handles all logistical support for the Review Panel, provides facilitation of the actual review meeting, and prepares all summary documentation.

Board on Research and Technology Development (BRTD)

The Board on Research and Technology Development (BRTD) governs the activities of the Center for Research and Technology Development (CRTD). ASME members with suitable industrial, academic, or governmental experience in the assessment of priorities for research and development, as well as in the identification of new or unfulfilled needs, are invited to serve on the BRTD, and to function as liaisons between BRTD and the appropriate ASME Sectors, Boards, and Divisions.

CO_2 Project Review Executive Committee

For each set of projects to be reviewed, the BRTD convenes a Project Review Executive Committee to oversee the review process. The Executive Committee is responsible to see that all ASME rules and procedures are followed, to review and approve the qualifications of those asked to sit on the Review Panel, to insure that there are no conflicts of interest in the review process, and to review all documentation coming out of the project review. There must be at least three members of the Project Review Executive Committee. They must have experience relevant to the program being reviewed. Members of the CO_2 Project Review Executive Committee were as follows:

- Dr. Adnan Akay, Chair. Dr. Akay is currently Division Director, Civil and Mechanical Systems at National Science Foundation (NSF). Prior to NSF, Dr. Akay was professor and head of the Mechanical Engineering Department at Carnegie Mellon University (CMU). Dr. Akay was previously Vice-President for Environment and Transportation on the ASME Council on Engineering. Dr. Akay has a broad working knowledge of many aspects of combustion engineering.

- Dr. Allen Robinson. Dr. Robinson is Associate Professor of Mechanical Engineering at Carnegie Mellon University. He brings to the CO_2 Program Review Executive Committee his special focus on combustion-generated air pollution, biomass combustion, and heat and mass transfer in porous media.

- Richard T. Laudenat. Mr. Laudenat is a manager with E.S. Boulos, a wholly-owned subsidiary of Northeast Utilities Enterprises, Inc. He was previously a Vice-President of the ASME Energy Conversion Group and is on the ASME Energy Committee. Mr. Laudenat is well versed on the issue of emissions from electric generating plants.

CO_2 Project Review Panel

The CO_2 Project Review Executive Committee accepted resumes for proposed Review Panel members from the DOE Program staff, from CRTD, and from a limited call to ASME members with relevant experience in this area. From these alternatives, the ASME Project Review Executive Committee oversaw the selection of a nine-member Project Review Panel and agreed that they had the experience necessary to review the broad range of projects under this program. The Review Panel in this case was large because of the need to cover multiple disciplines including: forestry, earth chemistry, geology, mathematical modeling, and clean coal technology.

Meeting Preparation and Logistics

The DOE Project Manager announced the upcoming project review two months ahead of the meeting. Prior to the meeting, each project team to be reviewed was asked to submit an 11-page report summarizing the goals of their project and accomplishments to

date. A standard set of specifications for preparing this document was provided by CRTD. These documents were collected and sent to the Project Review Panel for their background reading prior to the meeting. Based on their review of these project summaries, the reviewers were encouraged to provide questions or issues that needed clarification. These questions were forwarded to the PIs to assist them in preparing for the Review meeting.

Also one month ahead of the meeting, CRTD sent a complete set of instructions to all project teams on the standard format to be used in delivering a 30-minute summary of their project to the Review Panel. All presentations were done in Power Point format.

Project Presentations, Evaluations, and Discussion

At the meeting itself, presenters were held to a 30-minute (or a 45 to 60-minute) time limit so that all projects could be presented fairly within the limits of a 2½-day review meeting. After each presentation, the project team interacted with the Review Panel for 10 minutes of questions and answers.

Following each presentation the Review Panel spent 25 minutes in executive session considering the material that had been presented. To start, each reviewer scored the project against a set of predetermined review evaluation criteria. Ten criteria were used:

- Scientific and Technical Merit
- Anticipated Benefits if Successful
- Technical Approach
- Rate of Progress
- Knowledge of Related Research
- Economic Analysis
- Overall Utilization of Government Resources
- Commercialization Potential
- Consideration of Possible Adverse Effects
- Attention to Constituent Groups Concerns

For each of these categories the reviewers assessed whether the project "Met Expectations," "Exceeded Expectations," or "Did Not Meet Expectations." These categories are further defined in Appendix D.

After determining their individual evaluations, the Review Panel members each provided written comments about the project. Finally, the Panel discussed the project for the purpose of defining: project strengths, project weaknesses, recommendations for other possible activities by the project team, and a list of action items that the team should address as a result of the review.

The agenda for this meeting showing the organization of project presentations by category is provided in Appendix B.

Appendix B
Meeting Agenda

2005 Carbon Sequestration Project Review Schedule

Monday Evening Program—9/26/05

Room:
5:00-5:15 2005 Project Review Meeting Overview
Tinkleman
5:15-6:00 Feedback from 2004 Project Review Meeting [1]
Figueroa
Room:
6:30-7:30 Welcome Reception and Registration All

[Note: There will be a modest registration fee to cover the cost of meals.]

Tuesday Program – 9/27/05

Presenters Ready Room:
(LCD projector available in this room for laptop testing.)

