



CRTD-78

National Energy Technology Laboratory

**Final Report
Carbon Sequestration
Project Review Meeting**

Greater Pittsburgh International Airport Hyatt Hotel
March 30-April 1, 2004

**Volume I:
Meeting Summary and Recommendations**

**José D. Figueroa
NETL Project Manager and Meeting Coordinator**

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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 (CO₂). 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 CO₂.

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. In regard to the Carbon Sequestration Program, they 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 March 30, 2004, the American Society of Mechanical Engineers [ASME] convened a panel of ten 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 offered the following observations regarding projects reviewed in five carbon sequestration research categories:

- Monitoring, Measurement, and Verification Projects:

Monitoring of carbon sequestration sites and verification that they are safe is crucial to public acceptance of large-scale carbon sequestration in underground reservoirs. Verification of the amounts of carbon sequestered is critical to proposed carbon trading options being discussed in industry venues. For both reasons, MMV projects are important and should have more outreach to the public than has been common for these projects in the past.

- Geologic Sequestration Projects:

Early-stage projects must be able to show true potential to sequester significant amounts of CO₂. Geologic sequestration projects are advancing well and represent a likely success for the Program.

- Capture Related Projects:

Capturing CO₂ remains the leading technical challenge of the Sequestration Program and the projects reviewed in 2004 represent a variety of potential technical solutions.

- Terrestrial Sequestration Projects:

The projects reviewed this year and previously on new assessment technologies to scan terrestrial environments to verify the amount of carbon stored address important research areas. Several good projects have been reviewed so far. Given the near-term potential of terrestrial systems to store carbon Reviewers have asked if there are enough terrestrial projects in the portfolio.

- Novel Concepts:

Given the wide variety of projects included under Novel Concepts, it is difficult to characterize this category. This category includes two biomass related sequestration options reviewed at this meeting. Reviewers commented that there is a place for biomass related projects in the carbon sequestration portfolio.

Overview of Projects Review Process

Sixteen projects were reviewed as part of this process. Each project team prepared a 10-page summary of work to date for review by the ASME Panel prior to the meeting. At the meeting, each research team made a 30-minute presentation that was followed by a 10-minute question and answer session with the reviewers. Each reviewer, using a predetermined set of review criteria, numerically scored each project and provided written review comments following a group discussion of each project. Following is a brief summary of key findings from this project review meeting. Specifically, it was determined that:

- **It is difficult to do fundamental research.**
- **It is necessary to take risks.**

As a result, not all of the projects reviewed were able to score well against all review criteria. This should be viewed as if the DOE managers are taking sufficient risks in awarding projects that are trying to develop new or breakthrough technology. Supporting the DOE approach NETL requested that ASME implement a project review panel that will 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 will then be considered by the respective DOE project manager for project incorporation.

An Overview of Project Scoring

Scoring over the past three years has been relatively consistent in spite of the fact that each Review Panel has had at least two or three new members from the previous year. Every year one or more projects have been able to achieve a nearly perfect score from at least one reviewer. Each year the highest average score, accounting for all reviewers, is in the 800 range and lowest average score is in the 400 range.

In 2002, the highest percentage of scores was in the 600s. In 2003, the highest percentage of scores dropped back to the 500s but in 2004 the percentage of scores surpassed the previous years to be in the 700s. Although it is too early to suggest a trend, it is encouraging that the 2004 scores as a whole are the best yet. **It is, at least, an indication that the project's principal investigators are taking this process seriously and are doing a better job of presenting their projects.**

All 16 projects reviewed are compared to the 10 scoring criteria used by the Review Panel. In summary, all 16 projects scored well against 6 of the 10 criteria:

- Scientific Merit,
- Anticipated Benefits if Successful,
- Technical Approach,
- Rate of Progress,
- Knowledge of Related Research, and
- Utilization of Government Resources.

There were two criteria where the projects scored slightly lower, suggesting that modest improvements were necessary. These were “Commercialization Potential” and “Attention to Constituent Group Concerns”. It is not that these projects don't have commercialization potential but that the project teams may not have spent sufficient time to date considering commercialization opportunities, if considered, were not sufficiently presented, or within their scope of work. Likewise is the concern about “Constituent Groups.” In fairness to the projects, these review criteria have been developed more recently than the scopes of work for some of the projects. In some cases, additional expertise may be needed by the Principal Investigator's to address these criteria.

On the final two criteria “Possible Adverse Effects Considered” and “Economic Analysis”, the projects scored lower, suggesting that some of the reasons previously mentioned may exist requiring DOE to address these areas, either by providing technical assistance or including it in the work plan.

Recommendations for Future Project Reviews

Overall, the Panel feels that the review process used for these meetings is working well and should not be substantially revised. Reviewers did offer suggestions for additional information they might like to see in the pre-meeting summaries of each

project. Standardization of economic analyses and the resulting estimated potential of each project are still needed.

For More Information

For more information concerning the contents of this report, contact the Project Manager, José Figueroa at the National Energy Technology Laboratory (412) 386-4966.

A copy of the Carbon Sequestration Technology Roadmap and Program Plan is available at:

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

TABLE of CONTENTS

Volume I. Meeting Summary and Recommendations

Executive Summary.....	4
Table of Contents.....	8
I. Introduction.....	9
II. General Reviewer Comments on the DOE Sequestration Roadmap....	11
III. Summary of Projects Reviewed in 2004.....	12
IV. An Overview of Scoring in 2004.....	24
V. Process Considerations for Future Project Reviews.....	26
Appendix:	
A: ASME Project Review Methodology.....	29
B: Meeting Agenda.....	32
C: Project Review Panel Members.....	36
D: Reviewer Scoring Sheet.....	39

I. Introduction

For the third 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 US Department of Energy, the Office of Fossil Energy, and the National Energy Technology Laboratory (NETL), is fully committed to improving the quality and results of projects in the Carbon Sequestration Program.

