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AUG 29 2008

PUBLIC SERVICE COMMISSION

August 29, 2008

Mark R. Overstreet
(502) 209-1219
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moverstreet@stites.com

HAND DELIVERED

Stephanie L. Stumbo
Executive Director
Public Service Commission of Kentucky
211 Sower Boulevard
P.O. Box 615
Frankfort, KY 40602-0615

RE: P.S.C. Case No. 2008-00308

Dear Ms. Stumbo:

Please find and accept for filing the original and eight copies of the responses of Duke Energy Kentucky, Inc., Kentucky Power Company, Kentucky Utilities Company and Louisville Gas and Electric Company to the Staff's First Set of Data Requests in the above matter.

If you have any questions please do not hesitate to contact me.

Very truly yours,

Mark R. Overstreet

cc: Allyson K. Sturgeon
Rocco O. D'Ascenzo

RECEIVED
AUG 20 2008
PUBLIC SERVICE
COMMISSION

COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

In the Matter of:

JOINT APPLICATION OF DUKE ENERGY	)	
KENTUCKY, INC., KENTUCKY POWER	)	
COMPANY, KENTUCKY UTILITIES COMPANY	)	
AND LOUISVILLE GAS AND ELECTRIC	)	
COMPANY FOR AN ORDER APPROVING	)	CASE NO. 2008-00308
ACCOUNTING PRACTICES TO ESTABLISH	)	
REGULATORY ASSETS AND LIABILITIES	)	
RELATED TO CERTAIN PAYMENTS MADE TO	)	
CARBON MANAGEMENT RESEARCH GROUP	)	
AND THE KENTUCKY CONSORTIUM FOR	)	
CARBON STORAGE	)	

RESPONSES OF
DUKE ENERGY KENTUCKY, INC.,
KENTUCKY POWER COMPANY,
KENTUCKY UTILITIES COMPANY
AND
LOUISVILLE GAS AND ELECTRIC COMPANY
TO
FIRST DATA REQUEST OF COMMISSION STAFF
DATED AUGUST 19, 2008

REQUEST NO. 1

The Joint Applicants met with Commission Staff on January 17, 2008 to discuss their intent to request an accounting deferral. Explain in detail the reasons for the 7-month delay between the meeting and the July 25, 2008 filing of the Joint Application in this case..

RESPONSE:

The January 17, 2008 meeting was held at the request of Talina Mathews in her capacity as Executive Director of the Governor's Office of Energy Policy and as part of her efforts to solicit financial support from the Joint Applicants, as well as other generating utilities and energy companies (coal and petroleum), to match the funds to be provided by House Bill 1. The intervening period was used by the Joint Applicants to obtain the necessary corporate approvals and to coordinate the preparation of the joint application. In addition, the Joint Applicants were awaiting the preparation of documentation by the Carbon Management Research Group.

WITNESS: Timothy C. Mosher

KENTUCKY UTILITIES COMPANY
LOUISVILLE GAS AND ELECTRIC COMPANY

Response to First Data Request of Commission Staff
Dated August 19, 2008

Case No. 2008-00308

Question No. 2

Witness: Lonnie E. Bellar

Q-2. Refer to paragraph 5 of the Joint Application. The next-to-last sentence of the paragraph indicates that representatives of two of the Joint Applicants are members of the University of Kentucky Center for Applied Energy Research Advisory Board. Identify which of the Joint Applicants serve on the Advisory Board and provide the names of the individuals who represent the two Joint Applicants on the Advisory Board.

A-2. Kentucky Utilities Company and Louisville Gas and Electric Company are represented on the Advisory Board by Paul Thompson, Senior Vice President, Energy Services for E.ON U.S.

Duke Energy Kentucky, Inc.
Case No. 2008-00308
Kentucky Public Service Commission
First Set of Data Requests
Request Date: August 18, 2008
Response Due Date: September 2, 2008

KyPSC-DR-01-003(Duke)

REQUEST:

Refer to paragraph 14 of the Joint Application. With regard to Duke Energy's funding match of up to $200,000 to the Carbon Management Research Group ("CMRG"), provide the following information.

a. State the date that Duke Energy anticipates making its initial contribution to CMRG, whether the $200,000 initial contribution will be in a lump sum or in installments, and whether subsequent contributions, if made, will be at intervals of 12 months or at the beginning of each calendar year.

b. The paragraph indicates that Duke Energy will consider future participation in funding on a year-to-year basis contingent upon "progress made, work product reviews in subsequent years and CMRG's ability to secure additional funding sources." For each of these contingencies, identify Duke Energy's specific expectations of CMRG and any benchmarks or goals CMRG must achieve in order for Duke Energy to continue to make contributions.

c. Has CMRG agreed to any benchmarks or goals with respect to its progress to be made in subsequent years, its future work product, or its securing of additional funding? If yes, provide copies of each document which indicates such agreement by CMRG.

d. Is it Duke Energy's intention to seek rate recovery of the deferred contributions when it files its next general rate application, based on the level of contributions it has made at the time? Explain the response in detail

RESPONSE:

a. Initial payment date is anticipated to be within 30 days of the signature date of an Industrial Consortium Agreement signed by all participants and the Commission's approval of the application in this proceeding. DE-Kentucky anticipates quarterly payments. The exact timing, during the year, of the payments has not yet been established and a payment arrangement is pending approval of the Agreement by the Commission.
b. See attached Prospectus. Pages 3 & 4 identify the Tasks and Deliverables for Year 1 as "Project 1 – Task 1, 2, and 3", "Project III – Task 1" and on page 4 "deliverables 1 through 7." The membership is awarded an evaluation period on the project status prior to committing to subsequent years.

Soliciting additional In-State and Out of State members having interest and/or future involvement in this Project scope is a task assign to the Foundation. This task includes interest not only in the Power Sector, but Industrial and Transportation Sector's as well.

c. The scope of work for subsequent years include Project 2 – Task 1 from the Prospectus which starts with implementing the results from Year 1 at the CAER's pilot facility then extending these results to include field demonstrations as part of a commercial scale up process. Preliminary tasks have been identified in a confidential scope of work document prepared by the CAER's group. Detailed tasks will be assessed and included by the member board towards the end of the first year.
d. DE-Kentucky will seek rate recovery of the deferred contributions when it files its next general electric rate application. The amount of the deferral will be an annualized amount that reflects the Company's annual cash and in-kind contributions for the project.

PERSON RESPONSIBLE: John G. Bloemer

A Prospectus on the

Carbon Management Research Group

(An industrial, governmental and academic consortium advancing carbon capture and management technologies)

Overview

Teaming with Kentucky's major power companies, the University of Kentucky's Center for Applied Energy Research is forming an industrial-governmental-academic consortium called the "Carbon Management Research Group" (CMRG). The CMRG will carryout a ten-year program of research to develop and demonstrate cost-effective and practical technologies for reducing and managing CO_2 in existing coal-fired electric power plants. The intention is to position electric utilities to respond to a carbon-constrained economy prior to the imposition of environmental rules. Its purpose is to maintain and strengthen coal's competitive advantage as a least-cost fuel for electricity production, while improving environmental quality.

Why CMRG is important

- The overall cost of carbon capture and sequestration from a coal-fired power plant is: (1) Approximately 60% for capture/concentrate CO_2; (2) Approximately 20% to compress the CO_2 to pipeline pressures and (3) the remaining 20% for transportation & sequestration. These estimates show that the most promising area for cost reduction is in the CO_2 capture process.

- Available post-combustion technologies for capturing CO_2 are derived from chemical plant processes, and have not been investigated for electricity generation conditions with the presence of particulate matter, toxic gases, and trace elements. It is necessary to study the impact of these factors on the stability and operability of the CO_2-capture-island for an extended period. In addition, current technologies could potentially reduce a plant's power output by about 30%, equating to a 65% increase in the cost of electricity. Thus, a more cost-effective solution for reducing CO_2 emissions is needed if we are to continue to rely on our domestic energy resources and remain competitive in tomorrow's economy.

- Pilot- or full-scale research is costly, often making it too high-risk for a single utility or governmental agency to undertake. A research alliance that spreads costs and risks provides an opportunity to solve power generation problems in a manner affordable to members of the alliance.

