National Energy Technology Laboratory

Final Report
Carbon Sequestration
Project Review Meeting

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Volume I:
Meeting Summary and Recommendations

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Volume I. Meeting Summary and Recommendations

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 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 cooperation with the National Research Center for Coal and Energy at West Virginia University, on June 2, 2003, 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 total of 16 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 (longer for multi-participant teams) that was followed by a 10 -minute questions and answer session with the reviewers. Each reviewer using a predetermined set of review criteria numerically scored each project. Similar types of projects were discussed as a group by the reviewers and then rank-ordered. Following is a brief summary of key findings from this project review meeting.

Concerning the DOE Carbon Sequestration Technology Roadmap and Program Plan

The Project Review Panel received a briefing on the Sequestration "Roadmap" as background for the individual project reviews completed at this meeting. The reviewers very much appreciated having this background for the meeting and felt that the roadmap document as written provides good technical substantiation for such a review. Reviewers felt that, overall, there is an appropriate balance of projects in the Program and they were impressed to see so many industrial partners participating so early in such research.

In considering other uses for the roadmap itself the reviewers had two diverging comments. One line of thinking wished to see a document for the public that is far smaller and much more along the lines of a *Science Magazine* type of layout. The goal of this document would be to focus on the "big picture" concerning the underlying justification of Carbon Sequestration research.

An opposite line of thinking wished to see a document that would be much more forceful in driving the research agenda, including goals, objectives, budgets, and schedules for individual projects. This document would be much more a day-to-day management tool for guiding the program.

An Overall Comparison of Research Categories

The 16 projects reviewed fell into four categories: Geologic Related, Capture Related, Terrestrial Related, and Novel Concepts. With a perfect score being 1000 points, the average scores from reviewers were as follows:

- Geologic Related Projects 726
- Capture Related Projects 635
- Terrestrial Related Projects 623
- Novel concepts 474

It is important to remember that these category rankings are based solely on the projects selected for review at this session and do not constitute a review or a ranking of the entire portfolio of projects in the NETL program.

Geologic Sequestration Projects

Geologic projects are clearly the 'crown jewels' of this Program. They are significant and important and can be done even without a new scientific breakthrough. This technology may be the best long-term solution for sequestering large amounts of CO_2 but there are many major problems to be solved. The question of how to transport CO_2 economically to the wellhead has yet to be resolved. And, there needs to be more discussion of the long-term safety of the geologic sequestration approach.

Enhanced oil recovery (EOR) and enhanced coal bed methane (ECBM) could both move quickly as sequestration strategies if the economic aspects of their deployment are favorable. More information is needed about the potential ramifications of pumping large amounts of acidic fluids—like CO_2—into core rock like Mt. Simon sandstone. This would be a useful new area of research. There needs to be more work assessing saline aquifers in general.

Capture Related Projects

Capture is the key issue in sequestration but, unfortunately, it has possibly the greatest set of stumbling blocks. Capture technology is very difficult. It is based on standard chemical engineering technologies that have deployed for many years. There are likely to be no easy answers to improving these technologies and a scientific "breakthrough" will be difficult. It is appropriate to spend government resources on basic research in this regard. Many reviewers felt that this area is the most important part of the program. It is step one to decreasing emissions.

Terrestrial Sequestration Projects

Terrestrial sequestration is an important technology because it is cheapest and it is the readily implementable with few negative ramifications. Many on the Review Panel were unclear about the long-term potential for terrestrial sequestration. The argument was made strongly at the meeting that terrestrial sequestration is happening now through afforestation, reforestation, and sequestration in soils. More work needs to be done to explain the overall benefits of this approach to sequestration--the overall, cross-cutting analysis that establishes this technology as a viable way to sequester carbon.

Terrestrial projects will include hundreds of projects over thousands of acres all over the world. This DOE Program can support only a small part of that total. It is appropriate, therefore, for the Program to focus on degraded mining lands. These projects start with sites having no appreciable biomass and all of the carbon sequestered counts in an environmental assessment of sequestering new amounts of carbon. Although tropical forests may have very good growth rates, forests in the temperate US also have a role to play.

Novel Concepts

The Program was well advised to look into the various aspects of mineral sequestration. However, given all of its general and technical problems, it does not merit additional person-years of effort. Mineral sequestration is an attractive technology, but the deployment of this technology has major drawbacks —principally the shortage of serpentine in the world and the presence of asbestos, a hazardous mineral, in the geological formations that would be mined for serpentine. The consensus of the reviewers is that this technology will not be viable from an economic feasibility perspective and no additional funding should be directed to this program area.

Recommendations for Future Project Reviews

Both Review Panel members and DOE managers involved in the Project Review offered constructive comments about how the review process has worked to date and how it might be modified in the future. These comments are included at the end of this report and will be used in the planning of future Project Reviews.