ASME was selected as the independent contractor to run the project review which comprised of up to 16 projects that were selected by NETL for each project review meeting. Principal Investigators (PIs) for each selected project were asked to submit a written summary of the status of their project and then to make an oral presentation to a panel of Peer Reviewers selected and convened by ASME. ASME conducts the review meeting and includes a numerical scoring of each project. Results of the review are summarized and presented to NETL in two volumes. The first volume prepared by ASME provides a general overview of findings from the Project Review and is available to the public. The second volume prepared by ASME, which is not distributed publicly, contains scores and reviewer comments concerning each project reviewed. A third volume, prepared by NETL, summarizes the responses 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 under ASME's Center for Research and Technology Development (CRTD). 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 selecting all Review Panel members and insuring 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 project staff 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 Scoring Sheets

In cooperation with the West Virginia University (WVU) National Research Center for Coal and Energy (NRCCE), the ASME team first develops a set of agreed

upon review criteria to be applied to the projects under review at this meeting and then prepares a scoring sheet, based on these criteria, for use by the Review Panel. Written reviewer comments are also collected and the Review Panel spends time in private assessing the strengths and weaknesses of each project before providing to NETL managers both recommendations and action items. A more detailed explanation of this process and a sample Reviewer Scoring 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 2004

Summary description of the sixteen projects reviewed this year.

IV. An Overview of Scoring in 2004

Brief overview of scores 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 on the evaluation of 16 individual projects. 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 ahead 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 and Environmental Issues

The issue of what to do with carbon isn't going away. It is our most important environmental issue. Environmental esthetics is very important. How these projects will interact with the environment must always be addressed.

The Roadmap as a "Portfolio" of Projects

The current Sequestration Roadmap is essential as an overview of the Program. It is in this context that the individual projects can be seen to contribute to a portfolio. As seen over three years, the collection of projects reviewed does present a well-balanced portfolio. There are no significant research areas that are not addressed in the Program.

At future review meetings it would be useful to consider presenting the project portfolio in even greater depth. It would be useful to see an overview of the entire project portfolio with both all projects reviewed to date and all projects up for review at each session highlighted.

Integrating Roadmap Goals and Project Goals

The current Sequestration Roadmap is a good presentation of the overall goals of achieving carbon sequestration, but it is hard for the Reviewers to interpret these goals at the level of individual project goals. For example, it is important that an individual project make sense overall, including its scientific merit, but the research investigators should also be able to articulate how their project fits in and enhances the overall goals of the Program, as defined in the Roadmap. In many cases, the connection between overall Program goals and individual project goals is not clear.

III. Summary of Projects Reviewed in 2004

The sixteen projects that were reviewed by the ASME review panel represent a sample of projects within each of the five Carbon Sequestration Program categories. The Sequestration category was separated in the evaluation into geological and terrestrial type projects for differentiation. Two of the sixteen projects had been reviewed previously, 40248 and 5A402, in order to verify the progress of long term projects and whether they in fact incorporated the previous ASME evaluation panel comments. The remaining fourteen projects represent projects that were either near the end of their performance period or had at least twelve months of research conducted. 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 would also provide valuable insight on the technology and project process taken of a near completed project so that lessons learned could be available for future or ongoing similar projects.

The projects reviewed in the 2004 Carbon Sequestration Project Review Meeting, within the different categories, are as follows:

Monitoring, Measurement, and Verification (MMV):

Project #	Title
41587	A Sea Floor Gravity Survey of Sleipner Field to Monitor CO ₂ Migration
41150	Natural Analogs for Geologic Sequestration (NACS)
13W0205	In Field, Continuous, Non-invasive Soil Carbon Scanning System

Non-CO₂ Concepts:

Project #	Title
41905	Upgrading Methane using Velocys Ultra-Fast TSA Technology

Sequestration - Geological:

Project #	Title
40418	The Ohio River Valley CO ₂ Storage Project
41442	Analysis of Devonian Black Shales in Kentucky for Potential Carbon Dioxide Sequestration and Enhanced Natural Gas Production
45505	Carbon Dioxide Sequestration in Basalt formations

Capture of CO₂:

Project #	Title
40248	Syngas Upgrading – A Low-Temperature Approach
5A402	Carbon Dioxide Separation Using Thermally Optimized Membranes
41147	Advanced Oxyfuel Boilers and Process Heaters for Cost-Effective CO ₂ Capture and Sequestration
41440	Carbon Dioxide Capture by Absorption with Potassium Carbonate

Novel (Break Through) Concepts:

Project #	Title
40932	Enhanced Practical Photosynthetic CO ₂ Mitgration
40934	Recovery and Sequestration of CO ₂ from Stationary Combustion Systems by Photosynthesis of Microalgae
41621	Advanced CO ₂ Cycle Power Generation

Sequestration - Terrestrial:

Project #	Title
40930	Carbon Capture Water Emissions Treatment System (C-CWESTRS)
41903	Carbon Sequestration is Reclaimed Mined Soils of Ohio

The following sections provide general information on each of the projects reviewed.

Monitoring, Measurement, and Verification (MMV):

Project # 41587	Project Title: A Sea Floor Gravity Survey of Sleipner Field to Monitor CO ₂ Migration		
Principal Investigator: Scripps Institution of Oceanography	Performance Period: 09/19/2002 – 09/18/2004	% Complete as of 4/1/2004 : 75%	
Objectives: The acceleration due to Earth’s gravity varies with time and location owing to an observer’s latitude, altitude, tides, and the density of nearby rock. The gravitational attraction of a 3 cm-thick sheet of mass of density 1 g/cc is about 1 microGal (about 10 ⁻⁹ of the average Earth field; Gal = cm s ⁻²). Our group developed instrumentation which can measure gravity on the seafloor with a precision of about 5 microGal. CO ₂ injected into the Utsira sand displaces water from the formation’s pore spaces, decreasing the local bulk density. Gravity modeling indicates that the density changes due to a year of CO ₂ injection should cause a decrease in the local gravity ranging from 5-15 microGal (the range is due to an uncertainty in the reservoir temperature). Our primary goal is to detect the CO ₂ bubble gravitationally after two surveys separated by three years, and then estimate the in situ CO ₂ density.			

Project # 41150	Project Title: Natural Analogs for Geologic Sequestration (NACS)		
Principal Investigator: Advanced Resources International, Inc.	Performance Period: 08/01/2001 - 07/31/2004	% Complete as of 4/1/2004 : 86%	
<p>Objectives:</p> <p>Task 1: Evaluate Reservoir Settings and Develop Comprehensive Geologic Models of Five Natural CO₂ Fields. The five CO₂ fields are: Jackson, McElmo, and St. Johns Domes (detailed models) and Bravo Dome and Sheep Mountain fields (scoping models). This involves developing GIS-based geologic and reservoir models.</p> <p>Task 2: Conduct Geochemical and Geomechanical Analysis of Reservoir and Cap Rock. Data analyzed includes well logs, core description, and compositional and isotope gas analyses. Computer modeling of geochemical and geomechanical processes is planned at the natural CO₂ fields.</p> <p>Task 3: Develop Preliminary “Good Practices” Operational Technologies for Geologic Sequestration from Natural CO₂ fields, EOR Projects, and UGS Facilities. This includes documenting for the first time the specialized production and handling equipment and operating procedures in place at commercial CO₂ fields, as well as their costs. Operational data from EOR projects and UGS facilities also will be integrated into the Good Practices analysis.</p> <p>Task 4: <i>International Coordination, Project Reporting, Technology Transfer.</i> This comprises a broad range of technical presentations and papers, workshops, as well as review articles for a more general audience. We are also coordinating with a major natural analog R&D project called NASCENT, which is funded by the European Union and focusing mainly on “leaky” European CO₂ deposits and fluxes in populated areas; this complements NACS assessment of effectively sealed CO₂ fields in sparsely populated areas.</p>			

Project # 13W0205	Project Title: In Field, Continuous, Non-invasive Soil Carbon Scanning System		
Principal Investigator: BNL	Performance Period: 08/01/2003 – 09/30/2005	% Complete as of 4/1/2004 : 27%	
Objectives: The <u>long-term objective</u> is to develop a reliable well-characterized portable and noninvasive system to measure non-destructively soil carbon <i>in situ</i> that is well characterized for different soil types and conditions. A system that can be used in a stationary mode and for continuous scanning over large areas. The <u>short-term objective</u> is to construct a deployable prototype of a Soil Carbon scanner (SCS) system to measure non-destructively soil carbon in the field. This will be accomplished in two phases. <u>In Phase I</u> the design, system optimization, construction, and initial calibration in a sandpit with well characterized soils will be performed at BNL. Then the SCS calibration will be validated on site against chemical analysis in double-blind field studies. These will be followed with further system optimization and characterization that would address the parameters such as; sample volume, detection efficiency, minimum detection limit, reduction in error propagation and portability. At this point the effects of external parameters, such as soil moisture content and soil inhomogeneities (texture, presence of rocks and wood litter) will be evaluated. <u>In Phase II</u> the system will be thoroughly calibrated and validated using measurements in open fields outside of BNL in collaboration with soil experts. At this point scans over large areas and usage of such data, not available at present, against point measurements will be evaluated. In addition the system will be validated for compartmental analysis to separate organic-from non-organic carbon and for soil bulk density correction. Following feasibility demonstration there are not technical uncertainties just system development that would rich design criteria. Applications are widespread for belowground carbon monitoring for science and commerce.			

Non-CO₂ Concepts:

Project # 41905	Project Title: Upgrading Methane using Velocys Ultra-Fast TSA Technology		
Principal Investigator: Velocys Inc.	Performance Period: 10/10/2003 – 3/31/2005	% Complete as of 4/1/2004 : 16%	
Objectives: The Velocys TSA Project has multiple objectives with two phases of development. <ul style="list-style-type: none">• Phase I – Assess technical and economic feasibility of the Velocys TSA technology.<ul style="list-style-type: none">○ Task 1 – Select adequate absorbent material<ul style="list-style-type: none">▪ Subtask 1.1 – Identify candidate absorbent materials from literature sources.▪ Subtask 1.2 – Experimentally validate adsorbent performance characteristics.○ Task 2 – Conceptual Design to serve as the basis for a feasibility assessment.<ul style="list-style-type: none">▪ Subtask 2.1 – Develop a conceptual system design to determine nitrogen rejection requirements.▪ Subtask 2.2 – Design Velocys TSA component hardware.○ Task 3 – Complete an economic and technical feasibility assessment for Velocys TSA versus conventional nitrogen rejection technologies.• Phase II – Demonstrate Velocys TSA at the bench-scale.<ul style="list-style-type: none">○ Task 4 – Design, build and demonstrate a bench-scale nitrogen rejection unit.			

