Project No. DE-FC26-05NT42645
Coal-Based Oxy-Fuel System Evaluation and Combustor Development

16 October 2006

I. PROJECT PARTICIPANTS

Award Recipient: Clean Energy Systems, Inc., Rancho Cordova, California (CES)

Subcontractors: Siemens Power Company
Air Products
Future Energy
Kinder Morgan
G.C.Broach Company
Nexant

II. PROJECT DESCRIPTION

- **Objectives**

  The objective of the program is to develop and demonstrate application of the CES oxy-fuel combustor to the generation of electricity from coal syngas at electric utility scale with high efficiency, zero atmospheric emissions and total carbon capture.

- **Relevancy**

  Coal is the most abundant available fossil fuel in the United States. Successful development of a means to consume coal for electricity generation without pollution will enable this vast resource to provide zero-emission power to meet growing U.S. energy demand and also improve U.S. energy security. CES has successfully demonstrated its technology using natural gas and will demonstrate its capability to use low heating value coal syngas as fuel. Under the program, electricity generating efficiency from syngas will be improved to parity or better with other fossil fuel generating technologies.

- **Project Summary**

  CES selected three oxy-fuel cycles for rigorous study. Process modeling was used to evaluate and further define each concept. Modeling included identifying and quantifying opportunities for improvement through subsystem integration and advanced development of subsystems. Achievable near-term and long-term system performances were evaluated.

  CES modifying its existing natural gas fired Kimberlina Demonstration facility to operate on simulated coal syngas and hydrogen-depleted syngas. A blending station was installed to deliver gas mixtures replicating the constituents of various syngases to the combustor. Tests were performed at firing rates of up to 4.7 MW_{th} and pressures up to 340 psia using both the existing natural gas injector and a custom injector designed for syngas operation.

  Using information gained from modeling and testing, CES will design and construct a pre-commercial scale 50 MW_{th} combustor for demonstration with

coal-derived syngas. Testing may take place at either the Kimberlina site (coal gasifier to be installed) or at another facility with syngas generation capability.

- **Period of Performance**

  The project has been broken down into three phases. Each phase is one year in duration. Overall project duration is from November 2005 to October 2008.

  Phase I. (November 2005 to October 2006): Identify concepts, model cycles, test Kimberlina combustor. Prepare R&D Implementation Plan. Provide preliminary design concept for pre-commercial syngas combustor.

  Phase II (November 2006 to October 2007): Accomplish detailed design of a pre-commercial scale combustor, building upon information and experience gained in Phase I. Prepare a test plan.

  Phase III (November 2007 to October 2008): Fabricate and test a pre-commercial combustor utilizing coal syngas. Test site to be determined.

III. PROJECT COSTS $ 7,929,845

A. DOE Costs $ 4,407,837
B. Contractor Cost Sharing $ 3,522,008

IV. MAJOR ACCOMPLISHMENTS SINCE THE BEGINNING OF THE PROJECT

Nov-05—Selection of Aspen modeling subcontractor
Nov-05—Procurement of Aspen Plus model

- This tool allowed CES to independently evaluate cycles and exchange information with the modeling subcontractor (Nexant).

Dec-05—Selection of eight concepts for further study from fifty candidates

- The eight concepts comprise two CES cycle configurations utilizing two coal-derived fuels (syngas and H_2-depleted syngas) in both near-term and long-term scenarios. Near-term cases include technologies available by 2010 while long-term include those available by 2015, including the possibility of ITM systems for oxygen production.

Jan-06—Completion of Kimberlina suitability study

- CES determined that the existing gas generator at Kimberlina could be operated with simulated coal syngas, with some relatively minor hardware modifications. This enabled operation of the gas generator at syngas firing rates of up to 4.7 MW_{th}.

Mar-06—Completion of R&D Implementation Plan

- The R&D Implementation Plan was submitted to NETL March 30th.

May-06—Installation of syngas blending station

- A syngas blending station was installed at Kimberlina Demonstration Power Plant (KDPP). It will be used to blend tube trailers, bottles, and dewar containers of syngas constituents (CO, H_2, CH_4, CO_2, and N_2).