Technical Focus of the CMRG

Three research projects on CO_2 capture and separation will be carried out:

1. Investigation of Post-Combustion CO_2 Control Technologies using the CAER's Pilot Plant.
2. Slip-Stream Investigation of Post-Combustion CO_2 Control Technologies at Consortium Members' Power Plant(s).
3. Development of Chemical Looping Combustion/Gasification for Solid Fuels

Project I is a fundamental study under real coal-derived flue gas conditions. The study will focus on scrubber configuration (packed tower vs. open tower), formulation of new solvents [operability, the balance of kinetics (capital cost) and thermodynamics (O&M cost)], technologies to enhance CO_2 capture and reduce the energy penalty (catalyst and carbon enrichment for post-scrubber solution), process optimization (heat integration), metal corrosion control, solvent holdup characteristics (fluid dynamic) caused by foaming and the presence of particulate matter, water balance/management, solvent management, as well as the environmental impact from solvent evaporation and degradation under coal-derived flue gas. The expected output will be to provide an insightful view of post-combustion CO_2 capture technology with various solvents, and satisfy concerns regarding adapting this capture process from chemical plants to power plants. The pilot-scale apparatus will be used as the platform to trouble-shoot and develop modifications related to the slipstream apparatus (see Project II). This project is a near to medium-range solution for CO_2-emissions control.

Project II is necessary for subsequent engineering scale-up. A portable slip-stream pilot plant will be constructed to demonstrate post-combustion CO_2 capture technologies with a coal-fired power plant. Its capacity will be 0.5~1MWth. This facility will test the performance of new energy-efficient solvents and validate pilot-scale and modeling work. The test sites will be selected based on system configurations (FBC, Wall-fired and Four-corners fired PC), APCD configuration (SCR-plate/honeycomb, FGD-forced/natural oxidization) and coal types (low, high sulfur coal) at the plants.

The project will focus on the system operability (particulate matter impact), solvent management as related to coal types, gaseous and dissolved constituents, long-term verification, and material corrosion. At each site, a three-month parametrical study will be conducted to verify the results and findings obtained from the CAER's pilot-scale apparatus. Two solvents will be used for this investigation. A 30% MEA will be used as a baseline, followed by the best commercial solvent or a new solvent developed at the CAER.

Three heating sources for solvent regeneration will be evaluated for the CO_2 capture island's stability, operability, and flexibility. The heating sources are LP steam extraction, fire-tube oxyfuel natural gas, and fuel oil combustion. The best solvent will be used for the future scale-up. After identifying optimum operational conditions, two 1500-hour verification runs will be conducted sequentially -- one for the MEA baseline, and another for the second solvent. At one site, a downstream CO_2 compression train (which will require an additional capital investment) will be added to the portable slip-stream plant to study the compression characteristics, dehydration and heat integration.

At this time, system performance will be evaluated. The impact of fuel costs, CO_2 compression technologies, ammonia recovery rates and heat integration configurations on system performance and process economics will be determined for each process to aid cost comparisons as described in the DOE's Carbon Capture and Sequestration Systems Analysis guideline.

Project III, chemical looping combustion is a more appropriate project for the next generation of power plants and as such is a potential long-term solution. However, chemical looping combustion technology could ultimately prove to be the most cost-effective means for CO_2 control for coal-based power generation. This study will focus on scaling up work previously performed at the CAER involving oxygen carriers in a pilot gasification/combustion reactor.

Facilities Available

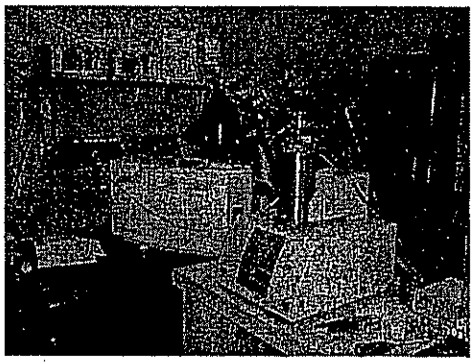


Figure 1: CAER's TG-DSC-MS System

- o A Netzsch Jupiter 449C a thermal analyzer-differential scanning calorimeter-mass spectrometer (TG-DSC-MS);
- o 0.1MWth CO_2 capture pilot-plant.

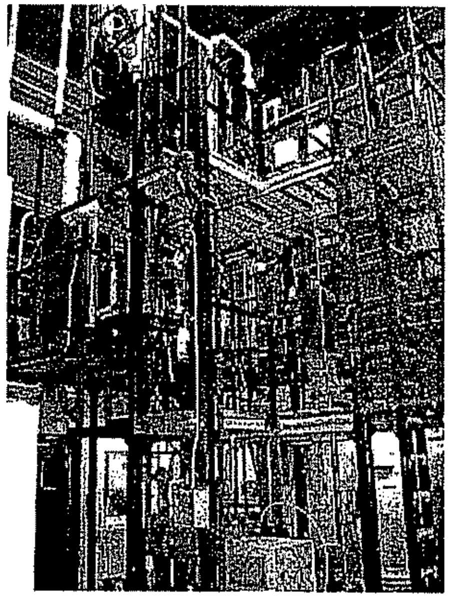


Figure 2: CAER's 0.1 MWth pilot-plant, constructed as part of a research project funded by E.ON US.

Tasks and Deliverables in Year (7/1/2008-6/30/2009)

		7/1/08-6/30/09
Project I: Investigation of Post-Combustion CO_2 Control Technologies using CAER Pilot Plant		
Task	1. Rebuild Coal-derived Flue Gas Generator	
	2. New Concept (such as additives and new solvent) and Process Development	
	3. Kinetic Data Collection for Solvent Developed at CAER	
Project II: Slip-Stream Investigation of Post-Combustion CO_2 Control Technologies at Consortium's Power Plant		
Task	1. Design of Slip-Stream Post-Combustion CO_2 Capture System	
Project III: Development of Chemical Looping Combustion/Gasification for Solid Fuels		
Task	1. Investigation on Oxidization and Decomposition Characteristic of Potential Oxygen Carriers using TGA	

As presented in the program's Gantt chart, Year 1 (7/1/2008-6/30/2009) is the year for preparation and fundamental study. The program **activities** include:

Project I: Investigation on the CAER's Pilot Plant
(Task 1) An existing coal-fired pilot plant will be rebuilt to produce coal flue gas used in subsequent tasks. The unit will be capable of producing over 50 scfm of flue gas similar to that of the coal-fired power stations that will be the focus of the slip-stream study in Project II.

(Task 2) Solid additives will be attached to the scrubber which will act as a catalyst to promote the scrubber's reaction rate via solid formation in the reaction liquid film at low pH. The solid will dissolve in the parent liquid, which has a high pH, due to mass transfer resistance. The solid formation will drop the reactant concentration in the film and could result in a significant increase in the ion concentration gradient across the film from the parent gas and liquid, resulting in high mass transfer rates across the film and a high CO_2 absorption rate. This approach could result in a smaller scrubber, and lower capital cost. CAER has identified a candidate, and completed the preliminary study.

Process development will focus the fluid dynamic study on various scrubber configurations. Scrubber designs will be investigated that reduce the potential blockage/pressure drop issues encountered when using a conventional packed bed scrubber for CO_2 capture. Then a new CO_2 scrubber similar to the WFGD type (open or tray column) will be designed.

(Task 3) Scrubbing with aqueous ammonia with chemical additives will be a target for Year 1. The research will focus on the NH_3-CO_2-H_2O phase diagram under utility flue gas conditions. Additives such as DCD and THAM will be included to control the ammonia's partial pressure.

Project II: Investigation on the Portable Slip-stream Plant
(Task 1) The design for the portable slip-stream facility will begin at the end of Year 1. The design will be based on the data/information obtained from the CAER's 0.1MWth pilot-plant using simulated flue gas. Before constructing the slip-stream operation, the design will be modified based on the data obtained when real coal-derived flue gas is used in the pilot-plant. The key consideration will be the capacity balance between the scrubber and the stripper when various solvents are applied. .

Project III: Chemical Looping Combustion
(Task 1) The TGA-DSC-MS will be used to study oxygen carrier behavior in the presence of coal or fly ash as it is cycled between an oxidation step and a reduction step at various temperatures.