The Panel works well as a team with complementary expertise and has developed a team identity do to the fact that most members have served on two reviews to date. Consideration should be given to maintaining a continuity of experienced reviewers as new team members might be added to cover additional areas of research. The use of an independent panel overseen by a respected technical society adds credibility to the review and enables the NETL managers to draw upon outside views in formulating their internal assessments of the merits and progress of each project.

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

I. Introduction

For the second year in a row, the U.S. Department of Energy (DOE), through the National Energy Technology Laboratory (NETL), asked the American Society of Mechanical Engineers (ASME) to provide an independent, unbiased, and timely review of 16 selected projects within the DOE Carbon Sequestration Program. This report contains a summary of the findings from that review.

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 for each assignment that is responsible for selecting all Review Panel members and insuring that there are no conflicts of interest within the panel or the review process. In consultation with DOE managers, ASME is responsible for organizing the review meeting agenda, advising DOE 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 DOE Program Manager, 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. Although only part of the review process (written reviewer comments are also collected), this numeric scoring process does make it relatively easy to compare projects both within their own category of research as well as across categories. 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 Review Comments on the DOE Carbon Sequestration Roadmap
   A summary of general comments from reviewers about the overall DOE Carbon Sequestration "Roadmap."

III. Project Review Comments for 2003
   A summary of key findings about the 16 projects reviewed at this meeting and general conclusions about the various categories of sequestration research.

IV. Comparing 2003 Scores with 2002
   General comments on how this year's scores compared to last year.

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

II. General Review Comments on the DOE Carbon Sequestration 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 or the Sequestration Program. 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.

Reviewer Roadmap Comments

The following items present a composite view of the Sequestration Roadmap in the reviewer's own words:

- "It was a big and constructive step to start the meeting with an overview of the current Carbon Sequestration Roadmap. With the benefit of the Roadmap, it was easier to judge projects this year as part of a portfolio. There is a nice balance of projects. I was impressed to see so many industrial partners so early."
- "However, even though the Roadmap is perfect background for a technical review like this, it is not yet in a form that can be easily digested by the public. DOE should try for the one-page, *Science Magazine* style summary that is the big picture of the big picture. It would also be good to see an even simpler matrix coming out of the Roadmap."
- "The Roadmap is coming up to a turning point. There must be the right balance among basic, applied, lab-scale, pilot-scale, and demonstration-scale research. At this moment in Sequestration research, DOE managers are like venture capitalists investing in high-risk research. It is all right for results to take time but the potential for success must be clear. Until now, it has been appropriate for the Roadmap to show great diversity. Now, the blind alleys are becoming apparent. It is important that all the blind alleys be exhausted. Because DOE doesn't have an infinite budget for Sequestration research, it is time to begin to trim unpromising research paths and to focus on the most promising paths. It may be time to begin to realign and rebalance the portfolio."
- "One way to enhance work at the margins in a constructive way is to team weaker projects in a topical area with stronger projects--encourage cross fertilization and perhaps joint work."
- "A criticism of the Roadmap is that not all of the projects presented have a clear or even potential application. For example, when Louis Pasteur solved the problem of spoiled milk, he had an instant market for his technical solution—the milk industry. The "driver" for this research, the "instant market," is not clear."
- "The current Roadmap is not a driving document. The research plan should set goals and objectives for individual projects, set schedules and budgets, and hold researchers accountable for achieving these goals."

III. Project Review Comments for 2003

Following is a summary of the key findings from the Project Review based on an analysis of reviewer scores. Many of the rankings presented here are based on a simple average of the reviewer scores received. In most cases, the range of scores is also shown by providing both the highest and lowest score received. Some care must be taken in looking at scores for categories of projects versus the individual projects themselves. The footnotes provided should be helpful in this regard. Projects are presented only by the project number used at the review meeting and by a simplified title. For further project related information, please contact the DOE team.

A Comparison of Overall Scores for All Research Categories

In a Comparison of Research Categories, Geologic Sequestration Did Best.

Of the four overall program elements reviewed in 2003: Geologic Sequestration rated the highest by nearly 100 points; Capture and Terrestrial were so close as to be virtually equal for the second and third ranking; and Novel Concepts ranked a distant fourth.

2003 DOE Carbon Sequestration Project Review
Comparison of Overall Categories Based on Reviewer Scores
(1000 is the maximum possible score.)

Rank	Project #	Title	Cat.[1] Low	Cat.[2] Avg.	Cat.[3] High
1	G-1 thru G-4	Geologic Related Projects	230	726	940
2	C-1 thru C-5	Capture Related Projects	235	635	890
3	T-1 thru T-5	Terrestrial Related Projects	250	623	940
4	NC1 thru NC2	Novel Concepts	135	474	865

[1] Category Low: the lowest single score out of all reviewers and all projects in the category.
[2] Category Avg: the simple average of all scores given by all reviewers for the category.
[3] Category High: the highest single score out of all reviewers and all projects in the category.

Overall, Project Scores Grouped Reasonably Well into Four Tiers.