Jun-06—Completion of Whitepaper on cycle analyses

- CES and Siemens submitted a draft joint Whitepaper to NETL summarizing the results of the cycle modeling for near-term and long-term applications. The long-

term analysis included several cases reflecting recent advances in supporting technologies.

Jun-06—Syngas cold-flow testing

- Cold-flow tests were performed at KDPP using nitrogen as a surrogate for the syngas fuel. These tests enabled the oxygen, fuel, and water valve sequencing to be optimized and for a modified start-up sequence to be tested.

Jul-06—Limited hot-fire tests

- The combustor was successfully fired with simulated syngas, at firing rates of up to 3.0 MW_{th}.

Aug-06—Fabrication of custom main injector for syngas operation

- An oxy-fuel injector was designed for syngas operation. The device was fabricated and installed in the Kimberlina combustor.

Aug-06—Completion of syngas testing

- Syngas combustion tests were successfully completed using both the original natural gas injector and the new syngas injector. Tests were performed at firings rates of 2.3-4.7 MW_{th}, and pressures of 265-340 psia.

Sep-06—Completion of hydrogen-depleted syngas testing

- Hydrogen-depleted syngas combustion tests were successfully completed using the syngas injector. Tests were performed at firings rates of 3.0-4.7 MW_{th}, and pressures of 255-320 psia.

Sep-06—Finalization of cycle modeling for near-term and long-term applications

- Using new gasifier input information from Future-Energy, CES completed the cycle analyses for the near and long-term cases. These will be included in the final Whitepaper to be submitted to NETL in October 2006.

V. MAJOR ACTIVITIES PLANNED DURING THE NEXT 18 MONTHS

- Perform detailed design of pre-commercial syngas combustor (Oct-06 to Jun 07)
  - Using information from the Phase I combustion tests, CES will prepare a detailed design of a pre-commercial 50 MW_{th} oxy-syngas combustor
- Perform detailed cost assessment of current cycle (Dec-06)
  - CES will perform an in-depth cycle analysis of the current (indirect) cycle. CES will then solicit cost and performance information from vendors for a nominal 50 MW_e plant using commercially-available technology. This information will be used to assess capital and operating costs of the plant.
- Prepare validation test plan (May-07)
  - CES will prepare a Validation Test Plan to support testing of the 50 MW_{th} combustor. The plan will define test sites, methods and operations, schedules, data acquisition/analyses, and the matrix of tests to be performed. Within the test matrix, independent and dependent test variables will be defined along with test goals and/or success criteria. CES will submit a copy of the Detailed Validation Test Plan to the DOE.
- Preliminary design of reheat combustor (Jun-07)
  - CES will conduct a preliminary design of an oxy-syngas reheat combustor required for the long-term cycle. This combustor will burn syngas in oxygen to reheat the exhaust gas from a high-pressure steam/CO_2 turbine. The design will follow the principles used in previous CES combustors.

- Fabrication of pre-commercial syngas injector (*tentative*)
  - CES believes it may be feasible to move one Phase III fabrication task forward into Phase II—construction of the main injector for the 50 MW_{th} syngas combustor—without increasing the existing Phase II budget. This injector precisely injects syngas, oxygen, and water into the combustion chamber. Should a budget analysis prove its feasibility, CES will formally propose to add this task to Phase II at no increase in contract cost. Using the detailed injector design developed early in Phase II, CES will fabricate the injector assembly using the same manufacturing methodologies employed in 170 MW_{th} natural gas applications. The fabrication of remaining combustor components (combustion chamber, cool-down chambers etc.) will occur in Phase III.

VI. ISSUES

- Delays in Phase I cycle analyses
  - The completion of the cycle analyses was delayed as a result of a change in the gasifier vendor. Specifically, ConocoPhillips was replaced by Future-Energy, a German-based gasifier vendor that was recently acquired by Siemens. This delayed the submission of the final Whitepaper on oxy-syngas cycle performance to October 2006 and completion of final cost assessment to Dec 06.