The **deliverables** of Year 1 will include:

1. A coal-derived flue gas generator;
2. Kinetic data including rate constant and mass transfer flux at various conditions;
3. Optimal process parameters for selected additive(s);
4. Fluid dynamics in scrubber and stripper with the presence of particulate matter;
5. A rapid velocity scrubbing technology that could significantly reduce scrubber size;
6. Preliminary design of the portable slip-stream apparatus; and
7. Kinetic data for various oxygen carriers.

Benefits from Participation in the CMRG

- Insight into technical information which will help identify appropriate post-combustion CO_2-control technologies for the existing power generation fleet;
- Maintenance of a low-cost power industry based on coal, and preservation of the existing coal-fired electricity generation fleet.
- Demonstration of a lower-cost solvent-based CO_2-capture process that could improve the economics of a national greenhouse gas sequestration program.
- Valuable first-hand experience with carbon capture technologies for power plant personnel from member companies.

- A program of instruction for the development and training of future generations of utility professionals and plant engineers needed to sustain the region's electric-power industry.

Cost and Fees

The Commonwealth of Kentucky, through the University of Kentucky Center for Applied Energy Research (CAER), will provide a match against industry financial support at 1:1, up to a maximum amount of $1 million per year for the first two years. After this period, funding will be dependent on resources made available by the state.

Any company may become a member of the CMRG. Membership will be extended to each company which provides financial support in amounts divided equally among the members and sufficient to cover one-half of the resources necessary for the anticipated scope of work. Such scope of work and fees will be determined and fixed by the Industrial Advisory Board (IAB) annually. IAB will be composed of representatives from each of the members. The members shall agree to contribute $200,000 for Year 1 in support of CMRG's research activities.

If you are interested in participating in CMRG or would like further information, such as our ten-year research plan, please email, mail or fax your inquiry to:

Dr. Kunlei Liu
Associate Director, Power Generation and Utility Fuels
University of Kentucky
Center for Applied Energy Research
2540 Research Park Drive
Lexington, KY 40511

Fax: 859-257-0220
Phone: 859-257-0293
Email: liu@caer.uky.edu

REQUEST NO. 4

Refer to paragraph 14 of the Joint Application. With regard to Kentucky Power's funding match of up to $200,000 to CMRG, provide the following information:

a. State the date that Kentucky Power anticipated making its initial contribution to CMRG, whether the $200,000 initial contribution will be in a lump sum or in installments, and whether subsequent contributions, if made, will be at intervals of 12 months or at the beginning of each calendar year.

b. The paragraph indicates that Kentucky Power will review the funding on a year-to-year basis contingent upon "progress made, additional funding sources secured and work product reviews in subsequent years." For each of these contingencies, identify Kentucky Power's specific expectations of CMRG and any benchmarks or goals CMRG must achieve in order for Kentucky Power to continue to make contributions.

c. Has CMRG agreed to any benchmarks or goals with respect to its progress to be made in subsequent years, its future work product, or its securing of additional funding? If yes, provide copies of each document which indicates such agreement by CMRG.

d. It is Kentucky Power's intention to seek rate recover of the deferred contributions when it files its next general rate application, based on the level of contributions it has made at this time? Explain the response in detail.

RESPONSE:

a. Subject to the Commission's Order granting the utility authority to establish a regulatory asset and liability in this proceeding; the Company would anticipate making the first payment during the first quarter 2009. The initial contribution would be a lump sum in the amount of $200,000. Subsequent contributions, if made, would be made each year on the anniversary date of the initial payment.

WITNESS: Timothy C. Mosher

RESPONSE CONTINUED

b. KPCo's annual decision for continued funding of the CMRG research project will include the following:

1. The progress made in meeting the objectives outlined on page 2 in the Scope of Work (copy attached). The document was prepared by CAER and agreed to by the participants.

2. The progress made in the three (3) technical projects also outlined on page 2 of the Scope of Work (copy attached) and detailed on pages 6, 12 and 17 of the Scope of Work.

3. Success of CMRG's efforts to broaden the financial support from additional participants.

4. Information received at the CMRG semi-annual presentation of research progress as detailed on page 3 of the Industrial Consortium Agreement (copy attached).

WITNESS: Timothy C. Mosher

c. The commitments by CMRG as to benchmarks and goals with respect to its progress to be made in subsequent years, its future work product and its securing of additional funding is included in either the scope of work document or the Industrial Consortium Agreement attached to the Company's response to item number 4(b).

WITNESS: Timothy C. Mosher

RESPONSE CONTINUED

d. Yes. For example, should the Commission issue its Order authorizing the establishment of the Regulatory Asset and Liability by November 15, 2008 the Company anticipates making its first payment during the first quarter 2009 and each of its following nine payments also during the first quarter of each year.
If the Company's first rate case, following the Commission Order in this proceeding, utilizes a test year of December 31, 2010, the Company would anticipates having a regulatory asset with a balance of $400,000 ($200,000 paid in 2009 plus $200,000 paid in 2010 payment). Due to the fact that there are only eight years left, the Company would make an adjustment to the test year of $50,000 ($400,000 / 8) to reflect the amortization of the regulatory asset. The Company would also make a $200,000 adjustment to the test year to reflect the annual ongoing payment.

Year	Annual Payments	Amount in Base Rates
2009	$200,000	$0
2010	$200,000	$0
2011	$200,000	$250,000
2012	$200,000	$250,000
2013	$200,000	$250,000
2014	$200,000	$250,000
2015	$200,000	$250,000
2016	$200,000	$250,000
2017	$200,000	$250,000
2018	$200,000	$250,000
Total	$2,000,000	$2,000,000

WITNESS: Timothy C. Mosher/Errol K. Wagner

Scope of Work

Carbon Management Research Group (CMRG)

U. K. Center for Applied Energy Research

Fossil fuels account for over 80% of the world's energy use and are expected to continue their dominance throughout this century. Fossil fuels also account for about three-fourths of the total emissions of carbon dioxide, which is a suspected prime contributor to global warming and climate change. This latter has a direct bearing on our continued reliance on coal to generate power since coal is the most carbon-intensive of the major fossil fuels. Considering that there is no near-term alternative for reducing dependence on fossil fuels, it is imperative that we develop technologies that can provide significant reductions in CO_2 in a practical and affordable manner

Coal releases carbon dioxide (CO_2), sulfur oxides (SO_2), nitrogen oxides (NOx), and trace heavy metals during combustion. New federal regulations implemented in March of 2005 target reductions in the emissions of mercury, as well as steeper reductions in the emissions of SO_2 and NOx. *A recent legislative proposal introduced in the 109th Congress would mandate CO_2* emission reductions in the US. If enacted, this proposed legislation would apply to all coal-fired power generation units within the state.

According to recent estimates, the overall cost for carbon capture and sequestration from a coal-fired power plant can be proportioned as: (1) Approximately 60% of the overall cost would be needed to capture/concentrate the CO_2; (2) Approximately 20% to compress the CO_2 to pipeline pressures and (3) the remaining 20% would be needed for costs associated with transportation & sequestration. It is clear from these estimates that the major cost for CO_2 capture and sequestration will be in the capture step making this the most promising area for significant cost reductions.

Closer to home, a carbon-constrained energy future would have a significant negative impact on the economy of Kentucky and region. Not only is coal production a signature Kentucky and regional industry, but, for instance due to the fact that over 90% of our electricity production derives from coal, Kentucky's electric-energy costs are among the lowest in the nation. Historically, low electricity costs have been instrumental in attracting a number of major and *relatively energy-intensive industries to our state such as aluminum and automobile* manufacturers, along with their related suppliers and high-wage jobs. If the region is to maintain a vibrant and low-cost power industry based on coal, a cost-effective CO_2 management strategy must be developed and implemented. Current technologies for capturing CO_2 from a coal-fired power plant can reduce power output by about 30%, potentially equating to a 65% increase in the cost of electricity. Thus, a more cost-effective solution for reducing CO_2 emissions is needed if we are to continue to rely on our domestic energy resources and remain competitive in tomorrow's economy.

Scope of Research/Research Projects of the Consortium

Objectives

- Provide guidance to the CMRG members to help identify appropriate post combustion CO_2-control technology for their existing power generation fleet;
- Position the CMRG to better respond to future carbon-reduction requirements, maintain and strengthen coal to electricity's comparative advantage as a viable low-cost producer of electricity, while simultaneously improving the environmental quality;
- Understand and describe the relevant mechanisms of CO_2 enrichment, separation, and capture for both post-combustion and in-situ combustion processes, and develop/demonstrate practical technologies for reducing CO_2 emissions from the CMRG's existing fleet of coal-fired power plants;
- Create a support infrastructure for research, development and demonstration (RD&D) of technologies related to pollution control, CO_2 management, byproduct management, energy efficiency, and power plant performance; and
- Train the consortium's workforce to effectively respond to challenges that will be faced in a carbon-constrained world.

Background

There are three ways to reduce the CO_2 emissions that are related to the consumption of fossil fuels for energy production. (1) The first and best method is to use energy more efficiently, thereby reducing the quantities of fossil fuels that must be combusted to meet our energy requirements. (2) The second is to increase our energy supply from carbon-free or renewable energy sources (e.g., nuclear, solar, wind, geothermal, biomass). In terms of the cost of electricity (COE), renewable energy is often expensive and may not be of sufficient quantity to have a significant impact. (3) The third is to separate, capture, and securely store the carbon dioxide as it is generated (carbon sequestration). Any of these approaches could significantly lower carbon emissions.

Considering that the CMRG has a vested interest in keeping the current fleet of power plants in operation into the foreseeable future and would like to position itself well regarding carbon management for future plants, three research projects dealing with the capture and separation of CO_2 at the utility site are suggested for investigation. The following is a listing of the technical projects in these areas:

- **I. Investigation of Post-Combustion CO_2 Control Technologies using CAER Pilot Plant**
- **II. Slip-Stream Investigation of Post-Combustion CO_2 Control Technologies at Consortium's Power Plant**
- **III. Development of Chemical Looping Combustion/Gasification for Solid Fuels**

Project I will focus on scrubber/stripper configuration, formulation of new solvents, technologies/process to enhance the CO_2 capture and reduce energy penalty, process optimization, metal corrosion control, solvent foaming, solvent management as well as secondary environmental impact from solvent evaporation and degradation under real coal-derived flue gas. The pilot-scale apparatus will be also used as the platform to trouble-shoot and to develop operating modifications related to the slipstream apparatus (see Project II). This project represents a near to medium-range solution for CO_2-emission control.

Project II represents a critical step in developing and demonstrating practical technologies for reducing CO_2 emissions from the CMRG's existing fleet of coal-fired power plants, and is considered a medium to long-term solution. A mobile slip stream pilot plant will be constructed to demonstrate the post combustion CO_2 capture technologies in conjunction with a coal-fired power plant. This pilot plant will be used to test the performance of new energy efficient solvents and to validate modeling work. By testing this unit at power plant sites, the reliability and long-term stability of the CO_2 capture technologies will be determined. Additionally, power plant personnel from the CMRG members will gain valuable experience with carbon capture technologies.

Project III, chemical looping combustion, is more appropriate for the next generation power plants and as such is a potential long-term solution. However, chemical looping combustion technology could ultimately prove to be the most cost-effective means for CO_2 control for coal-based power generation. This study will be focused on scale-up of work previously done at the CAER involving the use of oxygen carriers in a gasification/combustion reactor.

Each project is described in more detail beginning on the next page.

Foreword

The consortium is being built on the successes the CAER is showing with the 0.1MWth pilot plant using simulating flue gas we have built for post-combustion CO_2 capture (supported by E-ON US). The pilot-plant consists of a 20 ft tall by 6" ID clear PVC scrubber, an solvent recovery unit in the scrubber exhaust stream, two stainless steel heat exchangers (for cross-flow heat recovery and deep cooling of the CO_2-lean solution, respectively), a 14-foot stainless steel stripper that is 4" ID in the upper tower section and 8" ID in the lower reboiler section, and a condenser for ammonia recovery in the stripper exhaust. The pilot plant is operated via a computer control system and is instrumented as required for the monitoring and control of flow rates, temperatures, and pressures.

Project I: Investigation of Post-Combustion CO_2 Control Technologies using CAER 0.1MWth Pilot Plant

Among the post-combustion CO_2 capture techniques currently available, chemical-solvent methods (aqueous absorption/stripping) are generally recognized as the most effective. Of these, the monoethanolamine (MEA) process has been extensively studied and used successfully in chemical plants for CO_2 recovery. There are several small commercial facilities in the U.S. that use solutions of 15 to 30 % MEA by weight to recover CO_2 from coal-fired power plants and from gas turbines. In fact, the aqueous absorption/stripping (MEA) process is the only commercially-available technology for extracting CO_2 from post-combustion flue gas. This process involves the counter-current contact of the flue gas with the aqueous amine-based solvent to reversibly react CO_2 in an absorber column at 80-100°F. The solvent is regenerated in a stripper that liberates the CO_2 at 250°F.

With support from industry and US DOE, The University of Texas at Austin is conducting study on a pilot-scale post-combustion CO_2 capture facility with various aqueous solutions using simulating flue gas. A close-looped absorption/stripping pilot plant with 42.7 cm ID columns was used to capture CO_2 using an 32.5 wt% aqueous MEA solution. Both the absorber and stripper contained 20 ft of packing. Various packings, lean CO_2 loadings, gas and liquid rates, and stripper pressures were tested. The CO_2 material and heat balances converged within 6.5 and 6.9%, respectively. Measured heat duties for the pilot plant ranged from 369 to 1690 MJ/hr. These reboiler duties were especially high due to a lack of adequate preheat before the stripper.

The University of Texas at Austin is also undergoing an effort to improve the process for CO_2 capture by alkanolamine absorption/stripping by developing an alternative solvent, aqueous K_2CO_3 promoted by piperazine or piperazine only. A great deal of fundamental chemistry (kinetic and solvent degradation) has been conducted in past several years. The best K^+/PZ solvent, 4.5 m K^+/4.5 m PZ, requires equivalent work of 31.8 kJ/mole CO_2 (Aspen simulation) when used with a double matrix stripper and an intercooled absorber. The oxidative degradation of piperazine is reduced significantly compared to MEA. The study indicated that the energy requirement for stripping and compression to 10 MPa is about 20% of the power output from a 500 MW power plant with 90% CO_2

removal. The stripper rate model shows that a "short and fat" stripper requires 7 to 15% less equivalent work than a "tall and skinny" one. However, no continuous runs were carried out with this new solvent as of this writing.

In Canada, the University of Regina is conducting similar research to that of the University of Texas, focusing on amine-based post-combustion CO_2 capture approach using a pilot-scale packed tower apparatus with simulating flue gas. The emphasis there is on packing material/structure evaluation, solvent foaming behavior and elimination, and materials corrosion. However, their corrosion research is conducted under static simulated scrubber conditions.

In the past several years, other aqueous solutions have gained more interest, including potassium carbonate and particularly NH_3, with significant energy reduction associated with the CO_2 stripping process. The scrubbing capacity of NH_3 is approximately 0.9 -1.2 kg of CO_2/kg of NH_3, with a CO_2 removal efficiency of ~99% and energy consumption approximately 40% less than the conventional MEA process based upon data collected from the intermittent operating apparatus. Ammonium bicarbonate decomposes at a relatively low temperature of 60°C, as compared to a 120°C regeneration temperature for MEA solutions. However, the separation of CO_2 from stripper evolved gas after thermal decomposition and ammonia slip from the stripper are likely to be technical challenge. The potential NH_3 losses could influence the economics of the technology and cause environmental concern. However, the research conducted at NETL and SRI was based upon intermittent operational mode and using simulated flue gas.

As indicated in the study conducted at University of Texas and University of Regina, a trace amount of metals (such as Cu, Fe) will have significant impact on solvent deactivation/degradation (solvent management). Unfortunately, these elements identified thus far commonly exist in the coal-derived flue gas. Hence, it will be necessary to conduct research under real coal flue gas environments to judge the stability of candidate solvents.

In this project, with the CAER's existing 0.1 MWth pilot plant unit and the addition of a coal-derived flue gas generator, our research (see Table 1) will focus on:

- Scrubber configuration – target on a three phase (liquid-gas-solid) fluidized bed approach to reduce the scrubber capital cost.
- Formulation of new solvents besides NH_3, MEA, KS with criteria of low cost, low volatility and less degradation rate
- New process/technologies to enhance the reaction rate of CO_2 capture in scrubber and CO_2 release in stripper, which could result a reduction the capital cost and energy requirements.
- Process optimization (heat integration, and operational parameters)
- Corrosion control
- Solvent deactivation/degradation and management protocol.

Table 1 -- Project I Tasks & Schedule

TITLE	PROPOSAL DATE	PROJECT DURATION
Project I: Investigation of Post-Combustion CO_2 Control Technologies using CAER Pilot Plant	1/15/2008	07/01/2008 - 6/30/2016

GOAL

1. Provide guidance to the Kentucky's Utilities to help identify appropriate post combustion CO_2-control technology
2. Position the Kentucky's utilities to better respond to future carbon-reduction requirements, maintain and strengthen Kentucky's comparative advantage as a low-cost producer of electricity, while simultaneously improving the quality of Kentucky's environment
3. Understand and describe the relevant mechanisms of CO_2 enrichment, separation, and capture for both post-combustion and in-situ combustion processes
4. Creating a support infrastructure for research, development and demonstration (RD&D) of technologies related to pollution control, CO_2 management, byproduct management, energy efficiency, and power plant performance

OBJECTIVES

1. Understand the mechanisms of the aqueous-based scrubber under coal-power plant atmosphere
2. Develop novel solvent, and heat-integrated processes to minimize the energy penalty for CO_2 control
3. Investigate the various scrubber configurations, operating parameters on CO_2 capture efficiency, operation conditions etc
4. Study the impact of flue gas impurities on CO_2 capture performance and solvent durability
5. Identify appropriate configurations tailored for Consortium's existing fleet

DELIVERABLES

1. Optimum heat-integration design of post-combustion scrubber technology under various flue gas conditions
2. Guidelines on scrubber design with low capital and operating cost, and high CO_2 removal efficiency
3. Post-combustion pilot CO_2 control plant and coal-derived flue gas generator
4. Technical report

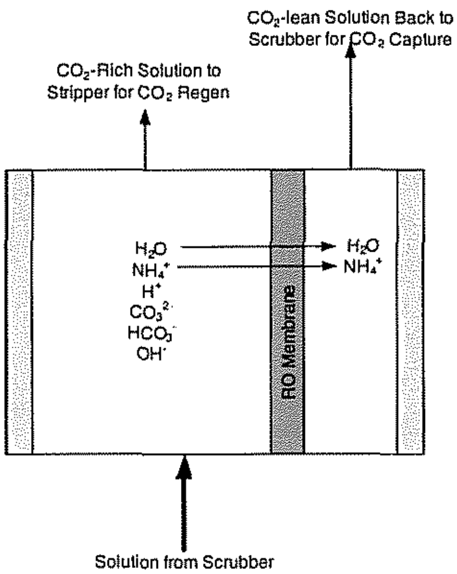
	Budget	07/01/2008 - 6/30/2016															
		08	09		10		11		12		13		14		15		16
TASKS X--X PLANNED	($K)	1st Half	2nd Half	3rd Half	4th Half	5th Half	6th Half	7th Half	8th Half	9th Half	10th Half	11th Half	12th Half	13th Half	14th Half	15th Half	16th Half
1. Rebuild Coal-derived Flue Gas Generator	1,200.0	X	XX	XX													
2. System/process Optimization	600.0			XX	XX	XX											
3. Impact of Coal Types, APCD Setup on Solvent Characters (such as degradations, deactivation etc)	400.0					XX	XX	XX	XX	XX	XX						
4. Operating parameters optimization for energy consumption vs. CO_2 capture efficiency	400.0					XX	XX	XX	XX	XX	XX						
5. Long-term Verification and Metal Corrosion Characteristics	400.0											XX	XX	XX	XX	XX	XX
6. New Concept (such as liquid membrane, additives and new solvent) and Process Development	1,500.0	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
7. Kinetic Data Collection for Solvent Developed at CAER	500.0	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
Budget Totals	5,000.0	350		1400		800		530		520		500		350		350	200

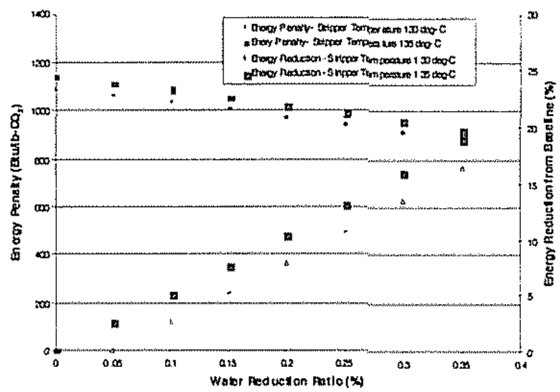
Specifically,

- In Task 1, a portion of an existing coal-fired pilot plant will be rebuilt to produce coal flue gas that will be used in subsequent tasks. The unit will be capable of producing over 50 scfm of flue gas similar to that of the coal-fire power stations that will be the focus of the slip-stream study in Project II.
- In Task 2, the research emphasis will be on scrubber & stripper configuration with the addition of a catalyst to enhance CO2 reaction rates – target on a three phase (liquid-gas-solid) fluidized bed approach or open tower –tray and spray approach to replace the current packed tower for reducing the scrubber capital cost. The current barrier for post-combustion CO_2 capture is the slow dissolution rate of the gas-phase carbon into liquid-phase carbon. In this task, the potential catalyst for enhancing carbon soluble rate will be evaluated and developed. In the packed tower, the superficial gas velocity is typically in the range of 3-5ft/s with the pressure drop of 0.1-0.3 inch WC/ft packing material. With internal packing, the gas velocity is limited to approximately 1/3 of superficial velocity in a typical WFGD system to prevent column flooding. Therefore the main objective of this task will be to minimize pressure drop across the scrubber while increasing flue gas superficial velocity in order to decrease the size of the scrubber system. A variety of new packing materials will be evaluated to achieve this goal.
- In Task 3, as we discussed before, the research will focus on the impact of trace elements from fly ash as well as vapor in the exhaust flue gas (metal, SO_2, SO_3, HCl/HF, NOx) on solvent management (blow-down/make-up rate, solvent foaming behavior, solvent reclaim protocol and etc).
- In Task 4, the research will focus on minimizing the energy requirements while optimizing CO_2 capture efficiency. Additionally, the impact of initial CO_2 concentration in the flue gas on energy consumption will be quantified. In general, high CO_2 capture efficiency requires a high energy input per ton of CO_2 captured basis because of unfavorable kinetics under relatively low CO2 partial pressures (compared to petrochemical or syngas applications). In this task, we will use an ASPEN plant model to simulate CO_2/inert gas compression separation to determine a sweet spot for future slipstream investigations.
- In Task 5, several 1500-hour long-term campaigns will be conducted to verify the solvent management protocol (which will be used for economic analysis), and material corrosion study with various CO2 capture solvents.
- In Task 6, two new concepts will be developed. One is focused on solid additives; another is to develop a membrane to remove water from carbon-rich solution in the solvent-based post-combustion CO_2 capture approach.
    - The concept of a solid additive into the scrubber is to reduce CO_3^{2-} and HCO_3^- concentration in the solution by physical adsorption or weak chemical absorption and forms a carbon-rich slurry system, which could promote and favor the CO_2 capture. A CO_2-rich slurry enrichment process to minimize the water content of the CO_2-rich slurry could result in significant savings in the heat required to heat the concentrated slurry. CAER has already identified a candidate, and completed the preliminary

study, and is currently modifying this additive to enhance its capacity and reduce its energy requirement for regeneration.

- According to recent scientific data, the overall cost for carbon capture and sequestration from a coal-fired power plant can be summarized as follows: (1) Cost for CO_2 capture is approximately 60% of the overall cost; (2) Cost of CO_2 compression is approximately 20%; and (3) The cost of transportation & sequestration is approximately 20%. The concept we are working on here is to develop an innovative membrane or an ionic liquid to remove a portion of water from the spent scrubber solution prior to the stripper, in an effort to increase the carbon concentration (e.g. CO_3^{2-} and HCO_3^- ions) in the solution, as illustrated in the figure below (left).





The benefit from the proposed concept is three fold: (1) reduce the quantity of CO_2-rich solution sent to the stripper, which could reduce the energy requirement for sensible heat significantly; (2) the high carbon load in the solution entering the stripper will favor the CO_2 desorption, which could drop the energy requirement for desorption of CO_2; and (3) a decreased stripper vessel size due to the chemical equilibrium shift.

An Aspen simulation developed at the CAER indicates the energy penalty could decrease the baseline consumption of energy by 20% if a membrane is deployed to remove 35% of the water from the post-scrubber solution, as presented in the Figure above (right).

The preliminary experimental data on the membrane indicates that the carbon concentration in the solution was increased to 10% by wt from 2% by wt using a commercial available reverse osmosis (RO) membrane.

However, a new membrane needs to be developed for the high carbon concentrations seen in scrubber solutions, which will be our research focus.

Literature search on potential ionic liquid candidates have been completed, and initial experiments are being planned

- In Task 7, new solvents will be developed and the kinetic data related to those solvents will be collected and determined.

Milestones:

(a) June 2009 complete investigation using simulated flue gas, and provide design specifications for slip-stream apparatus for Project II;

(b) December 2009, complete coal-combustion flue gas generator fabrication, installation and commissioning;

(c) December 2010, complete a detail parametrical testing for the particular coal that will be fired in the slipstream field testing site, and provide the optimum operational conditions as well as solvent management protocol;

(d) December 2014, complete membrane pilot-scale testing;

(e) December 2015, complete catalytic scrubbing and stripping pilot-scale experiment.

Project II. Slip-Stream Investigation of Post-Combustion CO_2 Control Technologies at Consortium's Power Plant

As part of the European Union integrated project "CO_2 from Capture to Storage" (CASTOR), a 1 t/h CO_2 absorption pilot plant has been erected at the 400 MW coal-fired Esbjerg power plant in Denmark. The main purpose of the pilot plant is to demonstrate the post combustion capture technology in conjunction with a coal-fired power plant. Additionally, the pilot plant will be used to test the performance of new energy efficient solvents and to validate modeling work. The design of the pilot plant is based on a commercial CO_2 production plant using alkanolamine as an absorbent.

The pilot plant operates on a slipstream of the flue gas taken after the deNOx and FGD plants. The flue gas does not undergo any further treatment or conditioning before it enters the CO_2 capture plant. In December 2006 - February 2007, a 1000 hours test campaign on a conventional solvent, 30 %-weight MEA solution, was conducted at the pilot plant. Among others, the campaign included tests to verify plant functionality and stability as well as a more detailed parametric study. The study shows that it is possible to maintain stable and reliable operation of the plant and to operate the plant at neutral water balance. The steam requirement for the MEA process was found to be 3.7 GJ/ton CO_2 and the MEA consumption 1.4 kg/ton CO_2. The operational costs, excluding maintenance and personnel costs was found to be around 14 EUR per ton CO_2 removed. In the coming years, the pilot plant will be used to gain more experience on post combustion capture and to evaluate the performance of novel solvents developed in the CASTOR project.

In collaboration with EPRI and others, Alstom is constructing a 5MWth chilled ammonia pilot-plant at the We Energies power plant in Pleasant Prairie, Wisconsin, that will capture CO_2 from a portion of boiler flue gas. The ALSTOM carbon capture process uses chilled ammonia to capture CO_2. This process dramatically reduces the energy required to capture carbon dioxide and isolate it in a highly concentrated, high-pressure form.

In May 2004, Powerspan and the Department of Energy's (DOE) National Energy Technology Laboratory announced a cooperative research and development agreement (CRADA) to develop a cost effective CO_2 removal process for coal- based power plants. The scope of the three-year CRADA includes laboratory testing, pilot testing and detailed studies of the CO_2 capture process economics.

The Powerspan process, that uses ammonia based solutions to capture SOx, NOx, CO_2, Hg and particulates from power plant flue gas have or will be demonstrated at FirstEnergy's R.E. Burger Plant in Shadyside, Ohio. Powerspan has conducted initial laboratory testing of the CO_2 absorption process, which demonstrated 90 percent CO_2 removal under conditions comparable to a commercial-scale absorber. Initial cost estimates indicate that the ammonia-based process could cost less than half of the next lowest-cost CO_2 capture technology currently under investigation.

CMRG Slip-Stream Project Proposal

In this project a series of slip-stream field investigations at selected utility's plants will be carried out using a portable 1MWth slip-stream post-combustion apparatus. The test sites will be selected based upon system configurations (FBC, Wall-fired and Four corners fired PC), APCD configuration (SCR-plate/honeycomb, FGD-forced/natural oxidization) and coal types (low, high sulfur coal) at the various power plants. This study conducted at a power plant represents a critical step in developing and demonstrating practical technologies for reducing CO_2 emissions from the CMRG's existing fleet of coal-fired power plants. The study will also help in training the workforce to response to challenges that will be faced in a carbon-constrained world.

Our research (as illustrated in Table 2) will focus on the system heat integration, solvent management, long-term verification and material corrosion. At each site, approximately 3-month parametrical study will be conducted to verify the results and findings obtained from CAER pilot-scale apparatus. Two solvents will used for this parametrical investigation – 30% MEA as baseline, and one best commercial solvent or a new solvent developed at CAER. The comparison between two solvents will be used as base for future scale-up. Upon the identification of optimum operational conditions, two 1500-hour verification runs will be conducted sequentially -- one for the MEA baseline, and another for second solvent.

Specifically, in addition to study listed above, the following research will also be conducted.

- At Site A, low pressure steam will be selected as the heat source for solution regeneration in stripper. The heat integration will focus on how to arrange the FW heater to recover the waste heat. The cost analysis including system modification will be studied.
- At Site B, natural gas will be chosen as heat source for solution regeneration in stripper. The combustion will be direct-oxyfuel fire-tube type. As many research papers have stated, approximately 30% of steam entering the low pressure turbine will be withdrawn into the stripper for solvent regeneration, which will result several significant impacts on the LP turbine and boiler operation besides hardware modification, such as (1) load change as a result of the CO_2 capture plant instability; (2) over-cool issue of steam at LP exhaust due to access excess condenser capacity while the CO_2 capture plant is on-line, especially winter time; (3) FW water temperature variation due to the CO_2 capture plant instability will result in potential plug flow for once-through boiler. The heat integration will be focus on how to recovery the waste heat of natural gas derived flue gas.
- At Site C, fuel oil will be chosen as heat source for solution regeneration in stripper. Similar to site 2, the combustion will also be direct-oxyfuel fire-tube type.

Table 2 – Project II Tasks & Schedule

TITLE	PROPOSAL DATE	PROJECT DURATION
Project II: Slip-Stream Investigation of Post-Combustion CO_2 Control Technologies at Consortium's Power Plant	11/27/2007	07/01/2008 - 6/30/2017

GOAL

1. Provide guidance to the Kentucky's Utilities to help identify appropriate post combustion CO_2-control technology
2. Position the Kentucky's utilities to better respond to future carbon-reduction requirements, maintain and strengthen Kentucky's comparative advantage as a low-cost producer of electricity, while simultaneously improving the quality of Kentucky's environment
3. Understand and describe the relevant mechanisms of CO_2 enrichment, separation, and capture for both post-combustion and in-situ combustion processes
4. Creating a support infrastructure for research, development and demonstration (RD&D) of technologies related to pollution control, CO_2 management, byproduct management, energy efficiency, and power plant performance

OBJECTIVES

1. Study the impact of flue gas impurities (coal types) on CO_2 capture performance and solvent durability at selected units
2. Evaluate the performance of various aqueous solvents
3. Conduct long-term field verification tests and obtain necessary operating experience
4. Collect information/data on material corrosion and sorbent degradation kinetic during the long-term verification runs
5. Conduct economic analysis for specific selected unit with future potential fuel switch/changes

DELIVERABLES

1. Optimum heat-integration design of post-combustion scrubber technology under various flue gas conditions
2. Guidelines on scrubber design with low capital and operating cost, and high CO_2 removal efficiency
3. Post-combustion slip-stream CO_2 control plant
4. Technical report

TASKS X--X PLANNED	Budget ($K)	07/01/2008 - 6/30/2017																	
		08	09		10		11		12		13		14		15		16		17
		1st Half	2nd Half	3rd Half	4th Half	5th Half	6th Half	7th Half	8th Half	9th Half	10th Half	11th Half	12th Half	13th Half	14th Half	15th Half	16th Half	17th Half	18th Half
1. Design of Slip-Stream Post-Combustion CO_2 Capture System	500		XX	X															
2. Fabrication, installation and shakedown	8,000			XX	XX	XX													
3. Slip-Stream Testing at Site 1 including install and teardown	1,700						XX	XX	X										
4. Slip-Stream Testing at Site 2	1,700								X	XX	XX								
5. Slip-Stream Testing at Site 3	1,700											XX	XX	X					
6. Slip-Stream Testing at Site 4	1,700													X	XX	XX			
7. Slip-Stream Testing at Site 5	1,700																XX	XX	X
Budget Totals	17,000			3200		5300		1300		1300		1400		1400		1400		1400	300

- At Site D, a downstream CO_2 compression train (will need additional capital investment) will be added to portable apparatus. The sweet-spot obtained from Task 4 in Project I will be adjusted and verified in this site. Heat integration study will include the waster heat recovery from compression train.
- At Site E, the study will include the impact of CO_2 concentration in flue gas on energy penalty vs. CO_2 capture efficiency. The inlet CO_2 concentration will be controlled by dosing high concentrated CO_2 from stripper outlet. The goal of this study is attempt to combine in-situ oxyfuel combustion with low-grade oxygen (pre-concentrated CO_2), and post-combustion CO_2 capture approach in the target to eliminate flue gas recirculation and reduce scrubber size.

Milestones:

(a) June 2009, finalize design specifications for potential slip-stream apparatus;

(b) December 2010, complete portable slip-stream apparatus fabrication, installation and commissioning;

(c) June 2012, complete the first site investigation; and

(d) June 2014, technology transfer.

Project III: Development of Chemical Looping Combustion/Gasification for Solid Fuels

Among the available or proposed technologies involving CO_2 purification, pressurized chemical looping combustion/gasification (CLC/G) may be the most promising. In CLC/G, coal is not combusted in the conventional sense. Rather, coal may be used to chemically reduce a metal oxide to its metallic form while the oxygen removed from the metal is used to oxidize the carbon in the coal. This can be envisioned by considering the manner in which coke is used to reduce iron ore to iron in a smelter as the iron ore, consisting of a mixture of iron oxides (FeO, Fe_2O_3, and Fe_3O_4), supplies oxygen to oxidize the coke to CO and CO_2. CLC/G produces a flue gas concentrated in CO_2 using atmospheric air for combustion and can do so with a much more modest derate than absorption/stripping or oxy-combustion (see figures on following pages). CLC/G technology differs from IGCC technology in that the production of syngas is not the objective in the CLC/G process. Rather, the application of in-situ gasification serves to promote the reaction rate between the solid fuel (coal) and the solid oxygen carrier and to decrease the reactor dimensions.

The heat generation step in chemical loop combustion occurs when the metal is transferred to a separate vessel where it is contacted with air and rapidly oxidizes (burns). Most of the heat generation takes place in this step. As a result, the metal is re-oxidized and then returned to the reduction vessel where it is again contacted with coal. No stand-alone air separation unit (ASU) is needed as oxygen is separated from air in-situ, during the metal-reoxidation step.

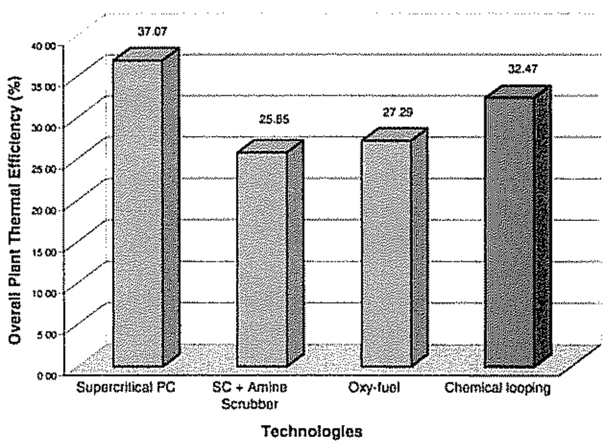
Chemical Looping Combustion is in its early stage of development. So far, most CLC development has focused on using natural gas as the reductant. Solid fuels such as coal and biomass have until now been ignored due to technical concerns. These concerns deal primarily with the challenges of solid-solid contact between the coal and the chemical looping material, i.e., the oxygen carrier. Solid-solid contact for the purpose of an oxidation-reduction reaction is a slow process compared to a gas-solid reaction. In addition, after the carbon in the coal is consumed, the ash will remain a solid that must be separated from the oxygen carrier at some point in the loop, e.g. via particle size or density.

The process proposed for development consists of both an advanced CLC/G process and a Brayton cycle utilizing CO_2 as the working fluid. The major focus will be on the *development of an advanced CLC/G process. The facility will consist of three major* components – a high-velocity riser serving to separate oxygen from air by fixing gaseous oxygen into the oxygen-carrier structure, a down-flow moving bed (Redox-M) acting as a gasifier and partial reduction reactor for converting the metallic oxygen carrier to its elemental form, and a low-velocity bubbling bed (Redox-B) acting as both a deep-reduction reactor and a device for separating the reduced oxygen carrier from the fuel ash and unburned carbon on the basis of density and/or particle size. The flue gas exiting the bubbling bed will be nitrogen-free, consisting primarily of CO_2 and H_2O and possibly CO and H_2. The resulting highly concentrated (>90%) CO_2 stream is suitable for subsequent sequestration.

Since the primary motivation for developing this process is to produce power while facilitating the capture and sequestration of CO_2, it would be useful to compare its energy efficiency potential to other competing technologies. The leading contenders for coal-based power production with CO_2 capture are amine absorption/stripping and oxy-combustion. Both of these technologies have the advantage of being adaptable to existing plants. However, the thermal and power penalties for these technologies are significant. Air Liquide recently performed a study for DOE that compared the energy efficiency of oxy-combustion to both conventional PC combustion and to conventional PC combustion with CO_2 capture with an amine scrubber. Using the same format, we have added the energy efficiency numbers for a conventional circulating fluid-bed boiler and chemical loop combustion. These results (below, Table 3 and figure)), show that chemical looping combustion offers significant advantages over the other two leading candidates for the concentration/capture of CO_2 during the combustion of coal (Air Liquide, Final Report to DOE-2005). If we use conventional, state-of-the-art PC combustion as the reference case, oxy-combustion will require 36% more heat input (fuel) to achieve the same electric power output. Amine scrubbing with MEA will require 43% more heat input. By comparison, chemical looping combustion will require only 6 % more heat input. No other combustion-based CO_2 concentrating technology can compare with chemical looping combustion on the basis of cycle efficiency.

Table 3.

Name	Unit	Pulv Coal Comb.	Circulating FBC	Coal based Chemical Looping Comb. w/ CO_2 Combined Cycle	Oxy-Comb.	Pulv Coal Comb. w/ CO_2 Capture by MEA
Gross Power Output	MW	533.2	533.2	607.1	533.2	533.2
Coal Feed Rate as-received	short tons/hr	262.5	262.5	279.7	253.3	4262.5
ASU Power	MW	---	---		101.1	---
CO_2 Compressors Power Use	MW	----	---	55.4	49.3	38.0
Other Aux. Power Use	MW	31.8	49.5	48.9	26.6	47.2
Net Power Output	MW	501.4	483.8	502.8	356.2	349.7
Net Efficiency (HHV)	%	37.07	35.76	34.88	27.29	25.80
Heat Rate (HHV)	Btu/kWh	9,213	9,549	9,792	12,514	13,212



Comparison on the Overall Plant Efficiency vs. CO_2 Capture/separation options

In this project, the study (as illustrated in Table 4) will focus on the evaluation of possible processes or configurations and the establishment of a viable concept for applying Chemical Looping Combustion to solid fuels. In this phase, 1) mass, energy, and pressure balances among the three components will be investigated using an ASPEN Process Simulation model; 2) oxidization and decomposition characteristics of potential oxygen carriers will be investigated by TGA; 3) a bench-scale system (Redox-M&B) will be designed, fabricated and tested; and 4) the technical risks and barriers will be identified.

Specially, the study will involve:

- Task 1. *Design and Fabrication of pilot-scale pressurized* Redox-M: The pilot-scale simulation of Redox-M consists of four components: a heated storage hopper, a down-flow moving bed (Redox-M), cooling section equipped with gas-injection and sampling ports, and a disposal hopper. The apparatus is 152 inches high with a 2-inch I.D moving bed (Redox-M). The storage-hopper capacity is 500 lbs, sufficient for an-8 hour test at a flowrate of 60 lb/hr of oxygen carrier.
- Task 2 & 3. Investigation of the pilot-scale pressurized Redox-M reactor: Due to the multiple functions the Redox-M must accomplish (in-situ coal gasification and combustion and OC reduction), the design and operation of this unit will be critical to the successful application of PCLC to solid fuels. In this task, coal char and simulating syngas generated in the pyrolysis unit will be combusted by contact with the OC selected in Task 4. The impact of the initial OC temperature, residence time, operating pressure, solids mixing profile, and gas composition in Redox-M on gasification and combustion of the solid fuel will be studied. Prior to each test, the OC will be preheated to a targeted temperature using electrical-heating elements installed in the storage hopper. Charcoal and natural gas will be used to simulate the char and syngas that would be generated in the coal pyrolyzer.

  The oxygen carrier, charcoal, and ash will be fed to the top of the moving bed. Natural gas and CO_2 will be injected from the side to maintain incipient fluidization at four levels and will exit from the bottom of the bed. The solids cool as they approach the bottom where the spent OC, combustion flue gases, and coal ash are conveyed into the disposal hopper through an auger. In addition to the equipment described, the pilot-scale facility will be equipped with separate feeders for the char and OC, water cooling for the bottom auger, a fixed-bed oxygen carrier regenerator (oxidizer), on line gas analysis equipment, gas-flow controllers, and instrumentation to measure gas-flow rates, temperatures, and pressures.

Table 4 – Project III Tasks & Schedule

TITLE	PROPOSAL DATE	PROJECT DURATION
Project III: Development of Chemical Looping Combustion/Gasification for Solid Fuels	1/15/2008	07/01/2008 - 6/30/2017

GOAL

1. Position the Kentucky's utilities to better respond to future carbon-reduction requirements, maintain and strengthen Kentucky's comparative advantage as a low-cost producer of electricity, while simultaneously improving the quality of Kentucky's environment
2. Understand and describe the relevant mechanisms of CO_2 enrichment, separation, and capture for in-situ combustion processes
3. Creating a support infrastructure for research, development and demonstration (RD&D) of technologies related to pollution control, CO_2 management, byproduct management, energy efficiency, and power plant performance

OBJECTIVES

1. Develop the most effective approach for CO_2 management
2. Understand the mechanisms of the chemical looping combustion of solid fuel.
3. Apply FBC with pulverized coal as a chemical looping combustion platform to burn solid fuels
4. Overcome the technical challenges such as fly ash separation, oxygen carrier de-activation, and slow solid-solid reaction kinetics
5. Identify external funding for potential Phase III - Demonstration facility

DELIVERABLES

1. Feasibility study on the application of chemical looping combustion to solid fossil fuels
2. General arrangement of CLC base system
3. Bench-scale CLC system for solid fuel combustion
4. Guidelines for oxygen carriers selection and evaluation
5. Technical report.

TASKS X—X PLANNED	Budget ($K)	07/01/2008 - 6/30/2017																	
		08	09		10		11		12		13		14		15		16		17
		1st Half	2nd Half	3rd Half	4th Half	5th Half	6th Half	7th Half	8th Half	9th Half	10th Half	11th Half	12th Half	13th Half	14th Half	15th Half	16th Half	17th Half	18th Half
1. Design and Fabrication of Bench-Scale Redox Apparatus of CLC	400.0						XX	XX											
2. Shakedown, and Testing in Bench-Scale CLC Redox	500.0							X	XX	XX	XX								
3. Long-Term Experiment Using Various Coals	500.0											XX	XX	XX	XX	XX	XX	XX	XX
4. Oxygen Carrier Development	300.0	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
5. Investigation on Oxidization and Decomposition Characteristic of Potential Oxygen Carriers using TGA	300.0	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
Budget Totals	2,000	30		70		70		540		350		250		190		190		190	120

- Task 4 & 5. Oxygen carrier (OC) development and investigations: In this task, a pressurized TGA will be used to study OC behavior as it is cycled between an oxidizing and a reducing environment at targeted pressures (ambient, 25, 50, 100, 150, and 250psia). A nitrogen-purged chamber will separate the oxidizing and reducing sections to minimize the potential for explosion. If possible, the behavior of OCs prepared from Ni, Co, and Fe and their associated oxides, applied with TDA's Geode [TDA, 2002] technology, will be evaluated. The feasibility of using the proprietary dual-layer oxygen carrier will also be investigated. The reducing agents to be studied will include H_2, CH_4, C_2H_2 and Charcoal. De-activation (poisoning) of OC by the coal ash will also be investigated by mixing with three coal ashes (eastern bituminous, PRB, and lignite). The most suitable OC, as determined by mechanical properties and reaction characteristics, will be selected in this task.

Milestone:

(a) December 2012, complete fossil-fuel based Redox fabrication, installation and commissioning; and

(b) December 2015, complete of the pilot-scale test campaign.

FINAL FOR SIGNATURE

INDUSTRIAL CONSORTIUM AGREEMENT
For the
CARBON MANAGEMENT RESEARCH GROUP

Between

____

And the
UNIVERSITY OF KENTUCKY RESEARCH FOUNDATION

THIS AGREEMENT, having an Effective Date of____________________, is made by and between _______ ____, a corporation having its principal place of business at ____ ___________________________(hereafter referred to as "MEMBER") and the UNIVERSITY OF KENTUCKY RESEARCH FOUNDATION, with offices and place of business at 109 Kinkead Hall, Lexington, KY 40506-0057 (hereafter referenced to as "FOUNDATION").

RECITALS

WHEREAS, MEMBER together with FOUNDATION agree to form an Industrial Consortium to be called the CARBON MANAGEMENT RESEARCH GROUP (hereafter referred to as "GROUP") aimed at serving the electric power industry with new and advanced technologies achieved through its research programs, technology transfer initiatives and graduate and undergraduate education; and

NOW THEREFORE, in consideration of the promises and the mutual covenants contained herein, the parties agree as follows:

ARTICLE I: DEFINITIONS

(A) "Confidential Information" means information that is proprietary and/or confidential to the discloser, and shall include trade secrets, as further set forth in Article IX.
(B) "Inventions" shall mean improvements and/or discoveries, including software, know how, patent and other intellectual or industrial property conceived, made or reduced to practice in the performance of this agreement, as further set forth in Article VII.
(C) "Member" or collectively "Members" shall mean the Members as further set forth in Article III.
(D) "Affiliate" means, with respect to any person, any other person (other than an individual) that directly or indirectly, through one or more intermediaries, controls or is controlled by, or is under common control with, such person. For this purpose, "control" means the direct or indirect ownership of fifty percent (50%) or more of the outstanding capital stock or other equity interests having ordinary voting power..

ARTICLE II: GROUP GOVERNANCE

(A) GROUP Administration. The GROUP will be administered through the Center for Applied Energy Research at the University of Kentucky (hereafter referred to as "UNIVERSITY"). It will follow all UNIVERSITY rules and procedures regarding expenditure of funds, personnel issues and accountability.

(B) GROUP Advisory Board. The GROUP shall have an Industrial Advisory Board (hereafter referred to as the IAB) which will be composed of representatives from each of the MEMBERS and GROUP's Director. The IAB will have the following responsibilities:

1. Develop and implement policies and policy changes which will provide the GROUP's guiding principles in so far as such policies are not in conflict with Kentucky statutes and UNIVERSITY regulations.

2. Establish and prioritize programs plans.
3. Identify program needs and recommend program changes.
4. Review and evaluate the program.
5. Review and recommend major research projects.
6. Promote the GROUP with other industry and agencies.
7. Assist in providing and procuring financial support for the program.
8. Review the effectiveness of the technology transfer effort.

The IAB also shall:

1. Elect its chairperson.
2. Determine the eligibility for membership to the IAB.
3. Meet at least once a year or more as scheduled by its chairperson.
4. Review, discuss, and act on the agenda as determined by its chairperson.
5. Amend agenda items in writing two weeks prior to the scheduled meeting or during a meeting provided at least one other MEMBER concurs by seconding the proposed addition or modification.

(C) GROUP Director. The GROUP's Director (hereafter referred to as "DIRECTOR") shall be appointed by the Director of the Center for Applied Energy Research. The DIRECTOR's responsibilities will be:

1. