OVERVIEW REPORT

DOE/NETL Clean Coal Research Program
Gasification Systems Program
FY2014 Peer Review Meeting

Pittsburgh, Pennsylvania
May 21-23, 2014

ASM INTERNATIONAL

OVERVIEW REPORT
CLEAN COAL RESEARCH PROGRAM
GASIFICATION SYSTEMS PROGRAM
FY2014 PEER REVIEW MEETING

Pittsburgh, Pennsylvania
May 21–23, 2014

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Work Performed for U.S Department of Energy, Office of Fossil Energy, National Energy Technology Laboratory Under
Prime Contract DE-FE0004002 (Subtask 300.02.02)

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The work performed on this task/subtask was completed under Leonardo Technologies, Inc. (LTI), Prime Contract DE-FE0004002 (Subtask 300.02.02) for DOE-NETL.

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INTRODUCTION AND BACKGROUND

Gasification Systems Program Mission and Goals

Gasification is used to convert solid feedstock (e.g., coal, petcoke, or biomass) into synthesis gas (syngas), which for oxygen-blown gasification primarily comprises hydrogen and carbon monoxide (CO). This process enables pollutants to be captured and disposed of or converted to useful products more easily than the conventional combustion of solid feedstocks.

Gasification also enables carbon dioxide (CO_2) capture. Adding steam to the syngas and performing water-gas shift converts CO to CO_2, which creates an additional hydrogen molecule for each CO molecule converted to CO_2. By separating the hydrogen and CO_2, the hydrogen can be used to make power and the CO_2 can be stored, converted to useful products, or used for enhanced oil recovery.

The syngas produced by gasification can also be cleaned and used to produce a wide range of fuels and chemicals. Gasification technologies have the unique ability to make plants that produce multiple products—or, "polygeneration plants"—possible. These benefits provide the nation with the flexibility needed to capitalize on changing markets and to use domestically available resources while meeting future environmental emission standards.

The Gasification Systems Program is developing technologies in three key areas to reduce the cost and increase the efficiency of producing syngas:

1. **Feed Systems** – Research is under way to achieve cost reduction and efficiency increases for commercial gasifiers through design improvements for fuel and oxygen feed systems and advanced plant integration. One focus area is high-pressure solid feed systems that can 1) expand the use of the nation's western low-cost, low rank coals for high-pressure gasifiers (which currently are limited to more expensive fuel); 2) enable co-feeding of coal with other advantageous fuels (such as biomass); and 3) encourage higher pressure (and, therefore, more efficient) operation of dry feed gasifiers. Advanced air separation technologies, such as ion transport membrane technology, are another area being pursued. Compared with cryogenic air separation, which is today's commercially available, energy-intensive technology commonly used for oxygen production, advanced air separation technologies can lower the cost of oxygen production through reduced capital costs and result in more efficient integrated gasification combined cycle power plants through turbine integration.

2. **Gasifier Optimization and Plant Supporting Systems** – The Gasifier Optimization and Plant Supporting System technologies under development aim to increase gasifier availability and efficiency, improve performance, and reduce the capital and operating costs of advanced gasification plants. Ongoing research and development projects are developing more durable refractory materials, creating models to better understand the kinetics and particulate behavior of fuel inside a gasifier, and developing practical solutions to mitigate the plugging and fouling of syngas coolers. Future projects may include advanced concepts to efficiently gasify low rank coals, hybrid coal/natural gas gasifiers, and catalytic gasification for use with fuel cells for power production. Future work will also aim to integrate technologies throughout the plant and beyond in a holistic approach to increase efficiency and reduce costs.

3. **Syngas Processing Systems** – A major cost element in gasification plants is converting raw syngas into a clean and tailored gas stream to support the plant's target product suite. High-hydrogen, low-methane, ultraclean syngas is versatile and can be used for power production with CO_2 capture, fuels or chemicals production, and for many

polygeneration applications. Current research and development work in this area emphasizes technologies (e.g., advanced hydrogen membranes) that can be efficiently integrated into the plant, be optimized with the temperature and pressure requirements of other systems, and meet product delivery specifications. The technologies being developed focus on high-efficiency processes that operate at moderate to high temperatures and clean syngas of all contaminants to the extremely low levels needed for chemical production—often significantly lower than the U.S. Environmental Protection Agency required levels for power plants.

Office of Management and Budget Requirements

In compliance with requirements from the Office of Management and Budget, DOE and NETL are fully committed to improving the quality of research projects in their programs. To aid this effort, DOE and NETL conducted a fiscal year (FY) 2014 Gasification Systems Peer Review Meeting with independent technical experts to assess ongoing research projects and, where applicable, to make recommendations for individual project improvement.

In cooperation with Leonardo Technologies, Inc., ASM International convened a panel of five leading academic and industry experts on May 21–23, to conduct a three-day peer review of selected Gasification Systems Program research projects supported by NETL.

Overview of Office of Fossil Energy Gasification Systems Program Research Funding

The total funding of the seven projects reviewed, over the duration of the projects, is $40,711,980. The funding and duration of the seven projects that were the subject of this Peer Review are provided in Table 1 below.

TABLE 1. GASIFICATION SYSTEMS PROGRAM PROJECTS REVIEWED

Reference Number	Project No.	Title	Lead Organization	Principal Investigator	Total Funding		Project Duration	
					DOE	Cost Share	From	To
N/A	N/A	Office of Program Performance & Benefits (OPPB) Support to the Gasification Systems Program	National Energy Technology Laboratory – Office of Program Performance & Benefits (NETL OPPB)	N/A	N/A	N/A	N/A	N/A
1	OPPB/PD-2	IGCC Low Rank Coal Pathway Study	National Energy Technology Laboratory - Office of Program Performance & Benefits (NETL OPPB)	Kristin Gerdes	$300,000	$0	05/01/2012	10/30/2013
2	FE0007859	Feasibility Studies to Improve Plant Availability and Reduce Total Installed Cost in IGCC Plants	General Electric Company	Christine Zemsky	$3,949,773	$987,446	10/01/2011	09/30/2014
3	FWP-2012.03.03 Tasks 2, 3, and 4	Advanced Gasification: Task 2, Refractory Improvement; Task 3, Conversion and Fouling; Task 4, Low Rank Coal Optimization	National Energy Technology Laboratory – Office of Research and Development (NETL ORD)	James Bennett	$3,093,000	$0	10/01/2013	09/30/2014
4	FE0012122	Hybrid Molten Bed Gasifier for Production of High Hydrogen Syngas	Gas Technology Institute	David M. Rue	$800,040	$200,133	10/01/2013	09/30/2014
5	FE0004895	Engineering Design of Advanced H_2 CO_2 PD and PD/Alloy Composite Membrane Separations and Process Intensification	Worcester Polytechnic Institute	Yi Hua Ma	$6,004,678	$1,501,799	10/01/2010	09/30/2015
6	FE0012065	Development of Ion Transport Membrane Oxygen Technology for Low-Cost and Low-Emission Gasification and Other Industrial Applications	Air Products and Chemicals, Inc.	Phil Armstrong	$11,188,366	$11,188,366	10/01/2013	12/31/2015
7	FE0012066	Benefits of Integrating Aerojet Rocketdyne and RTI Advanced Gasification Technologies for Hydrogen-Rich Syngas Production	Research Triangle Institute	Brian S. Turk	$1,198,703	$299,676	10/01/2013	09/30/2014
				TOTALS	**$26,534,560**	**$14,177,420**	**--**	**--**

OVERVIEW OF THE PEER REVIEW PROCESS

The U.S. Department of Energy (DOE), the Office of Fossil Energy, and the National Energy Technology Laboratory (NETL) are fully committed to improving the quality and results of their research projects. To support this goal, in fiscal year (FY) 2014, ASM International was invited to provide an independent, unbiased, and timely peer review of selected projects within the DOE Office of Fossil Energy's Gasification Systems Program. The peer review of selected projects within the Gasification Systems Program was designed to comply with requirements from the Office of Management and Budget.

On May 21–23, ASM International convened a panel of five leading academic and industry experts to conduct a three-day peer review of seven research projects supported by the NETL Gasification Systems Program. Throughout the peer review meeting, these recognized technical experts provided recommendations on how to improve the management, performance, and overall results of each individual research project.

In consultation with NETL, who chose the seven projects for review, ASM International selected an independent peer review panel, facilitated the peer review meeting, and prepared this report to summarize the results.

ASM International performed this project review work as a subcontractor to prime NETL contractor Leonardo Technologies, Inc.

Pre-Meeting Preparation

Several weeks before the peer review, each project team submitted a project technical summary and a draft final PowerPoint slide deck they would present at the peer review meeting. Additionally, the appropriate federal project manager provided the project management plan and other relevant materials, including a project fact sheet, quarterly and annual reports, and published journal articles, that would help the peer review panel evaluate each project. A Key Project Document Index Table helped map the reviewers to the locations within the documents where they could find specific information required to accurately review the project. The panel received all of these materials prior to the peer review meeting via a peer review SharePoint site, which enabled the panel members to come to the meeting fully prepared with the necessary project background information to thoroughly evaluate the projects.

To increase the efficiency of the peer review meeting, a pre-meeting orientation teleconference was held with the review panel and ASM International support staff about one month prior to the meeting to review the peer review process. Additionally, a WebEx meeting with the technology manager of the Gasification Systems Program was held about one month prior to the peer review meeting to provide an overview of the program goals and objectives.

Peer Review Meeting Proceedings

At the meeting, each research team made an uninterrupted 30- to 45-minute PowerPoint presentation that was followed by a 30- to 45-minute question-and-answer session with the panel and a 75-minute panel discussion and evaluation of each project. The time allotted for project presentations, the question-and-answer session, and the panel discussion was dependent on the individual project's complexity, duration, and breadth of scope. To facilitate a full and open discourse of project-related material between the project team and the panel, all sessions were limited to the panel, ASM International personnel, and DOE-NETL personnel and contractor support staff. The closed sessions ensured open discussions between the principal investigators and the panel. Panel members were also instructed to hold the discussions that took place during the question-and-answer session as confidential.

The panel discussed each project to identify and come to consensus on the project strengths, project weaknesses, and recommendations for project improvement. The panel designated all strengths and weaknesses as “major” or “minor” and ranked recommendations from most to least important. The consensus strengths and weaknesses served as the basis for determining the overall project score in accordance with the Rating Definitions and Scoring Plan of the Peer Review Evaluation Criteria Form. Formal strengths, weaknesses, recommendations, and a Project Rating were not recorded for Project 01, IGCC Low Rank Coal Pathway Study; instead, the panel provided the project team with comments and suggestions for improving their project during the question-and-answer session.

To facilitate the evaluation process, Leonardo Technologies, Inc. provided the panel with laptop computers that were preloaded with Peer Review Evaluation Criteria Forms for each project, as well as the project materials that the panel members were able to access via SharePoint prior to the peer review meeting.

Peer Review Evaluation Criteria

At the end of the group discussion for each project, the panel came to consensus on an overall project score. The panel scored each project (with the exception of Project 01), as one of the following:

- Excellent (10)
- Highly Successful (8)
- Adequate (5)
- Weak (2)
- Unacceptable (0)

The Rating Definitions that informed scoring decisions are included in Appendix B of this report.

NETL completed a Technology Readiness Assessment of its key technologies in 2012. The technology readiness level (TRL) of projects assessed in 2012 was provided to the panel prior to the peer review meeting. These assessments enabled the panel to appropriately score the review criteria within the bounds of the established scope for each project. Appendix C describes the various levels of technology readiness used in 2012.

SUMMARY OF KEY FINDINGS

This section summarizes the overall key findings of the seven projects evaluated at the FY2014 Gasification Systems Program Peer Review.

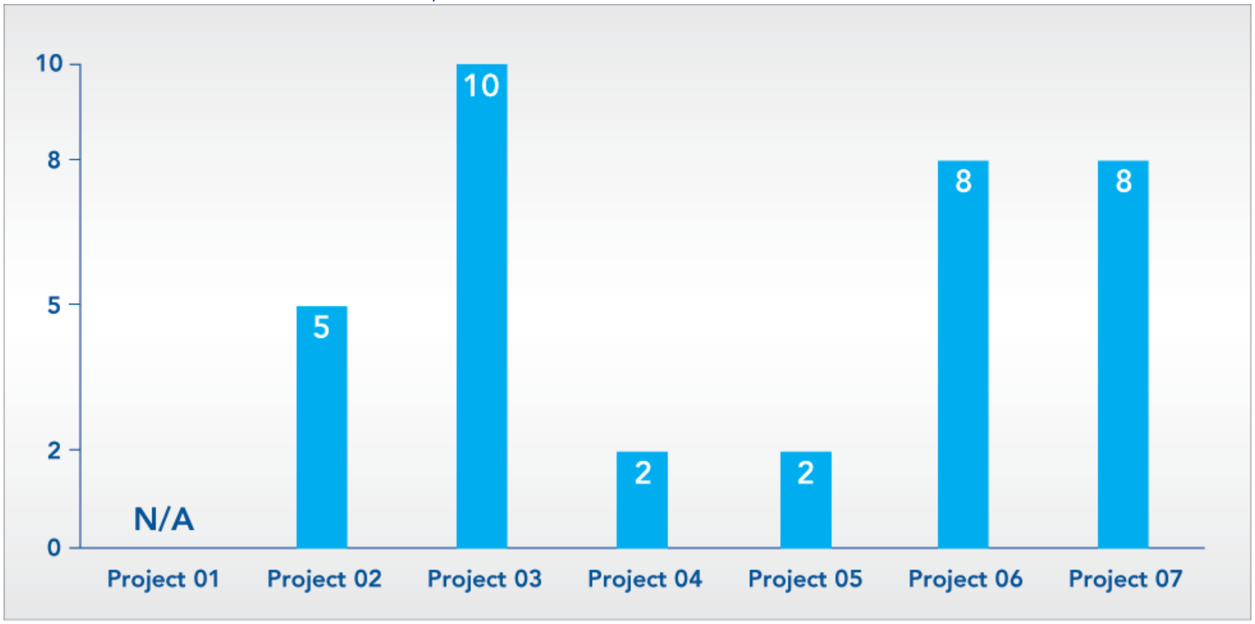
Overview of Project Evaluation Scores

The panel reached consensus on a score for each project:

- Excellent (10)
- Highly Successful (8)
- Adequate (5)
- Weak (2)
- Unacceptable (0)

It is not the intent of this review to directly compare one project with another. The score given to each project is shown in Figure 1.

FIGURE 1. EVALUATION SCORES, BY PROJECT



General Project Strengths

The panel was impressed by the high quality of most of the Gasification Systems projects they reviewed from DOE's Clean Coal Research Program. They indicated that the projects represent a diverse set of potentially disruptive technologies with ambitious goals and significant potential to advance gasification technologies toward their full potential for coal-based power generation. Based on the progress made to date by the projects reviewed, the panel was optimistic about the potential for these projects to support the achievement of DOE's challenging goals for cost of electricity and environmental performance. Panel members noted that the success of projects was largely attributable to assembling highly qualified teams that included partners with expertise in relevant topic areas, addressing key failure mechanisms, and leveraging the resources of NETL.

The highest-rated project was project 03, “Advanced Gasification: Task 2, Refractory Improvement; Task 3, Conversion and Fouling; Task 4, Low Rank Coal Optimization,” conducted by NETL. This project received the maximum rating of 10.

General Project Weaknesses

Many of the weaknesses presented by the panel members were unique to each project. The panel did not identify any common themes of weaknesses across the projects reviewed.

General Project Observations and Recommendations

The majority of the recommendations provided by the panel were technical in nature and specific to a particular project’s technology or approach. The most common recommendation provided by panel members that addressed both project strengths and weaknesses was related to the value of current estimates of cost/performance benefits, expressed in terms of NETL program goals and metrics. The panel recommended that the teams also express carbon dioxide (CO_2) capture performance in terms consistent with the U.S. Environmental Protection Agency’s metrics for integrated gasification combined cycle (i.e., CO_2 emitted per gross MWh).

PROJECT SYNOPSES

For more information on the Gasification System Program and project portfolio please visit the NETL website: http://www.netl.doe.gov/research/coal/energy-systems/gasification.

01: OPPB/PD-2
IGCC LOW RANK COAL PATHWAY STUDY

Kristin Gerdes, National Energy Technology Laboratory

2012 Technology Readiness Level: N/A
DOE Funding: $300,000
Cost Share: $0
Duration: 05/01/2012 – 10/30/2013

Project Evaluation Score

N/A

The overall project goal is to evaluate performance improvement and cost reduction from advanced DOE-funded technologies for power production from low rank coal gasification with carbon capture. As part of this effort, the project aims to provide system studies that assess the performance and cost impacts of advanced technologies and address the challenges of characterizing and modeling these novel technologies.

02: FE0007859
FEASIBILITY STUDIES TO IMPROVE PLANT AVAILABILITY AND REDUCE TOTAL INSTALLED COST IN IGCC PLANTS

Christine Zemsky, General Electric Company
Tom Leininger, General Electric Company

2012 Technology Readiness Level: 2
DOE Funding: $3,949,773
Cost Share: $987,446
Duration: 10/01/2011 – 09/30/2014

Project Evaluation Score

5

The goal of this project is to evaluate the effects of specific technical improvements on total installed cost and availability of integrated gasification combined cycle (IGCC) plants through deployment of a multi-faceted approach in technology evaluation, constructability, and design methodology. The main project objective is to reduce the time from design to technological maturity and enable plants to reach higher availability in shorter periods of time at lower installed costs. Specific objectives include conducting a technical investigation of technologies that can reduce the total installed cost of an IGCC plant; conducting a technical investigation of conceptual ideas that can improve the availability of an IGCC plant toward the targeted 90 percent without increasing total installed cost; and proposing a technology transfer plan, which will form the basis for future development, testing, and demonstration of conceptual ideas developed from the project.

03: FWP-2012.03.03 TASKS 2, 3, AND 4
ADVANCED GASIFICATION: TASK 2, REFRACTORY IMPROVEMENT; TASK 3, CONVERSION AND FOULING; TASK 4, LOW RANK COAL OPTIMIZATION

James Bennett, National Energy Technology Laboratory
Chris Guenther, National Energy Technology Laboratory

2012 Technology Readiness Level: 3 (for tasks 2, 3, and 4)
DOE Funding: $3,093,000
Cost Share: $0
Duration: 10/01/2013 – 09/30/2014

Project Evaluation Score

10

Task 2, Refractory Improvement: The goal of this project is to increase the gasifier service life, reliability, and availability to lower the cost of electricity via refractory development/improvements.

Task 3, Conversion and Fouling: The main goal of this project is to improve the reliability, availability, and maintainability of gasification plants by developing tools to evaluate the impact of fuel properties on slag and refractory interactions. By evaluating ash deposition from carbon feedstock, plugging and fouling throughout the synthesis gas cooling system can be reduced.

Task 4, Low Rank Coal Optimization: Researchers will conduct statistically designed experiments on gas-solids jets located on the side-wall of NETL's large-scale circulating fluidized bed to mimic the flow of coal into an industrial-scale transport unit. Smaller-scale, well controlled, and highly instrumented laboratory experiments will also be conducted to test model expressions for gas solids jets on drag, coefficients of restitution and friction, and polydispersity.

04: FE0012122
HYBRID MOLTEN BED GASIFIER FOR PRODUCTION OF HIGH HYDROGEN SYNGAS

David M. Rue, Gas Technology Institute

2012 Technology Readiness Level: N/A
DOE Funding: $800,040
Cost Share: $200,133
Duration: 10/01/2013 – 09/30/2014

Project Evaluation Score

2

The project includes three major activities. First, the project team will model the hybrid molten bed (HMB) gasifier to determine performance, synthesis gas (syngas) yield, and syngas composition data needed for the techno-economic analyses in both integrated gasification combined cycle (IGCC) and Fischer Tropsch (FT) diesel configurations. Second, the team will test the HMB gasification process and collect the performance and product syngas data needed to support the techno-economic analysis and to provide support for the next stage of HMB gasification process development. Finally, the team will perform techno-economic analyses for an IGCC plant with carbon capture and an FT plant with carbon capture using both a conventional slagging gasifier and the HMB gasifier. Analyses will include baseline cases and parametric calculations to develop optimized HMB plant configurations.

05: FE0004895

ENGINEERING DESIGN OF ADVANCED H_2 CO_2 PD AND PD/ALLOY COMPOSITE MEMBRANE SEPARATIONS AND PROCESS INTENSIFICATION

Yi Hua Ma, Worcester Polytechnic Institute

2012 Technology Readiness Level: 4
DOE Funding: $6,004,678
Cost Share: $1,501,799
Duration: 10/01/2010 – 09/30/2015

Project Evaluation Score

2

The project team will develop an integrated, cost-effective hydrogen production and separation process that employs palladium (Pd) and Pd-alloy composite membranes developed by Worcester Polytechnic Institute for use in water-gas-shift reactors. The project team will perform research and development leading to the demonstration of this process by constructing a system to produce hydrogen at the pilot scale. The team will develop strategies to effectively separate hydrogen from coal- or coal-biomass-derived synthesis gas with improved flux, reduced cost, and greater selectivity and chemical and mechanical robustness.

06: FE0012065

DEVELOPMENT OF ION TRANSPORT MEMBRANE OXYGEN TECHNOLOGY FOR LOW-COST AND LOW-EMISSION GASIFICATION AND OTHER INDUSTRIAL APPLICATIONS

Lori L. Anderson, Air Products and Chemicals, Inc.

2012 Technology Readiness Level: N/A
DOE Funding: $11,188,366
Cost Share: $11,188,366
Duration: 10/01/2013 – 12/31/2015

Project Evaluation Score

8

The project will further advance ion transport membrane (ITM) technology toward the ITM Oxygen Development Facility, a 2,000 tons per day demonstration-scale test unit. In addition, technical risks will be reduced through economic studies to assess cost and environmental benefits of the ITM system, which is expected to cost 30% less than conventional cryogenic oxygen separation technology.

07: FE0012066
BENEFITS OF INTEGRATING AEROJET ROCKETDYNE AND RTI ADVANCED GASIFICATION TECHNOLOGIES FOR HYDROGEN-RICH SYNGAS PRODUCTION

Brian Turk, Research Triangle Institute
David Denton, Research Triangle Institute

2012 Technology Readiness Level: N/A
DOE Funding: $1,198,703
Cost Share: $299,676
Duration: 10/01/2013 – 09/30/2014

Project Evaluation Score

8

The project will assess the potential for integrated advanced technologies to substantially reduce capital and production costs for hydrogen-rich synthesis gas with near-zero emissions from coal gasification for power production with carbon capture and for coal-to-liquids (specifically methanol) with carbon capture. These integrated technologies include those already tested successfully at pilot scale with a new and innovative water-gas-shift technology, to show how multiple advanced technologies will leverage each other for significant cost and efficiency gains.

APPENDIX A: ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Definition
CCC	Copyright Clearance Center
CCS	carbon capture and storage
CCUS	carbon capture, utilization, and storage
CO	carbon monoxide
CO_2	carbon dioxide
DOE	U.S. Department of Energy
FT	Fischer Tropsch
FY	fiscal year
GE	General Electric
GTC	Gasification Technologies Council
GTL	gas-to-liquids
H_2	hydrogen
HMB	hybrid molten bed
IGCC	integrated gasification combined cycle
IPO	Independent Professional Organization
ITM	ion transport membrane
KBR	Kellogg Brown & Root
LTI	Leonardo Technologies, Inc.
MW	megawatt
MWh	megawatt-hour
NETL	National Energy Technology Laboratory
OPPB	Office of Program Performance & Benefits
ORD	Office of Research and Development
Pd	palladium
R&D	research and development
RD&D	research, development, and demonstration
RTI	Research Triangle Institute
scfm	standard cubic feet per minute
SMR	steam methane reforming
syngas	synthesis gas
TRL	Technology Readiness Level

APPENDIX B: PEER REVIEW EVALUATION CRITERIA FORM

U.S. DEPARTMENT OF ENERGY (DOE)
NATIONAL ENERGY TECHNOLOGY LABORATORY

FY14 GASIFICATION SYSTEMS PEER REVIEW

MAY 21–23, 2014

Project Title:	
Performer:	
Name of Peer Reviewer:	

The following pages contain the criteria used to evaluate each project. Each criterion is accompanied by multiple characteristics to further define the topic. Each Reviewer is expected to independently assess the provided material for each project, considering the Evaluation Criteria on the following page. Prior to the meeting, the Reviewers will independently create a list of strengths and weaknesses for each project based on the materials provided.

At the meeting, the Facilitator and/or Panel Chairperson will lead the Peer Review Panel, in identifying consensus strengths, weaknesses, overall score, and prioritized recommendations for each project. The consensus strengths and weaknesses shall serve as a basis for the determination of the overall project score in accordance with the Rating Definitions and Scoring Plan detailed on the following page.

A **strength** is an aspect of the project that, when compared to the evaluation criterion, reflects positively on the probability of successful accomplishment of the project's goals and objectives.

A **weakness** is an aspect of the project that, when compared to the evaluation criterion, reflects negatively on the probability of successful accomplishment of the project's goals and objectives.

Consensus strengths and weaknesses shall be characterized as either "major" or "minor." For example, a weakness that presents a significant threat to the likelihood of achieving the project's stated technical goals and supporting objectives should be considered "major," whereas relatively less significant opportunities for improvement are considered "minor.

A **recommendation** shall emphasize an action that will be considered by the project team and/or DOE to be included as a milestone for the project to correct or mitigate the impact of weaknesses, or expand upon a project's strengths. A recommendation should have as its basis one or more strengths or weaknesses. Recommendations shall be *ranked* from most important to least, based on the major/minor strengths/weaknesses.

Per the Independent Professional Organization (IPO) request, Reviewers are to record their individual strengths, weaknesses, recommendations and general comments under the

Reviewer Comments section of this form (page 3). However, only the panel's consensus remarks/scores will be used in the IPO-generated reports.

EVALUATION CRITERIA	
1	**Degree to which the project, if successful, supports the program's near- and/or long-term goals** • Clear project performance and/or cost/economic* objectives are present, appropriate for the maturity of the technology, and support the program goals. • Technology is ultimately technically and/or economically viable for the intended application.
2	**Degree of project plan technical feasibility** • Technical gaps, barriers and risks to achieving the project performance and/or cost objectives* are clearly identified. • Scientific/engineering approaches have been designed to overcome the identified technical gaps, barriers and risks to achieve the project performance and/or cost/economic objectives*.
3	**Degree to which progress has been made towards the stated project performance and cost/economic* objectives** • Milestones and reports effectively enable progress to be tracked. • Reasonable progress has been made relative to the established project schedule and budget.
4	**Degree to which the project plan-to-complete assures success** • Remaining technical work planned is appropriate, in light of progress to date and remaining schedule and budget. • Appropriate risk mitigation plans exist, including Decision Points if appropriate.
5	**Degree to which there are sufficient resources to successfully complete the project** • There is adequate funding, facilities and equipment. • Project team includes personnel with needed technical and project management expertise. • The project team is engaged in effective teaming and collaborative efforts, as appropriate.

* Projects that do not have cost/economic objectives should be evaluated on performance objectives only.

RATINGS DEFINITIONS AND SCORING PLAN

The panel will be required to assign a consensus score to the project, after strengths and weaknesses have been agreed upon. Intermediate scores are *not* acceptable. The overall project score must be justified by, and consistent with, the identified strengths and weaknesses.

RATING DEFINITIONS	
10	**Excellent -** Several major strengths; no major weaknesses; few, if any, minor weaknesses. Strengths are apparent and documented.
8	**Highly Successful -** Some major strengths; few (if any) major weaknesses; few minor weaknesses. Strengths are apparent and documented, and outweigh identified weaknesses.
5	**Adequate -** Strengths and weaknesses are about equal in significance.
2	**Weak -** Some major weaknesses; many minor weaknesses; few (if any) major strengths; few minor strengths. Weaknesses are apparent and documented, and outweigh strengths identified.
0	**Unacceptable -** No major strengths; many major weaknesses. Significant weaknesses/deficiencies exist that are largely insurmountable.

REVIEWER COMMENTS

Per the IPO request, Reviewers are to record their individual strengths, weaknesses, recommendations and general comments in the space provided below. However, only the panel's consensus remarks/scores will be used in the IPO-generated reports.

STRENGTHS A **strength** is an aspect of the project that, when compared to the evaluation criterion, reflects positively on the probability of successful accomplishment of the project's goals and objectives.
WEAKNESSES A **weakness** is an aspect of the project that, when compared to the evaluation criterion, reflects negatively on the probability of successful accomplishment of the project's goals and objectives.
RECOMMENDATIONS A **recommendation** shall emphasize an action that will be considered by the project team and/or DOE to be included as a milestone for the project to correct or mitigate the impact of weaknesses or expand upon a project's strengths. A recommendation should have as its basis one or more strengths or weaknesses. Recommendations shall be *ranked* from most important to least, based on the major/minor strengths/weaknesses.
GENERAL COMMENTS

APPENDIX C: TECHNOLOGY READINESS LEVEL DESCRIPTIONS

Research, Development, and Demonstration (RD&D) projects can be categorized based on the level of technology maturity. Listed below are nine (9) TRLs of RD&D projects managed by the NETL. These TRLs provide a basis for establishing a rational and structured approach to decision-making and identifying performance criteria that must be met before proceeding to the next level.

TRL	DOE-FE Definition	DOE-FE Description
1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples include paper studies of a technology's basic properties.
2	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies.
3	Analytical and experimental critical function and/or characteristic proof of concept	Active R&D is initiated. This includes analytical and laboratory-scale studies to physically validate the analytical predictions of separate elements of the technology (e.g., individual technology components have undergone laboratory-scale testing using bottled gases to simulate major flue gas species at a scale of less than 1 scfm).
4	Component and/or system validation in a laboratory environment	A bench-scale prototype has been developed and validated in the laboratory environment. Prototype is defined as less than 5% final scale (e.g., complete technology process has undergone bench-scale testing using synthetic flue gas composition at a scale of approximately 1–100 scfm).
5	Laboratory-scale similar-system validation in a relevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Prototype is defined as less than 5% final scale (e.g., complete technology has undergone bench-scale testing using actual flue gas composition at a scale of approximately 1–100 scfm).
6	Engineering/pilot-scale prototypical system demonstrated in a relevant environment	Engineering-scale models or prototypes are tested in a relevant environment. Pilot or process-development-unit scale is defined as being between 0 and 5% final scale (e.g., complete technology has undergone small pilot-scale testing using actual flue gas composition at a scale equivalent to approximately 1,250–12,500 scfm).
7	System prototype demonstrated in a plant environment	This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Final design is virtually complete. Pilot or process- development-unit demonstration of a 5–25% final scale or design and development of a 200–600 MW plant (e.g., complete technology has undergone large pilot-scale testing using actual flue gas composition at a scale equivalent to approximately 25,000–62,500 scfm).
8	Actual system completed and qualified through test and demonstration in a plant environment	The technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include startup, testing, and evaluation of the system within a 200–600 MW plant CCS/CCUS operation (e.g., complete and fully integrated technology has been initiated at full-scale demonstration including startup, testing, and evaluation of the system using actual flue gas composition at a scale equivalent to approximately 200 MW or greater).
9	Actual system operated over the full range of expected conditions	The technology is in its final form and operated under the full range of operating conditions. The scale of this technology is expected to be 200–600 MW plant CCS/CCUS operations (e.g., complete and fully integrated technology has undergone full-scale demonstration testing using actual flue gas composition at a scale equivalent to approximately 200 MW or greater).

APPENDIX D: MEETING AGENDA

AGENDA

FY14 Gasification Systems Peer Review

May 21 – 23, 2014

Sheraton Station Square
Pittsburgh, PA

Wednesday, May 21, 2014 – Ellwood I & II

7:30 – 8:30 a.m.	**Registration – 2nd Floor Foyer**
8:30 – 9:00 a.m.	**Peer Review Panel Kick-Off Meeting** Open to National Energy Technology Laboratory (NETL) and ASM International staff only - Review of ASM International Process – Stanley C. Theobald, ASM International - Role of ASM International Panel Chair – James C. Sorensen, Sorensenergy, LLC - Peer Review Process Overview – David Wildman, Leonardo Technologies, Inc. (LTI) - Meeting Logistics – David Wildman, LTI
9:00 – 9:15 a.m.	**Technology Manager and Panel Q&A** Open to NETL and ASM International staff only - Gasification Systems Technology Manager – Jenny Tennant, NETL
9:15 – 9:30 a.m.	**BREAK**
9:30 – 10:15 a.m.	**Office of Program Performance & Benefits (OPPB) Support to the Gasification Systems Program – Overview** *Kristin Gerdes,* **National Energy Technology Laboratory**
10:15 – 10:35 a.m.	Q&A/Discussion
10:35 – 11:20 a.m.	**01 – Project # OPPB/PD-2** – IGCC Low Rank Coal Pathway Study *Kristin Gerdes,* **National Energy Technology Laboratory**
11:20 – 11:40 a.m.	Q&A/Discussion
11:40 – 12:45 p.m.	**Lunch (on your own)**
12:45 – 1:15 p.m.	**02 – Project # FE0007859** – Feasibility Studies to Improve Plant Availability and Reduce Total Installed Cost in IGCC Plants *Christine Zemsky and Tom Leininger,* **General Electric Company**
1:15 – 1:45 p.m.	Q&A
1:45 – 3:00 p.m.	Discussion
3:00 – 3:15 p.m.	**BREAK**
3:15 – 4:00 p.m.	**03 – Project # FWP-2012.03.03 Tasks 2, 3 and 4** – Advanced Gasification: Task 2, Refractory Improvement; Task 3, Conversion and Fouling; Task 4, Low Rank Coal Optimization *James Bennett and Chris Guenther,* **National Energy Technology Laboratory**
4:00 – 4:30 p.m.	Q&A
4:30 – 5:45 p.m.	Discussion

Thursday, May 22, 2014 – Ellwood I & II

7:00 – 8:00 a.m.	**Registration – 2nd Floor Foyer**
8:00 – 8:30 a.m.	**04 – Project # FE0012122** – Hybrid Molten Bed Gasifier for Production of High Hydrogen Syngas *David M. Rue,* **Gas Technology Institute**
8:30 – 9:00 a.m.	Q&A
9:00 – 10:15 a.m.	Discussion
10:15 – 10:30 a.m.	**BREAK**
10:30 – 11:00 a.m.	**05 – Project # FE0004895 –** Engineering Design of Advanced H_2 CO_2 PD and PD/Alloy Composite Membrane Separations and Process Intensification *Yi Hua Ma,* **Worcester Polytechnic Institute**
11:00 – 11:30 a.m.	Q&A
11:30 – 12:45 p.m.	Discussion
12:45 – 1:45 p.m.	**Lunch (on your own)**
1:45 – 2:15 p.m.	**06 – Project # FE0012065** – Development of Ion Transport Membrane Oxygen Technology for Low-Cost and Low-Emission Gasification and Other Industrial Applications *Lori L. Anderson,* **Air Products and Chemicals, Inc.**
2:15 – 3:00 p.m.	Q&A
3:00 – 4:15 p.m.	Discussion
4:15 – 4:30 p.m.	**BREAK**
4:30 – 5:00 p.m.	**NETL Model Mapping Effort** – Technical Gap Assessment in Support of Strategic Development and Application of Gasification Modeling Tools Open to NETL and ASM International staff only *Briggs White*, **National Energy Technology Laboratory**
5:00 – 5:30 p.m.	Q&A/Discussion

Friday, May 23, 2014 – Ellwood I & II

7:00 – 8:00 a.m.	**Registration – 2nd Floor Foyer**
8:00 – 8:30 a.m.	**07 – Project # FE0012066 –** Benefits of Integrating Aerojet Rocketdyne and RTI Advanced Gasification Technologies for Hydrogen-Rich Syngas Production *Brian Turk and David Denton,* **Research Triangle Institute**
8:30 – 9:00 a.m.	Q&A
9:00 – 10:15 a.m.	Discussion
10:15 – 10:30 a.m.	**BREAK**
10:30 – 11:30 a.m.	**Wrap-up Session**

APPENDIX E: PEER REVIEW PANEL MEMBERS

James C. Sorensen – Panel Chair

Jim Sorensen is a consultant with a primary focus on clean coal and supporting technologies, including Integrated Gasification Combined Cycle, Oxy-combustion, CO_2 capture, polygeneration, air separation, and gas treating technologies. His activities have included numerous peer reviews of DOE R&D programs and of proposals to DOE, consulting to Electric Power Research Institute on the CoalFleet program and other projects, and consulting to other clients on a variety of energy conversion activities. He is the former chief operating officer of GTLpetrol. Prior to founding Sorensenergy, LLC, Mr. Sorensen worked for Air Products and Chemicals as Director, New Markets, with responsibility for syngas conversion technology development and government systems and as Director, Gasification and Energy Conversion, with responsibility for air separation plant sales for gasification applications. Earlier responsibilities included project management of Air Products' baseload liquefied natural gas projects, commercial management of synthetic natural gas production, and general management of the Membrane Systems Department.

Mr. Sorensen is the founding chairman of the Gasification Technologies Council, and was vice chairman of the Council on Alternate Fuels and of Energy Futures International. He holds eight U.S. patents.

Mr. Sorensen received his B.S. and M.S. degrees in chemical engineering from California Institute of Technology and Washington State University, respectively, and an MBA from the Harvard Business School.

Bhadra S. Grover

Mr. Bhadra S. Grover is a chemical engineer and recognized expert in various technologies for chemical production and gas purification. He has industrial experience in engineering, R&D, business development, application development, and operation of the following processes and plants:

- Hydrogen and syngas (H_2+CO) production (gas-to-liquid, ammonia, methanol, and refinery applications) including:
    - Design and operation of world-scale hydrogen, CO, and syngas production by steam methane reforming (SMR), autothermal reforming, and partial oxidation using various feedstocks.
    - Catalyst (base metal and precious metal) development and evaluation for steam reforming applications and development of burners for SMR furnaces.
    - Development of high-temperature (300°C+) sorbents for CO_2 capture from syngas, and its application in high-temperature shift reactors.
    - Development of metallic and ceramic membrane reactor for steam reforming and shift reactors.
    - Acid gas removal from syngas produced from various feedstocks, including coal.
    - Evaluation of bio-fuel conversion technologies.
    - H_2 production and transport for H_2 energy market.
    - Syngas purification by pressure swing adsorption, membranes, solvents, and cryogenic methods.
    - Refinery H_2 balance and recovery of H_2 from refinery fuel gas.

- CO_2 abatement, capture and storage, including:
  - CO_2 capture by solvents (amines, K_2CO_3, Rectisol, Selexol), cryogenics, adsorbents, and membranes (polymeric and inorganic) and from coal gasification, natural gas processing plants, ammonia production, steel mills, and other chemical plants.
  - Pre- and post-combustion for CO_2 capture for power generation; integration of oxygen production with power production.
  - Integration of ion transport membranes for boilers, syngas generation, and steel mills; production of CO_2-rich flue gas.
  - Development of chemical looping for combustion and hydrogen production.
  - CO_2 abatement by process optimization and use of renewable fuels.
  - CO_2 compression and transport for enhanced oil recovery and sequestration.

Mr. Grover previously worked as Senior Corporate Expert, Engineering and Development for Air Liquide America; Process Manager for MW Kellogg (Now KBR), where he was responsible for process design and proposal preparation for various ammonia, methanol, and LNG plants; and for UOP (formally Union Carbide). He is the inventor of over 12 patents.

Mr. Grover received his M.S. in chemical engineering from Manhattan College in New York in 1978 and his B.Tech in chemical engineering from the Indian Institute of Technology in New Delhi, India in 1967.

Norman Z. Shilling, D. Sc., PE

Prior to entering into private consulting practice, Dr. Shilling was the Senior Product Manager–Policy for General Electric (GE) Energy's gasification product line, where he was responsible for developing policy and regulatory strategies and providing advocacy in Washington and international forums on solutions for greenhouse gas. Dr. Shilling is frequently called upon to share his expertise in gasification and carbon capture and sequestration as it relates to policy and regulation. He has offered conference and seminar speeches at many U.S. and global industry conferences, has provided testimony to many regulatory and legislative bodies, and is a member of several key coal forums and workgroups.

Dr. Shilling's experience in environmental and utility power generation includes roles as Product Line Leader for gas turbines applied to unconventional fuels, integrated gasification combined cycle, and the integration of power production with chemical refinery plants and steel mills. Prior to that position, he served as program manager for low-emissions Locomotive Diesel Development and as Environmental Systems Engineering manager at GE's Research Center, collaborating with many GE businesses on pollution prevention and energy efficiency initiatives. He also served an Advanced Engineering Manager at GE's environmental systems, where he was responsible for the development of advanced scrubbers and particulate controls for utility power plants. Dr. Shilling has also been a key leader in many GE strategic technology-planning initiatives.

Prior to the start of his GE career, Dr. Shilling worked in nuclear steam generator development and advanced automotive power plant development.

Dr. Shilling holds an S.M. degree from the Massachusetts Institute of Technology and B.S. and D.Sc. degrees from the New Jersey Institute of Technology. He has taught in the graduate engineering school at Pennsylvania State University and is a licensed Professional Engineer.

Douglas M. Todd

Mr. Douglas Todd is the owner and president of Process Power Plants LLC, a consulting company dedicated to integrating gas turbine combined cycles with gasification systems (IGCC) to provide clean, economical electric power and other useful products from low-cost fuels. Mr. Todd's industry experience includes 35 years with General Electric (GE) in engineering, marketing, and product management positions, culminating with business management responsibility for GE's Process Power Plants Organization. Mr. Todd developed and introduced combined cycle and IGCC power plant technology on a worldwide basis.

Mr. Todd led the IGCC power block technology into a variety of process power plant applications for co-production of power and hydrogen, clean fuels, gas-to-liquids, and carbon dioxide reduction technologies. By applying integration techniques and unique modifications in the power block, various process technologies have been enhanced, improving economics and extending commercial applications for these processes.

Mr. Todd is a member of the American Institute of Chemical Engineers, the Gasification Technologies Council (GTC), and Energy Frontiers International. He received the first European Institution for Chemical Engineers Medal for Excellence in Gasification in 2002 and the GTC Lifetime Achievement Award in 2003. Mr. Todd has published numerous technical papers for various entities including the American Society of Mechanical Engineers and the Electric Power Research Institute. Mr. Todd received a B.S. degree in chemical engineering from Worcester Polytechnic Institute.

Martin J. Van Sickels

Mr. Martin Van Sickels has been in the process and engineering construction business for more than 42 years. Upon taking early retirement from Kellogg Brown & Root (KBR) in late 2004, he formed MVS Consulting, LLC, where he serves as president. Since its formation, MVS has assisted many clients covering a broad range of services.

During a 30-year career with KBR, Mr. Van Sickels provided technology leadership that differentiated KBR in the domestic and international market place, resulting in significant bottom-line income from both license fees and resulting engineering and construction services. He served in a wide range of managerial, technical, and commercial assignments, with particular emphasis on technology management. As a member of the Executive Committee, he was, in his last position at KBR, vice president and chief technology officer. His duties in this position included worldwide responsibility for the management, marketing, and development of all KBR proprietary and licensed technologies (chemicals, fertilizers, olefins, petroleum refining, and coal gasification) and special execution technologies (liquefied natural gas, gas-to-liquids, gas processing, and offshore technology).

Mr. Van Sickels was responsible for all R&D programs within all of KBR's product lines, including onshore, offshore, operations and maintenance, and infrastructure. He led the development of a ranking methodology for all R&D activities to align them with KBR's strategic and business plans. He also was responsible for KBR's 67,000-square-feet R&D center.

Mr. Van Sickels was member of the Inquiry Review and Pricing committees and chairman of Technology Screening and Patent committees. Mr. Van Sickels' main areas of experience include coal gasification and coal and biomass liquefaction.

Mr. Van Sickels received a B.S. in chemical engineering from the City College of New York and an M.S. in chemical engineering from New York University.