Sequestration - Geological:

Project # 40418	Project Title: The Ohio River Valley CO ₂ Storage Project		
Principal Investigator: Battelle Memorial Institute	Performance Period: 07/2002 – 09/2004	% Complete as of 4/1/2004 : 75%	
<p>Objectives:</p> <p>The overall research effort is aimed at providing an understanding of the viability of geologic sequestration as a climate change countermeasure by demonstrating that deep saline reservoir sequestration is feasible from an economic and engineering perspective. The current phase of this effort is aimed at laying the foundation for an integrated demonstration of CO₂ capture and geologic sequestration at a meaningful scale. Although no CO₂ will be injected under the current phase, the intent is to prepare plans for potential future injection phases based on the injection potential at the site. The generalized sequence of activities under the project can be broadly categorized into three steps:</p> <ul style="list-style-type: none"> • Collect regional and site-specific information based on data compilation, seismic survey, and drilling and testing in the deep well. • Use the collected information to develop conceptual hydrogeologic models and support the risk assessment, reservoir simulations, and geochemical simulation activities. • Use the characterization data and the simulation results to prepare the final deliverables for the project including: <ul style="list-style-type: none"> ○ Design and monitoring plan for a potential future injection facility ○ Information related to UIC permits ○ Information needed by the DOE for NEPA permits ○ Information needed for stakeholder interactions. ○ Provide baseline conditions for post-injection monitoring should the project move into an injection phase. 			

Project # 41442	Project Title: Analysis of Devonian Black Shales in Kentucky for Potential Carbon Dioxide Sequestration and Enhanced Natural Gas Production		
Principal Investigator: Kentucky Geological Survey	Performance Period: 07/01/2002 – 06/30/2005	% Complete as of 4/1/2004 : 50%	
Objectives:			
<ul style="list-style-type: none"> • Characterization of the shale’s petrology, total organic content, and elemental composition. • Determination of the shale’s CO₂ adsorption isotherm character. • Determination of the relationship of petrology, total organic content and elemental composition to shale CO₂ adsorption capacity. • Determination of relationship of enhanced methane (CH₄) desorption with respect to CO₂ adsorption in the scale. • Determination of zones (facies, members) within the shale that have higher CO₂ adsorption capacities. • Delineation of the vertical and aerial extent of these zones. 			

Project # 45502	Project Title: Carbon Dioxide Sequestration in Basalt formations		
Principal Investigator: PNNL	Performance Period: 06/01/2003 – 09/30/2005	% Complete as of 4/1/2004 : 33%	
Objectives:			
<ul style="list-style-type: none"> • Compile the available geological information on major basalt formations in the U.S. and develop a GIS database of those formations that satisfy the requirements for a sequestration host medium. • Obtain and characterize representative core samples of vesicular flow tops from the CRBG and CAMP. • Conduct laboratory experiments to test hypothesis regarding mineralization reactions with basalt samples. • Develop a mechanistic understanding of carbonate mineralization reactions in basalts. • Determine rates of carbonate formation and key uncertainties impacting the estimated mineralization rates. • Conduct reservoir simulations to assess feasibility of a field demonstration. 			

Capture of CO₂:

Project # 40248 (Nexant)	Project Title: Syngas Upgrading – A Low-Temperature Approach		
Principal Investigator: Nexant, Inc.	Performance Period: 09/30/1999 – 08/31/2006	% Complete as of 4/1/2004 : 64%	
<p>Objectives: Phase 2 objectives –</p> <ul style="list-style-type: none"> • Engineering Test Model – Develop Engineering Design Data on Hydrate Process Unit Operations. • Hydrogen Flow Tests – Develop CO₂ Capture Separation Data in Hydrogen/H₂S Gas mixtures. • Design Slipstream Test Unit – Using Lab Results, Design a Slipstream Test Unit for Demonstration Testing at an Operating Gasifier. <p>Phase 3 Objectives: Commission and Develop Operational Know-How of the Slipstream Test Unit in Initial Tests of the STU.</p> <p>Phase 4 Objectives: Demonstrate Long-Term Continuous Operation and Develop Data for Reliable Prediction of Commercial-Scale Process Operation.</p>			

Project # 5A 402	Project Title: Carbon Dioxide Separation Using Thermally Optimized Membranes		
Principal Investigator: INEEL	Performance Period: 09/02/2000 – 03/30/2006	% Complete as of 4/1/2004 : 63%	
<p>Objectives: The major objective is the development of polymeric materials that achieve the important combination of high selectivity, high permeability, and mechanical stability at temperatures significantly above 25 C and pressures above 10 bar.</p>			

Project # 41147	Project Title: Advanced Oxyfuel Boilers and Process Heaters for Cost-Effective CO ₂ Capture and Sequestration		
Principal Investigator: Praxair, Inc.	Performance Period: 01/01/2002 – 12/31/2005	% Complete as of 4/1/2004 : 52%	
Objectives: Conceptual designs to identify an integrated OTM-boiler system with high likelihood of success, low environmental impact, high efficiency, integrated with typical CO ₂ capture systems, and low costs will be developed. These designs will be jointly developed by Praxair and Alstom Power. The information obtained from these will also be used to develop a conceptual design for a pilot scale 0.15-0.30 MW _t (0.5-1 MMBtu/h) boiler to be constructed and tested as part of a follow up effort pending successful completion of the program. A series of laboratory scale tests will address the technical issues associated with an integrated OTM-boiler. The issues that must be resolved include; (1) temperature control of the OTM tube at high oxygen fluxes and complete fuel oxidation, (2) mechanical stability of the membrane and ability of the OTM tubes to be thermally cycled at the same or faster rate as a conventional boiler system, and (3) to identify and demonstrate combustion strategies that minimize pollutant formation and maximize the thermal efficiency. A single-tube reactor and a multi-tube combustion reactor will be designed and build for combustion and heat transfer testing in a laboratory at the PTC, OTM materials will be developed that are suitable under reactive purge conditions. Selection criteria will include high and stable oxygen flux, good mechanical integrity and thermal shock resistance. The architecture of the membrane will need to be optimized to minimize oxygen mass transfer resistance while maintaining sufficient strength. The OTM material membrane development will yield tubes with the flux needed for the advanced oxygen-fired boiler.			

Novel (Break Through) Concepts:

Project # 41440	Project Title: Carbon Dioxide Capture by Absorption with Potassium Carbonate		
Principal Investigator: University of Texas	Performance Period: 07/09/2002 – 07/08/2005	% Complete as of 4/1/2004 : 50%	
<p>Objectives: Models will be developed to represent the integrated performance of the pilot plant. Thermodynamics will be represented by the electrolyte/NRTL model. CO₂ mass transfer rates will be simulated with a rigorous model using differential equations. An absorber model will be developed using Ratefrac in AspenPlus. The stripper will be represented by integration in AspenPlus with AspenCustom-Modeler. The complete model in AspenPlus will be validated by the pilot plant experiments. An pilot plant will be operated to demonstrate the process and validate the model. The existing 16.8-inch absorber and stripper will be modified to represent this process. The first campaign will test absorber performance. The second campaign will test stripper performance. The third campaign (funding pending) will provide baseline performance with 30% MEA.</p>			

Project # 40932	Project Title: Enhanced Practical Photosynthetic CO ₂ Mitgration		
Principal Investigator: Ohio University	Performance Period: 10/01/2000 – 10/01/2004	% Complete as of 4/1/2004 : 83%	
<p>Objectives: There are two main objectives First, investigate the technical and economic feasibility of using an “optimized” enhanced photosynthesis system that (a) separated and uses various spectral regions of direct, non-diffuse sunlight to maximize cyanobacteria growth, (b) directly decreases CO₂ concentrations in the emissions of fossil generation units, (c) reduce the required space needed (compared to other biological techniques) by a factor of 10, and (d) simultaneously produce enough electrical energy to nearly self-power the entire sequestration system. Second, once the basic investigation is completed, keeping in mind the goal to demonstrate the technology, a conceptual system design will be completed along with preliminary talks with potential industrial partners for demonstration.</p>			

Project # 40934	Project Title: Recovery and Sequestration of CO ₂ from Stationary Combustion Systems by Photosynthesis of Microalgae		
Principal Investigator: Physical Sciences Inc.	Performance Period: 10/02/2000 – 10/01/2004	% Complete as of 4/1/2004 : 79%	
<p>Objectives:</p> <p>The overall objective of this research is to address the following issues:</p> <ol style="list-style-type: none"> (1) Supplying CO₂ from a fuel combustion system to a photobioreactor; (2) Growing microalgae photosynthetically at industrial scales; (3) Optimizing the photobioreactor and photosynthesis process; (4) Developing the system design; and (5) Conducting an economic analysis. <p>Our program consists of the following tasks to meet the stated objectives:</p> <ol style="list-style-type: none"> (1) Evaluate and identify the best recovery method of CO₂ from power plant flue gas to photobioreactor; (2) Select the microalgae best suited for the proposed process; (3) Optimize and demonstrate industrial scale photobioreactor; (4) Conduct carbon sequestration system design; and (5) Conduct economic analysis. 			

Project # 41621	Project Title: Advanced CO ₂ Cycle Power Generation		
Principal Investigator: Foster Wheeler, North America	Performance Period: 07/01/2003 – 06/01/2004	% Complete as of 4/1/2004 : 67%	
<p>Objectives:</p> <ul style="list-style-type: none"> • Develop plant conceptual design and conduct thermodynamic cycle analyses to determine its performance characteristics. • Design the major plant components. • Specify balance of plant components and develop a plant cost estimate. • Conduct an economic analysis using plant capital and projected operating costs. 			

Sequestration - Terrestrial:

Project # 40930	Project Title: Carbon Capture Water Emissions Treatment System (C-CWESTRS)		
Principal Investigator: Tennessee Valley Authority	Performance Period: 10/2000 – 12/2005	% Complete as of 4/1/2004 : 71%	
Objectives: <ul style="list-style-type: none"> • Review and assess tree cultivation and other techniques to be used to sequester carbon at the site. • Conduct project site assessment, including baseline monitoring. • Conduct greenhouse studies to determine which plant species to use as related to existing soils and tolerance to the use of FGD gypsum “mulch” and ash sluice water as an irrigation source. • Develop recommendations for byproduct application and rates. • Develop recommendations for irrigation application methods and rates. • Develop and implement appropriate monitoring programs to assess carbon sequestration, water treatment, and environmental impact assessment. • Design the CCWESTRS system. • Construct the system. • Operate the system and monitor system progress. • Evaluate costs and benefits. • Complete final report. • Transfer the technology, as appropriate, to other users. 			

Project # 41903	Project Title: Carbon Sequestration in Reclaimed Mined Soils of Ohio		
Principal Investigator: OSU	Performance Period: 10/01/2003 – 09/30/2006	% Complete as of 4/1/2004 : 0%	
Objectives: <p>The project focuses on: (1) assessing the sink capacity of RMS to sequester SOC in selective age chronosequences, (2) determining the rate of SOC sequestration, and its spatial (vertical as well as horizontal) and temporal variation, (3) developing and validating models for SOC sequestration rate, (4) identifying the mechanisms of SOC sequestration in RMS, (5) assessing the potential of different methods of soil reclamation on SOC sequestration rate, soil development, and changes in soil mechanical and water transmission properties, and (6) determining the relation between SOC sequestration rate, and soil quality in relation to soil structure and hydrological properties.</p>			

IV. An Overview of Scoring in 2004

The ASME team, in cooperation with NETL and with input from the Peer Reviewers, continues to enhance and fine tune the process used for scoring the projects seen at each Project Review Meeting. A copy of the scoring sheet and an explanation of the process are provided in detail in Appendix D. Following is a brief overview of scores from the 2004 Project Review Meeting along with analysis and recommendations for action. The criteria that the projects scored well are not discussed since the focus of this section is to highlight the areas which need improvement.

Criteria Where Projects Need Modest Improvement

There are two review criteria where projects scored slightly lower than the other criteria:

- #8 Commercialization Potential, and
- #10 Attention to Constituent Group Concerns.

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 actually 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 a low score was given.

In the case of “Attention to Constituent Groups” the Review Panel was looking for some indication from the project team that they had considered how the public might look at their project. Many of the projects addressed key issues in this regard but a selection of projects did not.

There are at least two reasons that are at time inter-related as to why the Principal Investigators may not have addressed these review criteria sufficiently.

- The scopes of work for many of these projects do not include a task requirement or funding to address these criteria.
- The technical teams may not have the necessary skills to do the analysis to address these criteria for justifiable reason.

Attention to the fact must be given that:

- the review criteria were developed as critically important by the ASME with input from their Evaluation Panel, and
- the review criteria were developed after the projects reviewed were awarded therefore, they had no project requirement to develop the information to satisfy the criteria.

Criteria where Projects Need Significant Improvement

There are two review criteria where projects scored slightly lower:

- #9 Possible Adverse Effects Considered, and
- #6 Economic Analysis.

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. They wanted to see that potential issues of concern had been addressed.

In the case of “Economic Analysis” the Review Panel was looking for rudimentary analysis that the project team had considered possible costs of application if their project was successful. The Review Panel wanted to see that even modest consideration had been given to reaching the Carbon Sequestration Technology Roadmap economic targets for future technologies.

Only a handful of projects provided an economic analysis. In fairness to the project teams, as mentioned above, the project scope of work:

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

There is, however, a larger issue here as well. It would be good if all the projects in the program could draw upon some organized and quantitative thinking about how to address economic analysis within the whole Carbon Sequestration Program. NETL informed the review panel that they are working on a set of general guidelines which would be available by the end of the calendar year. In addition two presentations were given regarding NETL’s economic analysis efforts. A presentation by Edward Rubin from CMU of a “Modeling Framework to Evaluate CO₂ Capture and Storage Options” demonstrated the proposed need. Another presentation was provided by Jared Ciferno from NETL’s Systems Analysis Division about their efforts to conduct feasibility level economic studies on projects still at the fundamental levels of research.

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 the 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:

The review process is achieving an optimal format for the scope of the review. It is efficient and relatively low cost. Several of the Review Panel members do not charge full consulting rates because they believe in the necessity of the program and project review need. The logistics have been improved, the process is functioning well.

The Sequestration Roadmap presentation provided a good overview of the scope requirements of the program but it would be beneficial to the review panel if NETL could set the stage for each category of projects to be reviewed during the course of the meeting.

In general, the project presentations were better than last year. Both were “an order of magnitude” better than 2002. The researchers and the presenters are taking this process seriously. This is a good team of reviewers who interact well. Much has been invested in their education over the past three years and it is beginning to pay off with increased understanding and more in-depth questions and review comments.

Selecting Projects for Review:

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. The context of this comment is that, 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.

Pre-Meeting Documentation:

The pre-meeting project summaries are much better. The 3-page summary was well received and commended by several of the reviewers. For the general reader, the ten-page limit on the read-ahead materials was viewed as being optimal. However, it would be helpful if a way could be found for experts in the field of any given project to have access to more information, if they want it, about the projects to be reviewed. Perhaps there could be a CD with reports and other publications relevant to each project or website references.

There needs to be more in the pre-meeting package about the context of the project. Perhaps the first page of each 10-page package could be devoted to “context.” How does the project fit into the overall context of the Roadmap and how does it fit with

overall Program goals? It would also be good to have one page on documentation of the project to date: a publications list, applications for patents, workshop attendance and proceedings, and, in general, sources for digging deeper. As part of the pre-meeting documentation package, each project should be asked to provide a publication plan or other summary of how results from the project will be disseminated.

Economic Analysis:

The work presented from Carnegie Mellon University appears to be promising in regard to developing a standard economic criteria, but the model presented may need the help of others to attain an agreed upon format for economic analyses. A possible model for this kind of effort would provide a common definition and generally accepted practices. Another approach might be to use prototype cases for common problems—like standard configurations for typical power plant designs. This would provide a simple way to measure differences (from common practice) in the projects presented for review. Whatever approach is taken, it must in the end be standardized, simple, consistent, and transparent. Reviewers must know how much sequestration the individual project is after and the likelihood that it can reach this goal economically.

Outreach:

All of the projects should have an outreach element in their project plans. More projects addressed outreach plans at this review than in past years but there are many projects that still do not address this component.

Meeting Agenda:

The concept of equal time for every project presentation is seemingly fair, but in reality the relative size and importance of all projects is not equal. Some should be done in greater depth.

Project Discussions:

The format of discussing each project individually after presentation was better than discussing several similar projects as a group, as was done in previous years. This year's format allowed reviewers to focus on each individual project. It is important to have both the written summary and the group discussion. Several reviewers commented that the group discussion did change his or her perceptions of selected projects, sometimes substantially.

Scoring:

What does each score mean and how will it be used? Scoring is very useful to force conclusions about each project. Several reviewers felt that it was good this year to drop the process of ranking projects against one another. However, none of the reviewers proposed dropping altogether the process of scoring.

Appendix

- A. ASME Project Review Methodology**
- B. Meeting Agenda**
- C. Project Review Panel Members**
- D. Reviewer Scoring Sheet**

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 review 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 Council on Engineering (COE)

One of the five Councils responsible for the activities of ASME's 125,000 members worldwide, the Council of Engineering 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 CRTD operates under the COE. 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 Councils, Boards, and Divisions.

CO₂ 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 program 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 CO₂ Project Review Executive Committee were as follows:

- Dr. Adnan Akay, Chair. Dr. Akay is 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. In his capacity as head of the CMU Mechanical Engineering Department, Dr. Akay has a broad working knowledge of many aspects of combustion engineering.
- Dr. Allen Robinson. Dr. Robinson is Assistant Professor of Mechanical Engineering at Carnegie Mellon University. He brings to the CO₂ Program Review Executive Committee his special focus on combustion-generated air pollution, biomass combustion, and heat and mass transfer in porous media.
- Richard T. Laudemat. Mr. Laudemat is a manager with Northeast Generation Services. He is also Vice-President of the ASME Energy Conversion Group of the Council on Engineering (COE) and is on the COE Energy Committee. Mr. Laudemat is well versed on the issue of emissions from electric generating plants.

CO₂ Project Review Panel

The CO₂ 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 ten-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. One month prior to the meeting, each project team to be reviewed was asked to submit a 10-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.

Also at 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, Scoring, and Discussion

At the meeting itself, presenters were held to a strict 30-minute time limit so that all 16 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 considering the material that had been presented. To start, each reviewer scored the project against a set of predetermined review 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.

Each of these categories is defined on the scoring sheet (see Appendix D). A score up to 1000 could be achieved.

After providing a numeric score, 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

2004 Carbon Sequestration Project Review Schedule

Monday Evening Program—3/29/04

Wright-A&B

5:00-5:45	Feedback from 2003 Project Review Meeting ¹	Klara
5:45-6:00	2004 Project Review Meeting Overview	Tinkleman
Yeager-A		
6:30-7:30	Welcome Reception and Registration	All

Tuesday Program – 3/30/04

Presenters Ready Room – Foerster Boardroom

(LCD projector available in this room for laptop testing.)

Allegheny

6:30-7:30	Continental Breakfast	
7:30-8:00	DOE/NETL 2004 CO ₂ Seq. Overview/Roadmap	Klara
8:00-8:25	DOE/NETL Seq. Program economic Analysis Update	Rubin/Ciferno

Section I: Monitoring, Measurement, and Verification (MMV)

8:30-9:00	MMV-1: 41587-Sea Floor Gravity Survey	UC San Diego
9:00-9:10	Q&A	
9:10-9:35	Scoring, written comments, and discussion ²	
9:35-9:55	Break	
10:00-10:30	MMV-2: 41150-Natural Analogs for Geologic Seq.	Adv. Res. Intl
10:30-10:40	Q&A	
10:40-11:05	Scoring, written comments, and discussion	
11:10-11:40	MMV-3: 13W0205-AAC-Soil Carbon Scanning Sys.	BNL
11:40-11:50	Q&A	
11:50-12:15	Scoring, written comments, and discussion	

Wright-B

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.

12:15-12:45 Lunch (Provided for Review Team Only)

Section II: Non-CO₂ Concepts

Allegheny

12:45-1:15 **Non-1: 41905-Upgrading Methane with Ultra Fast TSA** Velocys

1:15-1:25 Q&A

1:25-1:50 Scoring, written comments, and discussion

Section III: Sequestration - Geologic

2:00-2:30 **G-1: 40418-Chem. Seq. in Deep Saline Formations** Battelle Columbus

2:30-2:40 Q&A

2:40-3:05 Scoring, written comments, and discussion

3:05-3:20 Break

3:20-3:50 **G-2: 41442-Seq. in Devonian Black Shale in KY** UKY Foundation

3:50-4:00 Q&A

4:00-4:25 Scoring, written comments, and discussion

4:30-5:00 **G-3: 45505-Seq. in Basalt Formations** PNNL

5:00-5:10 Q&A

5:10-5:35 Scoring, written comments, and discussion

5:35 Adjourn

Wright-A&B

6:00 Reception

7:00 Dinner for all participants

Wednesday Program—3/31/04

Allegheny

7:00-8:00 Continental Breakfast

Section IV: Capture of CO₂

8:00-8:30 **C-1: 40248-Hydrate for Shifted SynGas Stream** Nexant

8:30-8:40 Q&A

8:40-9:05 Scoring, written comments, and discussion

9:10-9:40 **C-2: 5A402-Thermally Optimized Membranes** INEEL

9:40-9:50 Q&A

9:50-10:15 Scoring, written comments, and discussion

10:15-10:30	Break	
10:30-11:00	C-3: 41147-Advanced Oxyfuel Boilers	Praxair
11:00-11:10	Q&A	
11:10-11:35	Scoring, written comments, and discussion	
11:45-12:15	Lunch (Provided for Review Team Only)	Wright-B
12:15-12:45	C-4: 41440-Absorption with Potassium Carbonate	UT/Austin
12:45-12:55	Q&A	
12:55-1:20	Scoring, written comments, and discussion	
<u>Section V: Novel (Break Through) Concepts</u>		
Allegheny		
1:25-1:55	NC-1: 40932-Photo Synthetic CO2 Migration	Ohio U
1:55-2:05	Q&A	
2:05-2:30	Scoring, written comments, and discussion	
2:35-3:05	NC-2: 40934-Seq. by Micro Algae Photosynthesis	Phys. Sci, Inc.
3:05-3:15	Q&A	
3:15-3:40	Scoring, written comments, and discussion	
3:45-4:00	Break	
4:00-4:30	NC-3: 41621-Adv. CO₂ Power Cycle Generation	FWDC
4:30-4:40	Q&A	
4:40-5:10	Scoring, written comments, and discussion	
5:15	Adjourn	
Armstrong-A		
6:00-7:00	Reception (Dinner on your own)	

Thursday Program—4/1/04

Allegheny		
7:00-8:00	Continental Breakfast	

Section VI: Sequestration - Terrestrial

8:00-8:30 **T-1: 40930-CO₂ Capture and Water Treatment** TVA
8:30-8:40 Q&A
8:40-9:05 Scoring, written comments, and discussion

9:10-9:40 **T-2: 41903-Seq. in Ohio Reclaimed Mine Soils** OSU
9:40-9:50 Q&A
9:50-10:15 Scoring, written comments, and discussion

10:15-10:30 Break

Closing Session with Reviewers and Program Managers³

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 16 projects to be reviewed, the CRTD staff and the ASME Project Review Executive committee in cooperation with the Program 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 Program Manager, the CRTD also worked extensively with ASME committees and their chairs to find qualified reviewers. Collected resumes were submitted to the CO₂ Project Review Executive Committee for review. Ten members were selected for the Project Review Panel:

- Dr. John R. Benemann, Consultant
- Dr. Garry Brewer, Yale University
- Dr. Robert C. Burruss, US Geological Survey
- Dr. John F. Clarke, University of Maryland
- Dr. Baldur Eliasson, IEA Committee
- Dr. Florencia Montagnini, Yale University
- Mr. Dale Simbeck, SFA Pacific, Inc.,
- Dr. Reuben Simoyi, Portland State University
- Dr. David Thomas, Consultant
- Dr. Raymond 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. Scoring and review comments were collected at that time. Panelists received an honorarium for their time as well as travel expenses.

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

Garry Brewer, Ph.D.

- Weyerhaeuser Chair, Joint Forestry and School of Management, Yale
- Previously member of the President's Nuclear Waste Technical Review Board
- Previously Dean, School of Environmental Sciences, U. of Michigan
- Founding member Swedish National Environmental Research Foundation and King Carl XVI Gustaf Professor of Environmental Sciences
- Focus: Economic and management implications of environmental strategies
- Located: Hew Haven, CT

Robert C. Burruss, Ph.D.

- Project Chief Assessment of Geological Reservoirs for Carbon Dioxide Sequestration, U.S. Geological Survey
- Project Scientist, North Alaska Petroleum Evaluations;
- Previously, Geochemistry Scientist, Gulf Oil Corp.
- Focus: Assessment of Repositories for Geologic Sequestration of CO₂
- Located: Reston, VA.

John F. Clarke, D.Sc.

- Joint Global Change Research Institute, University of Maryland
- Focus: application of conditional choice theory to the market competition of energy technologies in macro-economic models
- Previously: DOE Associate Director of Energy Research and Executive Director of DOE Climate Activities
- Located: College Park, MD

Baldur Eliasson, Ph.D.

- Head, Energy and Global Change Program, ABB, Switzerland
- Vice-Chairman, R&D Program on Greenhouse Gas Mitigation Technologies, International Energy Agency
- Board of Directors, European Climate Forum
- Steering Committee, International Project on Ocean Sequestration of CO₂
- Focus: Energy and Global Change Programs worldwide
- Located: Birmenstorf, Switzerland

Florenia 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

Dale Simbeck

- Founding Partner and VP Technology, SFA Pacific, Inc
- Heads company work in assessment of Greenhouse Gas mitigation costs and options
- Technical Peer Reviewer for Canadian Clean Power Coalition
- Focus: Technical and economic assessment, process design, and commercialization of energy technologies.
- Located: Mountain View, CA.

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

At the Project Review, the panel of reviewers was asked to comment on the projects presented in a number of ways. Providing an individual score for each project, based on predetermined scoring criteria, was the only quantitative method used. Following is a brief description about how scoring was done.

Criterion

The ASME team, in cooperation with the DOE Project Manager and the National Research Center for Coal and Energy developed a set of 10 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 CO₂ 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.

Scores

Reviewers were asked to consider these definitions carefully in assessing the progress and achievements of each project presented and then apply a “Score” for each criteria based on their own best judgment. Possible scores were divided into five discrete intervals: Unacceptable, Poor, Acceptable, Good, and Outstanding. These intervals were not continuous from 0 to 10 in order to force a somewhat wider spread among project scores, making it somewhat easier to see differences across the many projects reviewed.

The ASME team also worked with the National Research Center for Coal and Energy to assign weighting factors to each of the scoring intervals. This approach was taken to acknowledge that not all criteria are equal in importance. A perfect score is 1000. A blank copy of the Reviewer Scoring Sheet follows.

These Review 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. Reviewers commented that the economic information provided this year, as well as other project related information, was significantly improved based defining these criteria ahead of time to the PIs and presenters.

Reviewer Scoring Sheet

Project Code _____ Principal Investigator(s) _____

Reviewer _____

Criterion	Unacceptable	Poor	Acceptable	Good	Outstanding	
Project Merit:						Score Assigned:
1: Scientific and Technical Merit	0	40	100	160	200	_____
2: Anticipated Benefits if Successful	0	20	50	80	100	_____
Approach and Progress:						
3: Technical Approach	0	30	75	120	150	_____
4: Rate of Progress	0	20	50	80	100	_____
5: Knowledge of Related Research	0	20	50	80	100	_____
6: Economic Analysis	0	20	50	80	100	_____
7: Utilization of Government Resources	0	10	25	40	50	_____
Deployment Considerations:						
8: Commercialization Potential	0	20	50	80	100	_____
9: Possible Adverse Effects Considered	0	10	25	40	50	_____
10: Attention to Constituent's Concerns	0	10	25	40	50	_____

Total Score:

Reviewer

Comments: _____

If there are additional comments on back, please check here: _____