Room:
7:00-8:00 Continental Breakfast
8:00-8:30 DOE/NETL 2005 CO_2 Seq. Overview/Roadmap Plasynski

Section I: Economics

8:30-9:00 **E-1: 29904—Integrated Environmental Control Model-IECM-CS** CMU
9:00-9:15 Evaluation, written comments, and discussion [2]

9:15-9:30 Break

Section II: Sequestration--Geologic

9:35-10:05 **G-1: 42209--Landfill Gas Sequestration in Kansas** Kansas Geo. Soc.
10:05-10:15 Q&A
10:15-10:40 Evaluation, written comments, and discussion

[1] This session from 5 PM to 6 PM on Monday is open only to panel members, selected DOE personnel, and review coordinators.
[2] Only panel members, selected DOE personnel, and review coordinators will be permitted in the meeting room for these sessions. All other visitors and principal investigators will be asked to wait outside the meeting room while the panel engages in confidential discussion regarding each project presented.

10:45-11:15 **G-2: OST44-04--Modeling Coal Bed Methane** NETL
11:15-11:25 Q&A
11:25-11:50 Evaluation, written comments, and discussion

Room:
11:50-12:40 Lunch (Provided for Review Team Only)

Room:
12:40-1:25 **G-3: FEW34895—Sequestration in Depleted Oil Reservoirs** LANL
FWP0402-34895 SNL
1:25-1:35 Q&A
1:35-2:00 Evaluation, written comments, and discussion

Section III: Sequestration--Terrestrial

2:00-2:30 **T-1: 41151--Cost Effective Sequestration** Nature Conservancy
2:30-2:40 Q&A
2:40-3:05 Evaluation, written comments, and discussion

3:05-3:20 Break

3:20-3:50 **T-2:42208--Carbon Pools in Reclaimed Mine Soil** Ohio State
3:50-4:00 Q&A
4:00-4:25 Evaluation, written comments, and discussion

4:30-5:00 **T-3: FWP02FE18—Applied Terrestrial Seq.** LANL
5:00-5:10 Q&A
5:10-5:35 Evaluation, written comments, and discussion

5:35 Adjourn

Room:
6:00 Reception
7:00 Dinner for all participants

Wednesday Program—9/28/05

Room:
7:00-8:00 Continental Breakfast

Section IV: Capture of $C0_2$

8:00-9:00 **C-1: 40248-Hydrate for Shifted SynGas Stream** Nexant
FWPA24C LANL

9:00-9:30	Q&A	
9:30-10:00	Evaluation, written comments, and discussion	
10:00-10:15	Break	
10:15-11:00	**C-2: 5A402-Thermally Optimized Membranes 02FE19AC03**	INEEL LANL
11:00-11:30	Q&A	
11:30-12:00	Evaluation, written comments, and discussion	
Room:		
12:00-1:00	Lunch (Provided for Review Team Only)	
Room:		
1:00-1:30	**C-3: OST0704—Adsorbent Development**	NETL
1:30-1:40	Q&A	
1:40-2:05	Evaluation, written comments, and discussion	
2:10-2:40	**C-4: OST0304—Aqueous-Ammonia Solvent**	NETL
2:40-2:50	Q&A	
2:50-3:15	Evaluation, written comments, and discussion	
3:15-3:30	Break	

Section V: Non-GHG Concepts

3:30-4:15	**Non-1: FWPAEFY0519—Enhance Natural Seals FWPFY0508**	Albany Research Center
4:15-4:35	Q&A	
4:35-5:00	Evaluation, written comments, and discussion	
5:00	Adjourn	
Room:		
6:00-7:00	Reception (Dinner on your own)	

Thursday Program—9/29/05

Room:	
7:00-8:00	Continental Breakfast

Section VI: Breakthrough Concepts

8:00-8:30	**BC-1: 42121—Metal Organic Frameworks (MOF)**	UOP, LLC
8:30-8:40	Q&A	
8:40-9:05	Evaluation, written comments, and discussion	
9:10-9:40	**BC-2: 42123—Neutralizing Carbolic Acid Below the Sea Floor**	Harvard
9:40-9:50	Q&A	
9:50-10:15	Evaluation, written comments, and discussion	
10:15-10:30	Break	

Closing Session with Reviewers and Program Managers [3]

10:30-12:30	Summary Comments from Reviewers (12 min. each)
12:30	Adjourn

[3] This session is open only to the panel members, selected DOE personnel, and review coordinators.

Appendix C
Project Review Panel Members

After reviewing the wide range of scientific and engineering related issues represented by the 18 projects to be reviewed, the CRTD staff and the ASME Project Review Executive Committee in cooperation with the Project Manager from NETL, developed the following list of "Areas of Expertise" that would need to be represented by the Project Review Panel:

- Advanced Biology
- Chemistry (both hydration and carbonates)
- Clean Coal Technology
- Computer Modeling (both chemical and geologic)
- Design Engineering/Systems Analysis
- Environmental Economic Analysis
- International Sequestration Activities
- Mineral Geology
- Petroleum Engineering
- Petroleum Geology
- Plants/Forestry/Soils

It was also important that the Project Review Panel represent the distinctly different perspectives of the academia, industry, government, and non-profit sectors.

In addition to recommendations made by the NETL Project Manager, the CRTD also worked extensively with ASME committees and their chairs to find qualified reviewers. Collected resumes were submitted to the CO_2 Project Review Executive Committee for review. Nine members were selected for the Project Review Panel:

- Dr. John R. Benemann, Consultant
- Dr. John F. Clarke, University of Maryland
- Dr. Jonathan J. Kolak, U.S. Geological Survey
- Dr. Florencia Montagnini, Yale University
- Mr. Bruce Reynolds, Idaho National Laboratory
- Dr. Kenneth R. Richards, Indiana University
- Dr. Reuben Simoyi, Portland State University
- Dr. David Thomas, Consultant
- Dr. Raymond L. Zahradnik, Consultant

A brief summary of their qualifications follows. In addition to reviewing materials sent prior to the meeting, each Review Panel member spent two and a half days together at the review session in Pittsburgh. Evaluation and review comments were collected at that time. Panelists received an honorarium for their time as well as travel expenses.

Review Panelists

John R. Benemann, Ph.D.

- Consultant
- 1993-2000: Assoc. Research Engineer, Dept of Civil Engineering and Plant Microbial Biology, Univ. Calif. Berkeley
- Focus: Biomass Energy; Environmental Biotechnology; Greenhouse Gas Mitigation; and Microalgae
- Located: Walnut Creek, CA

John F. Clarke, D.Sc.

- Deputy Director, Office of National Labs in Science and Technology, Department of Homeland Security (DHS).
- Previously: Joint Global Change Research Institute, University of Maryland, and DOE Associate Director of Energy Research and Executive Director of DOE Climate Activities.
- Focus: application of conditional choice theory to the market competition of energy technologies in macro-economic models
- Located: Washington, DC

Jonathan J. Kolak, Ph.D.

- Associate Coordinator, Energy Resources Program, U. S. Geological Survey.
- Strategic planning and 5-year research planning.
- Focus: a framework for assessing CO_2 storage opportunities in coal-bearing units.
- Located: Reston, VA

Florencia Montagnini, Ph.D.

- Professor and Director, Program in Tropical Forestry, Global Institute of Sustainable Forestry, Yale University
- Focus: Sustainability of managed ecosystems in the tropics and carbon sequestration in above ground biomass and soils in forestry ecosystems.
- Editorial Boards of Forest Ecology and Management and Journal of Sustainable Forestry
- Located: New Haven, CT

Bruce Reynolds

- Department Manager Fossil Energy Technology, Idaho National Laboratory
- Broad background in environmental management, R&D and technology transfer
- Fossil Energy Technology Department has responsibility for all aspects of oil and natural gas exploration and production, coal, hydrogen and methane hydrates.
- Located: Idaho Falls, ID

Kenneth R. Richards, Ph.D.

- Associate Professor, School of Public & Environmental Affairs, Indiana University
- Ph.D, Public Policy and Management & Juris Doctor
- Focus: Public Management Economics, Natural Resources Policy & Management, Climate Change Science & Policy, and Law & Public Policy
- Located: Bloomington, IN

Reuben Simoyi, Ph.D.

- Professor, Department of Chemistry, Portland State University
- American Society of Chemistry, American Physical Society, & Royal Society of Chemistry
- Extensive experience in computer modeling and mathematics related to chemistry
- Located: Portland, OR

David Thomas, Ph.D.

- Consultant
- Previously, 24 years with BP Amoco Corp, including Manager, CO2 Mitigation Technology, Green Operations
- Focus: CO2 mitigation technology and related policy issues
- Located: Naperville, IL

Raymond L. Zahradnik, Ph.D.

- Consultant and Partner in Appalachian-Pacific LLC
- Previously, Professor of Chemical Engineering, Carnegie-Mellon University
- Previously, Director of Coal Conversion and Utilization, Energy Research and Development Administration (ERDA)
- Previously, Director of Energy Research for Occidental Petroleum Corp and President of Occidental Oil Shale, Inc.
- Focus: Clean Coal Technology
- Located: Steamboat Springs, CO

Appendix D
Reviewer Evaluation Sheet

At the Project Review, the panel of reviewers was asked to comment on the projects presented in a number of ways. Following is a brief description about how the project evaluation was done.

Evaluation Criteria

The ASME team, in cooperation with the DOE Project Manager and the National Research Center for Coal and Energy developed a set of 10 evaluation review criteria to be applied to each project. They were defined as follows:

Project Merit:

1: Scientific and Technical Merit

- The underlying project concept is scientifically sound.
- Substantial progress or even a breakthrough is possible.
- A truly innovative approach to long-term CO_2 disposal and storage.

2: Anticipated Benefits if Successful

- A clear statement of potential benefits if research is successful.
- Potential emissions reduction through sequestration is substantial.
- There are possible collateral benefits or by-products.

Approach and Progress:

3: Technical Approach

- Work plan is sound and supports stated goals.
- A thorough understanding of likely technical challenges.
- Effective methods to address likely technical uncertainties.

4: Rate of Progress

- Progress to date against stated goals and schedule is reasonable.
- Continued progress against possible barriers is likely.
- Overall momentum is sufficient to achieve goals and benefits.

5: Knowledge of Related Research

- Familiar with relevant literature in the field.
- Up to date with reference citations.
- In communication with other experts in this field and no duplication.

6: Economic Analysis

- At least “ballpark” estimates made of costs to implement.
- Cost estimates are sensible given uncertainties.
- There is hope of meeting DOE ultimate sequestration cost goals.

7: Overall Utilization of Government Resources

- Research team is adequate to address project goals.
- Good rationale for teaming or collaborative efforts.
- Equipment, materials, and facilities are adequate to meet goals.

Deployment Considerations:

8: Commercialization Potential

- Researchers know and can describe a "real world" application.
- Basic metrics of this application have been at least theorized.
- This project is likely to be implemented if research is successful.
- Barriers to commercialization have been considered.

9: Possible Adverse Effects Considered

- Potential negative effects on the environment or public have been considered.
- Scientific risks are within reasonable limits.
- Mitigation strategies have been considered.

10: Attention to Constituent Groups Concerns

- Relevant constituent groups have been identified.
- An assessment of positive or negative reactions has been made.
- A plan for constituent relations has been considered.

Evaluation

Reviewers were asked to consider these definitions carefully in assessing the progress and achievements of each project presented and then develop an evaluation rating for each criterion based on his/her own best judgment. Possible evaluations were divided into three discrete categories: Meets Expectations, Exceeds Expectations, or Does Not Meet Expectations.

These Evaluation Criteria were also provided to all of the project teams as part of their instructions for preparing for the meeting. This seems to have had a positive effect as many of the teams commented that they might not have addressed one or more of these topics had they not been told ahead of time that they would be important.

A blank copy of the two-page Reviewer Evaluation Sheet follows.

Reviewer Evaluation Sheet

Project Code_____ Principal Investigator(s)_____

Reviewer_____

Criterion:	**Does Not Meet Expectations***	**Meets Expectations**	**Exceeds Expectations**
Project Merit			
1: Scientific and Technical Merit			
2: Anticipated Benefits if Successful			
Approach and Progress			
3: Technical Approach			
4: Rate of Progress			
5: Knowledge of Related Research			
6: Economic Analysis			
7: Utilization of Government Resources			
Deployment Considerations			
8: Commercialization Potential			
9: Possible Adverse Effects Considered			
10: Attention to Constituent's Concerns			

* Note: If you ranked any of the above criterion as "Does Not Meet Expectations," please explain why in the space provided on the reverse side.

1. **Strengths** _____

_____

_____

_____

2. **Weaknesses** _____

_____

_____

_____

3. **Recommendations** _____

_____

_____

_____

4. **Action Items** _____

_____

_____

_____

5. **General Comments** _____

_____

_____

6. **Why this project "Does Not Meet Expectations"** _____

_____

_____

_____

Project Code _____ **Reviewer Name:**_____

Appendix E
Project Summaries

Section I: Economics

<table>
<tr><td>Project #:

DE-AC21-92MC29094</td><td colspan="2">Project Title:
Development of Integrated Environmental Control Model, Carbon Sequestration Version (IECM-cs) [Subtasks under project title, “Development and Application of Optimal Design Capability for Coal Gasification Systems”]</td></tr>
<tr><td colspan="2">Principal Investigator:
Edward S. Rubin
Carnegie Mellon University</td><td>Performance Period:
10/1/03 – 9/30/06</td><td>% Complete as of 9/30/2005: 55%</td></tr>
<tr><td colspan="4">Primary Project Goal:
The primary goal of this project is to develop a user-friendly computer model to systematically characterize the plant-level performance, emissions and cost of alternative CO_2 capture and storage technologies for a broad range of electric power systems.</td></tr>
<tr><td colspan="4">Objectives:
The product of this work is a desktop computer model that allows different CCS technology options to be evaluated systematically at the level of an individual plant or facility. The model takes into account not only the avoided carbon emissions, but also the impacts on multi-pollutant emissions, plant-level resource requirements, and net plant efficiency.

In addition, uncertainties and technological risks also can be explicitly characterized. The modeling framework—known as the IECM-cs (Integrated Environmental Control Model–Carbon Sequestration version) — is designed to support a variety of technology assessment and strategic planning activities by DOE and other organizations.

The model currently includes four types of fossil fuel power plants: a pulverized coal (PC) plant, a natural gas-fired combined cycle (NGCC) plant, a coal-based integrated gasification combined cycle (IGCC) plant, and an oxyfuel combustion plant. Each plant can be modeled with or without CO_2 capture and storage. The IECM-cs can thus be employed to quantify the costs and emission reduction benefits of CCS for a particular system or to identify the most cost-effective option for a given application.

The model also can be used to quantify the benefits of technology R&D and to identify advanced technology options having the highest potential payoffs.</td></tr>
</table>

Section II: Sequestration -- Geologic

Project # DE-FC26-04NT42209	**Project Title:** **Investigation of Integrated Subsurface Processing of Landfill Gas and Carbon Sequestration, Johnson County, Kansas**	
Principal Investigator: K. David Newell Kansas Geological Society	**Performance Period:** 10/1/04 – 9/30/06	**% Complete as of 9/30/2005: 38%**
Primary Project Goal: Study the reservoir mechanisms and technical feasibility of subsurface-coal seam processing of Landfill Gas (LFG) at the Johnson County Landfill in eastern Kansas.		
Objectives: Project objectives are: • Collection and laboratory testing of coal-bearing cores from strata underlying a major urban landfill (Kansas) o Assemble geologic data o Core acquisition o Physical and chemical characterization of coals and coalbed gas • Physical/Chemical characterization of coal/LFG interactions in autoclave experiments using coal samples obtained from seams underlying a major urban landfill (ORNL) o Mixed gas sorption/desorption analysis o Mixed gas flow-through (coal permeability) analysis • Model gas movement in, and sequestration potential of, coalbeds underlying a major urban landfill o Digital-data compilation o Reservoir modeling • Evaluating the feasibility of subsurface processing of LFG using the coal seams that underlie the Johnson County Landfill in eastern Kansas o Site-specific processing economics o Regional and national potential o Monitoring, mitigation and verification o Regulatory environment		

Project # OST-44-04	**Project Title:** **Modeling CO_2 Sequestration in Coal Seams**	
Principal Investigator: Duane H. Smith National Energy Technology Laboratory	**Performance Period**: 10/1/04 – 9/30/06	**% Complete as of 9/30/2005: 42%**

Primary Project Goal:

The primary goal of this project is to promote environmentally and commercially successful sequestration of carbon dioxide in coal with reduced emissions of greenhouse-gas methane and increasing production of coal bed methane energy.

Objectives:

1. Increase the technical reliability and cost-effectiveness of DOE co-funded projects by offering technical assistance.
2. Help the sequestration program to meet selected technology targets and dates
3. Perform economic analyses to help optimize program plans, field-project designs, and planning of simulations, modeling, and laboratory experiments.
4. Use a combination of modeling and experiments to develop fundamentally new physics and chemistry needed to increase the accuracy and reliability of sequestration practices.
5. Write, validate, and use more-accurate and reliable reservoir engineering simulators, which use new applied physics and chemistry.
6. Help to train current and future engineers and scientists in sequestration fundamentals and technologies.
7. In a timely manner, share R&D progress with DOE planners, partners, and industrial and academic technologists.

Project #: FEW34895	**Project Title:** **Sequestration in Depleted Oil Reservoirs**	
Principal Investigator: Rajesh Pawar Los Alamos National Laboratory	**Performance Period:** 2/10/01 – 9/30/06	**% Complete as of 9/30/2005: 78%**

Primary Project Goal:

To identify the technical efficacy and long-term effectiveness of CO_2 sequestration in sandstone-hosted depleted oil reservoirs.

Objectives:

In order to address the primary project goal, a number of activities have been proposed and performed over the course of the project. These activities addressed the following objectives: establish a U.S. field demonstration site; understand response of reservoir to CO_2 injection and storage; test and evaluate remote monitoring technologies; provide laboratory and field data for model validation; predict CO_2 storage capacity and reservoir property changes; predict long-term fate of CO_2 in oil reservoirs.

The milestones needed to be completed to meet these objectives included: a field experiment where CO_2 was injected in a depleted oil reservoir, injected CO_2 was allowed to interact with the reservoir by shutting in the injection well for six months. After six months the injection well was vented to let injected CO_2 out of the reservoir; acquisition of geophysical surveys, including, 3-dimensional surface seismic surveys prior to and after injection, passive seismic survey during injection; determination of changes in reservoir rock properties due to exposure to CO_2 through laboratory experiments; numerical simulations of field experiment; and integration of simulations, field and laboratory experiment results.

Section III: Sequestration--Terrestrial

Project #: DE-FC26-01NT41151	**Project Title:** **Application and Development of Appropriate Tools and Technologies for Cost-Effective Carbon Sequestration**	
Principal Investigator: Bill Stanley The Nature Conservancy	**Performance Period:** 7/11/01 – 7/10/07	**% Complete as of 9/30/2005: 68%**

Primary Project Goal:
The goals of this effort are to: 1) improve and lower the costs of measurement, monitoring and verification during both planning and implementation phases of terrestrial sequestration activities; and 2) evaluate new activities throughout the U.S. to identify where biodiversity conservation and low cost carbon sequestration opportunities overlap at a cost of less than $10 per ton of CO_2.

Objectives:
The project is occurring in two phases. The first is a focused exploration of a specific carbon measurement and monitoring methodologies and pre-selected carbon sequestration opportunities. The second is a more systematic and comprehensive approach to compare various competing measurement and monitoring methodologies, and assessment of a variety of carbon sequestration opportunities in order to find those that are the lowest cost with the greatest combined carbon and other environmental benefits.

In the first phase we worked in the U.S., Brazil, Belize, Bolivia, Peru, and Chile to develop and refine specific carbon inventory methods, pioneering a new remote-sensing method for cost-effectively measuring and monitoring terrestrial carbon sequestration. We also evaluated the costs and carbon benefits of a number of specific terrestrial carbon sequestration activities throughout the U.S., including reforestation of abandoned mined lands in southwest Virginia, grassland restoration in Arizona and Indiana, and reforestation in the Mississippi Alluvial Delta. The most cost-effective U.S. terrestrial sequestration opportunity we found through these studies was reforestation in the Mississippi Alluvial Delta.

A small portion of the Phase I work is ongoing. The primary past milestones of this first phase are represented by the numerous products submitted to DOE, the presentations given, and papers published and listed in the bibliography at the end of this document.

In Phase II we are conducting a more systematic assessment and comparison of several different measurement and monitoring approaches, and a broad regional, rather than pre-selected and targeted, analysis of terrestrial sequestration costs and benefits. Below we lay out the objectives and significant milestones of the remaining work.

Future Objectives and Milestones

Measurement and Monitoring: Forest Cover and Carbon Changes in Coastal Temperate Rainforest, Chile 1) Quantify past forest cover and forest carbon changes for the section of coastal temperate rainforest between Rio Calle and Rio Huevelhue, Chile; 2) Project possible

future forest cover in the area of analysis using forest restoration carbon analysis (FRCA) method; 3) Estimate potential forest carbon sequestration of restoration of native forest in the Reserva Costera Valdiviana

Forest Species Patterns and Carbon Changes in Moist Tropical Forest in La Selva Central, Peru
1) Assess forest species patterns and tree sizes in Amazon and Yungas tropical forest; 2) Estimate past forest carbon changes and project a future forest carbon baseline; 3) Identify activities that will reduce emissions and enhance sequestration.

Phase II
Comparing methods for Monitoring Forest Carbon and Impacts of Climate Change with Forest Inventories, High-Resolution Satellite Images, and LIDAR in Northern California
1) Assess and compare the operational characteristics and costs of QuickBird and LIDAR for monitoring forest carbon sequestration in two ecologically significant, high biomass forest areas in California.
2) Analyze changes in forest species and forest carbon along an altitudinal gradient in the Sierra Nevada.

Project #: DE-FC26-04NT42208	**Project Title:** **Assessing Fossil and Recent Carbon Pools in Reclaimed Mined Soils**	
Principal Investigator: Rattan Lal Ohio State University	**Performance Period:** 10/1/04 – 9/30/06	**% Complete as of 9/30/2005: 38%**

Primary Project Goal:

The overall aim of this project is to develop and test analytical procedures to determine the pool size of coal derived C in the reclaimed mined soils so that reliable estimates of SOC pools and C sequestration rates can be determined.

Objectives:

The specific objectives are to:

(i) develop and test 13C based procedure to determine the fraction of coal-C present in reclaimed mined soils;

(ii) evaluate chemi-thermal treatment procedure, based on the higher recalcitrance of coal than recent C pools to partition organic C in reclaimed sites into coal-derived and newly deposited C fractions;

(iii) establish an optimum sampling protocol (intervals and number of sampling points) to produce accurate assessment of C sequestration in reclaimed sites; and

(iv) develop simple routine and economical procedures for determining SOC pool in reclaimed mined soils contaminated by coal.

Project #: FWP02FE18	**Project Title:** **Applied Terrestrial Sequestration and Carbon Management**	
Principal Investigator: Michael H. Ebinger Los Alamos National Laboratory	**Performance Period:** 10/1/01 – 9/30/09	**% Complete as of 9/30/2005: 49%**

Primary Project Goal:
Provide advanced methods of carbon management and sequestration practice in terrestrial systems and demonstrate improved carbon measurement while reducing uncertainties and minimizing costs.

Objectives:
There are three key objectives to the Los Alamos Terrestrial Carbon Project, each representing new applications of novel technologies to understand carbon dynamics on land. Each application improves significantly on currently available methods and technologies for carbon sequestration and verification.

1) Develop Advanced Monitoring, Mitigation, & Verification Technologies
   Laser-induced breakdown spectroscopy (LIBS): New configurations of field portable LIBS instrumentation show significant promise to measure and account for the extreme heterogeneity of soil carbon distributions.

2) Develop Soil Microbial Indicators of Carbon Sequestration Processes
   Microbial indicators: Soil microbes respond to increases in carbon in soils. Microbes responsible for the activation of carbon sequestering processes are sensitive indicators of rapid and minute changes in soil carbon concentrations.

3) Demonstrate Carbon Sequestration through Land Management and Reclamation
   Field demonstrations: Use abandoned mine lands, agricultural lands, and forested lands to demonstrate the advanced measurement and process technologies.
   Demonstrate co-benefits of land management to maximize carbon sequestration in terrestrial systems.

Section IV: Capture of CO_2

Project #: DE-AC2699FT40248 FWPA24C	**Project Title:** **Syngas Upgrading – A Low-Temperature Approach**	
Principal Investigator: Gordon Deppe Nexant	**Performance Period:** 11/1/99 – 3/31/06	**% Complete as of 9/30/2005: 92%**
Primary Project Goal: The primary project goal is to develop and demonstrate a functional CO_2 capture process using the SIMTECHE process of hydrate formation. The demonstration will be done by capturing the CO_2 from a slipstream of syngas from an operating coal gasifier.		
Objectives: Project objectives – • Develop Fundamental Equilibrium Data for Prediction of Hydrate Behavior • Demonstrate the Process Concept in a Continuous-Flow Bench-Scale Unit • Evaluate the Economic Feasibility of the Process • Develop Engineering Design Data on Hydrate Process Unit Operations (ETM apparatus) • Syngas Flow Tests – Develop CO_2 Capture Separation Data in Hydrogen/H_2S Gas mixtures The project is currently in the last stage of phase 2, and the current contract will expire at March 31, 2006. The goal of the current work is to facilitate the transition to a cooperative agreement and complete the planned slipstream test at an operating gasifier.		

Project #: FWP5A402 FWP02FE19AC03	**Project Title:** **Carbon Dioxide Separation Using a Thermally Optimized Membrane**	
Principal Investigator: Kathryn A. Berchtold Los Alamos National Laboratory	**Performance Period:** 9/2000 – 9/2006	**% Complete as of 9/30/2005: 79%**

Primary Project Goal:

The overall goal of this project is to develop polymeric-metallic composite membranes for carbon dioxide separations that operate under a broad range of conditions relevant to the power industry while meeting the Carbon Sequestration Program goals of 90% CO_2 capture at less than a 10% increase in the cost of energy services. This project entails the development of an innovative membrane technology that achieves the critical combination of high selectivity, high permeability, chemical stability, and mechanical stability at elevated temperatures.

Objectives:

The primary objective of this project is the development of polymeric-metallic composite membrane structures that achieve the critical combination of high selectivity, high permeability, chemical stability, and mechanical stability all at elevated temperatures (>150 °C). Stability requirements are focused on tolerance to the primary synthesis gas components and impurities at various locations in the process. Since the process stream compositions and conditions (temperature and pressure) vary throughout the IGCC process, the project focus has been the optimization of a technology that could be positioned upstream or downstream of one or more of the water-gas-shift reactors (WGSRs) or integrated with a WGSR.

At this stage of the research project, two major development pathways to the primary goal are being pursued. The first involves extending the current PBI-based polymeric-metallic composite membrane to its limits. In this regard, much effort is being placed on membrane productivity optimization, module design, in-lab and out-of-lab testing of optimized composite membranes and modules, systems integration, economic analysis, and developing and executing the technology commercialization plan. LANL and Pall Corporation are leading this effort. The second pathway is aimed at the synthesis and development of a number of new PBI-based compounds that improve upon the base PBI material utilized in the first pathway.

The major objectives of this second pathway involve building upon the base PBI framework to develop materials with enhanced gas separation properties (primarily H_2/CO_2 selectivity and H2 flux) while maintaining the desirable chemical, mechanical, and thermal stability exhibited by the unmodified PBI and improving polymer solvent solubility. INL is leading this effort. In support of the objectives of both pathways, a methodology is being developed that provides an improved understanding of the relationship between mechanical and transport behavior at elevated temperature and enables a unique approach to the prediction and optimization of long-term membrane performance under challenging operating conditions. Colorado University is leading this effort.

Project #: OST0704	**Project Title:** **Solid Sorbents for CO2 Removal from Pre-Combustion and Post-Combustion Gas Streams**	
Principal Investigator: Ranjani Siriwardane National Energy Technology Laboratory	**Performance Period:** Annual Renewal for 4 years	**% Complete as of 9/30/2005: 40%**

Primary Project Goal:
To develop technologies to capture CO_2 from pre and post combustion gas streams that are superior to the existing capture technologies and commercialize these novel technologies.

Objectives:

Post-Combustion

- Develop a sorbent (lab scale) that is suitable for CO_2 capture at 30-60 ^{0}C and regenerable at 80-100 ^{0}C. The sorbent should be able to remove CO_2 from post combustion gas streams.
- Evaluate feasibility of sorbent preparation in a commercial scale unit and bench scale reactor tests.
- Develop regeneration schemes to obtain concentrated CO_2 stream at 60-80 ^{0}C.
- Optimize the sorbent formulation to improve the performance.
- Conduct long-term tests to determine the chemical and physical stability of the sorbents.
- Study effect of trace contaminants on the sorbent performance
- Test the sorbent in a pilot scale reactor unit.

Pre-Combustion

- Develop regenerable sorbents that operate at higher temperatures suitable for CO_2 capture from pre-combustion gas streams such as from IGCC.
- Conduct a complete system analysis incorporating sorbent enhanced water gas shift reaction.
- Test/Evaluate the feasibility of utilizing the sorbent for sorbent enhanced water gas shift reaction.
- Test/Evaluate the sorbent for the GE Fuel Flexible Gasification-Combustion Technology.

Project #: OST 03-04	**Project Title:** **Ammonia-Based Process for Multi-Component Removal**	
Principal Investigator: James T. Yeh National Energy Technology Laboratory	**Performance Period:** 10/1/05 – 9/30/05	**% Complete as of 9/30/2005: 75%**
Primary Project Goal: To technically develop a sound ammonia-based scrubbing process from which it can be further advanced to the proof-of-concept stage in the immediate future.		
Objectives: The expansion of a knowledge base pertaining to the development of an ammonia-based scrubbing process for capture of CO_2 from flue gas is a key objective. After a detailed literature review, the concept for a wet, regenerable process to scrub carbon dioxide from flue gas emerged. Initial experimental studies were planned on a semi-continuous reactor system. From these studies, information pertaining to CO_2 loading capacity between the absorption and regeneration steps, reaction species identification, vapor losses, and cyclic nature of the process was determined. These findings aided in the design of a continuous gas/liquid flow reactor system that is currently being used to further optimize the process with respect to operability and efficiency. Successful testing in the continuous unit could lead to a proof-of-concept demonstration that would further thrust the technology towards commercialization.		

Section V: Non-Greenhouse Gas Concepts

Project #: FWPAE-FY-05-019	**Project Title:** **Geological Sequestration – Enhancement of Natural Seals**	
Principal Investigator: William K. O'Connor Albany Research Center	**Performance Period:** 10/1/04 – 9/30/05	**% Complete as of 9/30/2005: 100%**
Primary Project Goal: Determination of the physical and chemical impact of the CO_2 flood on whole core samples from typical saline aquifer host rocks.		
Objectives: 1. Acquisition of whole core sample of the Mt. Simon sandstone from the Illinois Basin. 2. Acquisition and installation of core test apparatus. 3. Physical and chemical characterization of Mt. Simon core samples prior to CO2 flood tests. 4. Design and fabrication of whole core CO_2 flood test apparatus. 5. Conduct of baseline CO_2 flood tests on the Mt. Simon sandstone core samples.		

Project #: FWPAE-FY-05-08	**Project Title:** **Concepts to Improve Carbon Dioxide Sequestration by Mineral Carbonation**	
Principal Investigator: William K. O'Connor Albany Research Center	**Performance Period:** 10/1/04 – 9/30/05	**% Complete as of 9/30/2005: 100%**
Primary Project Goal: Determination of mineral availability, mineral-specific optimum process parameters, and conduct of a mineral carbonation process feasibility study (through FY04). Final year (FY05) focus on the investigation of mineral carbonation reactivity of several materials at geological conditions.		
Objectives: 1. Conduct of baseline whole core CO_2 flood studies on typical sedimentary saline aquifer host rocks (sandstones). 2. Acquisition of core analysis equipment. 3. Installation and utilization of core analysis equipment. 4. Conduct of baseline carbonation reactivity studies on ultramfic minerals at typical geological conditions.		

Section VI: Breakthrough Concepts

Project #: DE-FG26-04NT42121	**Project Title:** **Carbon Dioxide Separation with Novel Microporous Metal Organic Frameworks (MOF's)**	
Principal Investigator: Robert Bedard UOP	**Performance Period:** 8/5/04 – 8/4/07	**% Complete as of 9/30/2005: 33%**
Primary Project Goal: The program addresses carbon capture for both pre-combustion and post-combustion applications. A novel class of sorbents is being evaluated for chemisorption and physisorption of CO_2 from flue gas and syngas streams.		
Objectives: • To develop a theoretical model to predict the structure of MOFs with good CO_2 sorption properties. This model will allow for the efficient screening of existing MOFs and for the design of new MOFs and the prediction of their sorption properties. • To develop an understanding of the sorption sites in MOFs. • To develop MOFs tailored for CO_2 separation from flue gas. • To develop MOFs tailored for CO_2 separation from gasifier streams. • To assess the commercial potential of MOFs for separation and capture of CO_2. • To integrate an MOF-based process into a coal-fueled power plant to recover CO2 from actual plant generated gas mixtures.		

Project #: NT42123	**Project Title:** **Carbon Dioxide Sequestration in Carbonate Sediments Below the Sea Floor: Neutralizing Carbonic Acid in Deep Carbonate Strata Below the North Atlantic**	
Principal Investigator: Daniel P. Schrag Harvard University	**Performance Period:** 7/15/04 –7/14/07	**% Complete as of 9/30/2005: 35%**

Primary Project Goal:

The goal of this project is to investigate the feasibility of carbon dioxide disposal by injection and neutralization deep below the ocean floor in calcium carbonate sediments. This method has the potential to combine several of the advantages of deep well injection and deep ocean deposition but avoid some of the most serious risks. However, the idea is relatively unexplored and several key questions must be addressed before the idea can be considered for possible field applications.

Objectives:

In particular, we seek to understand the mechanical and chemical behavior of CO_2 and CO_2-water mixtures injected into carbonate sediments under a range of pressures and temperatures of geological interest and with a range of sediment compositions (e.g., clay content) and rheologies (i.e., ooze, chalk, limestone). Using high-pressure experiments, we are working on measuring the kinetics of carbonate dissolution at temperatures and pressures appropriate to deep sea carbonate deposits.

We will also measure the affects of carbonate dissolution on sediment porosity and permeability. To complement the experimental work, we are using numerical models of fluid injection and flow in porous media to understand the fate of CO_2 and CO_2 -water mixtures upon injection into the sediment-pore fluid system. We are simultaneously working with economists on estimating costs of this method of carbon storage, and working with drilling logs to establish the optimal sites for carbon repositories.

Finally, we are considering a collaboration with experimental petrologists who have expertise in large-volume, high pressure experiments an imaging techniques to do a simulation of CO_2 injection into carbonate sediments in the laboratory.