In comparing the average scores of all 16 projects together, there were: four First Tier projects (scoring 700-850); four Second Tier projects (scoring in the 600s); five Third Tier projects (scoring in the 500s); and three Fourth Tier projects (scoring in the 400s).

2003 DOE Carbon Sequestration Project Review
Comparison of All Projects Based on Reviewer Scores
(1000 is the maximum possible score.)

Rank	Project #	Title	Proj[1] Low	Proj[2] Avg.	Proj[3] High	
1.	G-1	Optimal Disposal in Saline Aquifers	630	849	940	
2.	G-3	Sequestration in Deep, Unmineable Coal	330	787	960	(700s/
3.	G-2	Evaluation of Deep Saline Formations	415	784	980	800s)
4.	T-5	Sustainable Forests on Mined Lands	430	744	915	
5.	C-1	Separating CO_2 from Syngas Using Hydrates	370	697	890	
6.	C-5	Selective Ceramic Membrane for Recovery	555	670	890	(600s)
7.	T-2	Applied Terrestrial Sequestration	290	663	940	
8.	C-3	Emissions Control by Oxygen Firing	235	623	835	
9.	C-2	Advanced Oxyfuel Boilers	265	598	780	
10.	T-4	Sequestration on Surface Mine Lands	380	596	945	
11.	C-4	Capture Using Dry Regenerable Sorbents	285	587	725	(500s)
12.	T-1	Development of Appropriate Tools	335	571	735	
13.	T-3	Reclamation of Abandoned Mine Lands	250	543	885	
14.	NC-1	Mineral Sequestration	255	486	760	
15.	G-4	Enhancing Methane Production	230	483	730	(400s)
16.	NC-2	Sequestration by Mineral Carbonation	135	461	865	

[1] Project Low: lowest project score out of the nine reviewers.
[2] Project Avg: average of all nine scores for the projects.
[3] Project High: highest project score out of all nine reviewers.

Geologic Sequestration Projects

<u>Among Geologic projects: Scoring was highly consistent across all methods; G-1, G-2, and G-3 all ranked very high; but G-4 ranked very poorly.</u>

Reviewer Comments are summarized in the list below:

- "Geologic projects are clearly the 'crown jewels' of this Program. They are significant and important and can be done even without a breakthrough. This may be the best long-term solution to sequestering large amounts of CO_2 but there are lots of major problems to be solved. Can the transport questions be solved economically."
- "Enhanced oil recovery (EOR) and enhanced coal bed methane (ECBM) could both move quickly as sequestration strategies if the economics work. We don't know a lot about the effect from pumping large amounts of acidic fluids—like CO_2—into core rock like Mt. Simon sandstone. This would be a useful new area of research. And, we do need to take some 'baby steps' in assessing saline aquifers in general as suitable for sequestration. We can pick the best aquifers later."
- "The US clearly likes the geologic sequestration option. But I missed the discussion of safety. There is no problem putting CO_2 into the ground. The problem is the potential of an unpleasant 'burp' sometime in the future."

Comparison of <u>Geologic</u> Projects Based on Reviewer Scores

(1000 is the maximum possible score)

Rank	Project #	Title	Proj Low	Proj Avg.	Proj High
1.	G-1	Optimal Disposal in Saline Aquifers	630	849	940
2.	G-3	Sequestration in Deep, Unmineable Coal	330	787	960
3.	G-2	Evaluation of Deep Saline Formations	415	784	980
4.	G-4	Enhancing Methane Production	230	483	730

Comparative Rankings:

Rank:	Total Score (Rating Factors x Weighting Factors)	Raw Score (Rating Factors Only)	By Discussion Among Reviewers
First:	G-1	G-1	G-1
Second:	G-3	G-2	G-2
	(Very Close Scores)		
Third:	G-2	G-3	G-3
Fourth:	G-4	G-4	G-4

(Note: In this case, the scores between G-2 and G-3 were so close as to make the switch in ranking based on weighting factors to be marginally meaningful.)

Capture Projects:

Among Capture projects, C-1 was the standout for high and consistent rankings. Group discussions changed the ranking order in this category more than any other. C-2 benefited most from a second look during group discussion while both C-5 and C-3 fell.

Reviewer Comments are summarized in the list below:

- "Capture is the key issue in Sequestration with possibly the greatest set of stumbling blocks. There is no sequestration solution without capture. Capture technology is very difficult. It is based on standard chemical engineering that has been looked at for many years. There are no easy answers so having a breakthrough will be difficult. It is OK to spend some money on basic research. Get some help from other parts of DOE for this if necessary. This is the most important part of the program. It is step one to decreasing emissions."
- "The research teams need to more carefully draw the baseline of what it is possible to do today. Although amine systems have been proven so far, innovation is still needed. The basic and applied science and the membrane work going on in these projects are on the cutting edge."

Comparison of Capture Projects Based on Reviewer Scores
(1000 is the maximum possible score.)

Rank	Project #	Title	Proj Low	Proj Avg.	Proj High
1.	C-1	Separating CO_2 from Syngas Using Hydrates	370	697	890
2.	C-5	Selective Ceramic Membrane for Recovery	555	670	890
3.	C-3	Emissions Control by Oxygen Firing	235	623	835
4.	C-2	Advanced Oxyfuel Boilers	265	598	780
5.	C-4	Capture Using Dry Regenerable Sorbents	285	587	725

Comparative Rankings:

Rank:	Total Score (Rating Factors x Weighting Factors)	Raw Score (Rating Factors Only)	By Discussion Among Reviewers
First:	C-1	C-1	C-1
Second:	C-5	C-5	C-2
Third:	C-3	C-3	C-5
Fourth:	C-2	C-2	C-4
Fifth:	C-4	C-4	C-3

(Note that in this case, project rankings were significantly changed by reviewer group discussions.)

Terrestrial Sequestration Projects

Among Terrestrial projects: there was high scoring consistency across all scoring methods. Rankings did not change as a result of discussions. Terrestrial projects showed the largest spread over the 16 projects reviewed—from near the top to near the bottom.

Reviewer Comments are summarized in the list below:

- "Terrestrial is an important solution because it is cheapest and it is where we start. Many on the Review Panel are skeptical of the potential for terrestrial sequestration. But it is happening now through afforestation, reforestation, and sequestration in soils. More needs to be done to explain the overall benefits of this approach to sequestration."
- "I saw lots of operational information in the terrestrial projects presented but I am still missing the overall, cross-cutting analysis that establishes this technology as a viable way to sequester carbon. How well does it work at steady state?"
- "Terrestrial projects will include hundreds of projects over thousands of acres all over the world. This Program can do only a small piece of that. It is sensible for this Program to focus on degraded mining lands. These projects start with a clean slate and all of the carbon sequestered counts. Although tropical forests may have very good growth rates, forests in the temperate US have a role to play. Forget about biomass conversion and go for the trees!"

Comparison of Terrestrial Projects Based on Reviewer Scores
(1000 is the maximum possible score.)

Rank	Project #	Title	Proj Low	Proj Avg.	Proj High
1.	T-5	Sustainable Forests on Mined Lands	430	744	915
2.	T-2	Applied Terrestrial Sequestration	290	663	940
3.	T-4	Sequestration on Surface Mine Lands	380	596	945
4.	T-1	Development of Appropriate Tools	335	571	735
5.	T-3	Reclamation of Abandoned Mine Lands	250	543	885

Comparative Rankings:

Rank:	Total Score (Rating Factors x Weighting Factors)	Raw Score (Rating Factors Only)	By Discussion Among Reviewers
First:	T-5	T-5	T-5
Second:	T-2	T-2	T-2
Third:	T-4	T-1	T-4
Fourth:	T-1	T-4	T-1
Fifth:	T-3	T-3	T-3

Novel Concepts

Among Novel Concepts: reviewers saw little distinction between the two projects presented. Both projects ranked at the bottom of the 16 projects reviewed.

Reviewer Comments are summarized in the list below:

- "The Program was well advised to look into the various aspects of mineral sequestration. However, given all of the general and technical problems, it does not merit additional person-years of effort. Even though the mineralization teams were better this year than last, it is still a nice idea with huge problems. It will never work. No more money should be put into this."
- "There are some good teams here, but it is time to change the business plan. It is time for a real brainstorming workshop--including industry, academia, and the national labs—to get some other truly novel concepts developed."

Comparison of Novel Concept Projects Based on Reviewer Scores
(1000 is the maximum possible score.)

Rank	Project #	Title	Proj Low	Proj Avg.	Proj High
1.	NC-1	Mineral Sequestration	255	486	760
2.	NC-2	Sequestration by Mineral Carbonation	135	461	865

Comparative Rankings:

Rank:	Total Score (Rating Factors x Weighting Factors)	Raw Score (Rating Factors Only)	By Discussion Among Reviewers
First:	NC-1	NC-1	(Not Done)
Second:	NC-2	NC-2	

IV. Comparison of 2003 Scores with 2002

It is difficult to make any sort of precise comparison of project review scores from one year to the next. The Review Panel does not have the same members. The selection of projects to be reviewed can be quite different. Individual project teams can show a wide variation in the quality of their presentations.

Nevertheless, on a very qualitative level, it is interesting to look at scores from last year, compare them to this year, and make some observations. The next page provides a summary of all the scores from 2002. Compare this to the summary of all the scores from 2003 (found at the beginning of Section III). Following are three simple observations, among many, that can be taken from this comparison:

<u>Comparing the Mix of Projects in the Top Tier (Projects Scoring over 700):</u>

- In 2002: Geologic, Capture, Ocean, and Advanced Concepts all had projects in the top tier.
- In 2003: Geologic dominated the top tier with three projects and Terrestrial broke into the top tier for the first time with one project.

<u>The Capture group of projects ranked better in 2002:</u>

- In 2002: Capture had three projects in the top tier.
- In 2003: Capture had no projects in the top tier.
  (To be fair, the projects reviewed in this category in 2003 were very different from the projects reviewed in 2002).

<u>Advanced or Novel Concepts fell significantly this year:</u>

- In 2002: Advanced Concepts ranked in the high, medium and low tiers.
- In 2003: Novel Concepts ranked only in the lowest tier.

In general, scores showed a wide range. There was typically a wide range between highest and lowest scores. The average score per project shifted significantly throughout the range from highest to lowest, suggesting that there were groupings of reviewers who agreed but there were always significant outliers.

It appears that the scoring mechanism—using both discreet intervals for reviewers and weighting factors—did help to separate scores. As was the case last year, the scores have a fairly nice continuum but can be broken fairly easily into tiers relative to one another.

A quick check against last year suggests that our reviewers may be scoring a little harder in general:

- Last year 8 of 22 projects (36%) scored over 700.
- This year 4 of 16 projects (25%) scored over 700.

Provided for Comparison Only

2002 Carbon Sequestration Project Review

Comparison of All Projects Based on Reviewer Scores
(1000 is the maximum possible score.)

Rank	Project #	Title	Proj Low	Proj Avg.	Proj High	
1.	G-2	Geologic Sequestration of CO2	545	857	1000	
2.	C-1	Thermally Optimized Membranes	710	822	1000	(800's)
3.	C-5	Sorbent Development for CO2	650	808	960	
4.	O-1	Explor. Measurements of Hydrates	555	787	970	
5.	O-2	Oceanic Sequestration	695	777	880	
6.	C-3	Eval. Of CO2 Capture/Util/Disp	635	775	870	(700's)
7.	G-1	Seques. In Depleted Oil Reserves	620	736	910	
8.	AC-3	Mineral Carbonation	275	712	970	
9.	G-8	Monitoring Techniques for Geo. Seq.	480	692	910	
10.	T-2	Ecosystem Dynamics	470	669	970	
11.	T-1	Enhancing Seq. and Reclamation	270	653	835	(600's)
12.	AC-2	Mineral Sequestration	303	650	930	
13.	T-3	Advanced Plant Growth	425	635	840	
14.	G-7	Pore-Level Modeling	440	616	910	
15.	G-6	High Performance Algorithms	0	584	740	
16.	G-5	Field Research Facility	380	568	755	
17.	G-9	Comp. Equation of State	250	555	800	(500's)
18.	G-3	Coal Seam Sequestration	200	540	620	
19.	C-4	Electrochemical Devices	230	531	770	
20.	G-4	Geo. Seq. Simulation Facility	150	478	650	
21.	AC-1	Structured Microorganisms	200	442	755	(400's)
22.	C-2	Vortex Tube & Demo	200	415	695	

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 to be used when planning future project review sessions.

<u>It appears beneficial to have a broad-based Review Panel.</u>

The review panel as seated for this meeting drew praise as a good interdisciplinary group. There appeared to be good “chemistry” among well-respected colleagues. This was seen as a gathering of world experts to address an incredibly complex problem, which they did with impartiality. Panel members said they felt comfortable and were encouraged to comment. Given the wide range of topics to be addressed, the panel must have and rely upon complementary strengths.

Checking the reviewer’s scoring habits by their professional orientation gave some interesting results:

- Academics collectively gave the highest scores.
- Government and non-profit oriented reviewers gave mid-range scores.
- Private sector reviewers were the toughest scorers.

Although not surprising, this simple finding does underline the need to keep balance on the review panel across these three professional orientations.

2003 DOE Carbon Sequestration Project Review
Comparison of Reviewer Scores Based on Professional Orientation
(1000 is the maximum possible score.)

Professional Orientation	**Avg. Low**	**Avg.**	**Avg. High**
Academics: (Benemann, Brewer, Montagnini, Simoyi)	484	700	921
Govt./Non-Profit: (Finley, Clarke)	325	666	870
Private Sector: (Eliasson, Thomas, Zahradnik)	280	518	818

Avg. Low: Average of all low scores of reviewers in the group.
Avg.: Average of all scores of reviewers in the group.
Avg. High: Average of all high scores of reviewers in the group.

[Editor’s Note: There are not enough data points to suggest that this analysis is statistically significant. However, it does at least suggest that it is important to have a variety of professional perspectives on any review panel and that some care should be taken to see that these perspectives are well balanced.]

The ASME team did provide a fully independent Project Review Panel. This panel was encouraged to speak freely. It was generally agreed that the panel provided frank and open comments on all projects to the general benefit of the NETL and DOE managers. It was further agreed that valuable information was exchanged: from projects to the reviewers; from the reviewers to NETL and DOE management; and among project teams. This is a worthwhile exchange of information and should continue on a regular basis.

Following is a summary of reviewer comments concerning various aspects of the meeting.

<u>Pre-Meeting Documentation</u>

- "Some of these descriptions were highly valuable but some were unreadable. The 10-pagers provided the main issues ahead of time so that I could prepare. I would like to see a consistent form up front for all projects that stated both project budget and schedule status. We must see the budget for each project. (Mentioned by many.) And we must have a graphic or statement explaining where the project currently stands relative to the overall planned duration." (Mentioned by many.) It would also be good for researchers to show where they fit into the overall Program."

<u>Meeting Agenda and Facilitation</u>

- "The organization and support of this meeting are excellent. I was pleased to see both of the NETL managers present and listening through the whole review. It boosted morale and improved the process."
- "Sixteen is a nice group of projects to review. The 22 projects done last year were too many. All presenters should have an equal time allocation. Ten minutes is sufficient for the Q&A." (Agreed by many.)

[Editor's Note: The consensus of all participants was that the meeting format is working well and shouldn't be changed. The number of projects chosen for review this year fit the two and a half-day time frame better than last year. It was very beneficial to start with an overview of the Program Roadmap.]

<u>Scoring and Scoring Sheets</u>

- "It is necessary to have a scoring sheet to force conclusions about the relative merits of various projects. This one is fine and better than last year."
- "Three categories on the back page—Commercialization Potential, Adverse Effects, and Constituent Groups—were not equally applicable to

all projects. In some cases I had to force these scores to be consistent. I was really done scoring by the time I turned over the page."

[Editor's Note: Interestingly, there was virtually no difference between rankings using the 1000-point scale with weighting factors and the 100-point scale of "raw scores" given by the reviewers before weightings were applied. In the case of the Capture group of projects, the discussion by reviewers appears to have had a significant effect on changing the ranking of projects. In the other categories of projects, discussions appear to have had less effect.]

<u>International Scientific Units</u>

- "Presenters must use international scientific units. I know it is difficult but they must keep trying. The use of international units must be taken seriously. This goes without question for all serious journals. To do otherwise shows a lack of respect."

<u>Economic Analysis by the Presenting Teams</u>

- "Compared to last year, I was pleasantly surprised to see that every team at least tried to present some economic analysis. DOE must keep economic considerations in the face of every team to prevent them from simply getting lost in the technical woods. Economic analysis should be ongoing at the projects and should be used to drive decisions. It is the deciding factor for any applied research program."

<u>Outreach to Stakeholders and the Public</u>

- "Researchers still need to be more aware of stakeholders—academia, labs, industry, and most importantly the public. Greenhouse gasses are a growing concern for everyone. Outreach was sorely missing last year and was at least addressed this year.
- "But, attention to this varied significantly across teams. The team from Battelle had a comprehensive and sophisticated approach to this issue. Consider having them do a handbook, workshop, or other training process for other projects in the program."
- "Outreach pays for itself in goodwill. Any industrial project the size of these would have a full time staff person working on outreach. These projects probably can't afford that. But, at least get some bright young people to help. Not every project needs a PR department. But, outreach is a public service and should be part of every PI's evaluation."

Commercialization

- "Results from presenters were mixed on this. Some were good but most had not seriously considered it."

Publications

- "In many scientific endeavors, quality is judged by publications—either as juried articles or as patents. There is no such driver for this Program. I would like to see more emphasis put on publishing what comes out of this Program. I would also like to see anything previously published as part of the introductory material provided for projects to be reviewed."

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 Program 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 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.

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 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 CO_2 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 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 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. 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 Program 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. Projects with large teams were granted additional time. All presentations were to be in Power Point format. A projector was provided at the meeting site.

At the meeting itself, presenters were held to strict time limits 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 Q&A.

Following each presentation, 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
- Possible Adverse Effects Considered
- Attention to Constituent Groups Concerns.

Each of these categories is defined on the scoring sheet (see Appendix D). Reviewers gave a Rating Factor from 0 to 10. When combined with Weighting Factors developed in cooperation with the DOE Program staff, a score up to 1000 could be achieved. Results of this scoring process are reported in Section II of this report.

The 16 projects were divided into four groups of relatively similar projects as follows:

- Capture and related projects (5 projects)
- Novel Concepts (2 projects)
- Geologic Sequestration (4 projects)
- Terrestrial Sequestration (5 projects).

After reviewing each group of projects, the Review Panel would discuss both the group in general and each project specifically. At the end of this discussion, the Panel would rank order the projects. The results of these discussions and the rankings are reported in Sections II and III.

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

Appendix B

Meeting Agenda

2^{nd} Annual Carbon Sequestration Project Review Schedule

Monday Evening Program—6/2/03			**Room**
4:30-6:00	Project Review Panel Orientation	NETL/ASME/Panel	**Wright-A&B**
6:00-8:00	Welcome Reception and Registration	All	**Yeager-A**

Tuesday Program – 6/3/03			**Allegheny**
	Presenters Ready Room – **Foerster Room** **(LCD projector available in this room for laptop testing.)**		
7:00-8:00	Continental Breakfast		
8:00-8:30	DOE/NETL Carbon Sequestration Overview	Klara	
8:30-8:45	Q&A		
Section I: Capture of $C0_2$			**Allegheny**
8:45-9:30	C-1: Hydrate Process for Gas Separation		
9:30-9:40	Q&A		
9:45-10:00	Break-(Coffee outside Allegheny Room.)		
10:00-10:45	C-2: Oxyfuel Boilers		
10:45-10:55	Q&A		
11:00-11:45	C-3: Emissions Control by Oxygen Firing		
11:45-11:55	Q&A		
12:00-12:30	Lunch (Provided for Review Team Only)		**Wright-B**
12:30-1:00	C-4: Capture Using Dry Regenerable Sorbents		**Allegheny**
1:00-1:10	Q&A		
1:15-1:45	C-5: Selective Membrane for Recovery		
1:45-1:55	Q&A		
2:00-3:00	Discussion and Ranking of Projects in Category C		
3:00	Break (Snacks outside Allegheny Room.)		

Section II: Novel Concepts		**Allegheny**
3:30-4:00	NC-1: Mineral Sequestration	
4:00-4:10	Q&A	
4:15-4:45	NC-2: Sequestration by Mineral Carbonation	
4:45-4:55	Q&A	
5:00-5:30	Discussion and Ranking of Projects in Category NC	
5:30	Adjourn	
6:30	Reception	**Wright-A&B**
7:00	Dinner for all participants	
Wednesday Program—6/4/03		**Allegheny**
	Presenters Ready Room – **Foerster Room** (LCD projector available in this room for laptop testing.)	
7:00-8:00	Continental Breakfast	
Section III: Geological Sequestration		**Allegheny**
8:00-8:45	G-1: Optimal Disposal in Saline	
8:45-8:55	Q&A	
9:00-9:45	G-2: Evaluation of Deep Saline Formations	
9:45-9:55	Q&A	
10:00	Break-(Coffee outside Allegheny Room.)	
10:15-11:00	G-3: Sequestration in Deep, Unmineable Coal	
11:00-11:10	Q&A	
11:15-11:45	G-4: Enhancing Methane Production	
11:45-11:55	Q&A	
12:00-1:00	Working Lunch, Discussion and Ranking of Projects in Category G	**Wright-B**

Section IV: Terrestrial Sequestration **Allegheny**

1:00-1:30	T-1: Development of Appropriate Tools
1:30-1:40	Q&A
1:45-2:15	T-2: Applied Terrestrial Sequestration
2:15-2:25	Q&A
2:30-3:00	T-3: Reclamation of Abandoned Mine Lands
3:00-3:10	Q&A
3:15	Break-(Snacks outside Allegheny Room.)
3:30-4:00	T-4: Sequestration on Surface Mine Lands
4:00-4:10	Q&A
4:15-4:45	T-5: Sustainable Forests on Mined Lands
4:45-4:55	Q&A
5:00-5:45	Discussion and Ranking of Projects in Category T
5:45	Adjourn
6:30-7:30	Reception (Dinner on your own) **Armstrong-A**

Thursday Program—6/5/03 **Allegheny**

7:00-8:00 Continental Breakfast

Closing Session with Reviewers and Program Managers
Allegheny

8:00-10:30	Summary Comments from Reviewers (15 min. each)
10:30-11:00	Comments from DOE and NETL Managers
11:00	Adjourn

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 CO_2 Project Review Executive Committee for review. Nine members were selected for the Project Review Panel:

- Dr. John R. Benemann, Consultant
- Dr. Garry Brewer, Yale University
- Dr. John F. Clarke, University of Maryland
- Dr. Baldur Eliasson, IEA Committee
- Dr. Robert Finley, Illinois State Geological Survey
- Dr. Florencia Montagnini, Yale University
- Dr. Reuben Simoyi, Portland State University
- Dr. David Thomas, Consultant
- Dr. Raymond Zahradnik, Consultant

A very 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 a small honorarium for their time as well as travel expenses.

John R. Benemann, Ph.D.

- Consultant
- 1993-2000: Associate Research Engineer, Department of Civil Engineering and Plant Microbial Biology, University of California-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 University
- 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: New Haven, CT

John F. Clarke, D.Sc

- Joint Global Change Research Institute, University of Maryland
- Previously: 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: College Park, MD

Baldur Eliasson Ph.D.

- Former 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 CO_2
- Focus: Energy and Global Change Programs worldwide
- Located: Birmenstorf, Switzerland

Robert Finley, Ph.D.

- Senior Geologist and Head, Economic Geology Group, Illinois State Geological Survey
- Geological Consultant, U.S. Energy Information Administration
- Focus: Characterization of subsurface reservoir frameworks; natural gas, oil, and coalbed methane resource assessment and world energy resources
- Located: Champaign, IL

Florencia Montagnini, Ph.D

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

Reuben Simoyi, Ph.D.

- Professor, Department of Chemistry, Portland State University
- American Chemical Society, American Physical Society, and Royal Society of Chemistry
- Focus: Computer modeling and mathematics related to chemistry
- Located: Portland, OR

David Thomas, Ph.D.

- Consultant
- Previously, 24 years with BP Amoco Corp, including Manager, CO_2 Mitigation Technology, Green Operations
- Focus: CO_2 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 developed a set of 10 review criteria to be applied to each project. Based on input from reviewers at the 2002 Project Review, these Review Criteria were significantly reworked and expanded. They were defined as follows:

Project Merit:

Scientific and Technical Merit

- The underlying project concept is scientifically sound.
- Substantial progress or even a breakthrough is possible.
- A truly innovative approach to the long-term capture, disposal, and storage of greenhouse gasses.

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

Technical Approach

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

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.

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.
- No duplication of on-going research by others.

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.

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

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 and remedies or additional research seem reasonable.

Possible Adverse Effects Considered

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

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.

Reviewers were asked to consider these definitions carefully in assessing the progress and achievements of each project presented and then apply a “Rating Factor” for each criteria based on their own best judgment.

These Review Criteria were 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 addresses one on 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 on the spelling out of these criteria ahead of time to the PIs and presenters.

Rating Factors

Rating factors were also defined ahead of the meeting and provided to reviewers for their use at the meeting. Definitions were as follows:

10…Strengths substantially greater than weaknesses. (Outstanding)
8… Strengths outweigh weaknesses but there are concerns. (Good.)
5….Strengths equal weaknesses. (Acceptable)
2….Significant weakness outweigh strengths. (Poor)
0….Weaknesses substantially greater than strengths. (Unacceptable.)

Note that the rating factors are in discrete intervals and not continuous from 0 to 10. This was done on purpose to force a somewhat wider spread among project scores, making it a bit easier to see differences in scores across many projects.

Weighting Factors

The ASME team also worked with the DOE Project Manager to assign weighting factors to the scoring criteria. This was done to acknowledge that not all criteria are equal in importance. Although somewhat subjective, this is another way of demonstrating where DOE project managers are putting emphasis on the projects in their programs. In order of importance, the weighting factors used in this review were as follows:

Scientific and Technical Merit	20
Technical Approach	15
Anticipated Benefits if Successful	10
Rate of Progress	10
Knowledge of Related Research	10
Economic Analysis	10
Commercialization Potential	10
Overall Utilization of Government Resources	5
Possible Adverse Effects Considered	5
Attention to Constituent Groups Concerns	5
Total of Weighting Factors:	100

Weighting factors were not provided to the project teams ahead of the meeting so as to reduce the risk of presenters trying to "game" the scoring system.

Score

Total score for a project is the sum of the products of the rating score times the weighting factor for each criterion (Rating x Weight = Score). A perfect score is 1000 (100 points from Rating Factors given by reviewers x 100 weighting points). A blank copy of the Reviewer Scoring Sheet follows.

Reviewer Scoring Sheet

Project Code________ Principal Investigator(s)______________________________

Reviewer____

Criterion	**Rating[1]**	**Weight**	**Score[2]**

A: Project Merit:

A-1: Scientific and Technical Merit **x 20=**

- The underlying project concept is scientifically sound.
- Substantial progress or even a breakthrough is possible.
- A truly innovative approach to the long-term capture, disposal, and storage of greenhouse gasses.

A-2: Anticipated Benefits if Successful **x10=**

- 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.

B: Approach and Progress

B-3: Technical Approach **x15=**

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

B-4: Rate of Progress **x10=**

- 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.

B-5: Knowledge of Related Research **x10=**

- Familiar with relevant literature in the field.
- Up to date with reference citations.
- In communication with other experts in this field.
- No duplication of on-going research by others.

B-6: Economic Analysis **x10=**

- 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.

B-7: Overall Utilization of Government Resources **x5=**

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

____

Page 1 Sub-Total:

(Back of Sheet)

Rating[1] Weight Score[2]

C: Deployment Considerations

C-8: Commercialization Potential **x10=**

- 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 and remedies or additional research seem reasonable.

C-9: Possible Adverse Effects Considered **x5=**

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

C-10: Attention to Constituent Groups Concerns **x5=**

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

Total Scores:

Reviewer Comments:

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[1]**Rating Factors: 10**…Strengths substantially greater than weaknesses. (Outstanding)
8… Strengths outweigh weaknesses but there are concerns. (Good.)
5….Strengths equal weaknesses. (Acceptable)
2….Significant weakness outweigh strengths. (Poor)
0….Weaknesses substantially greater than strengths. (Unacceptable.)

[2]**Rating x Weight = Score**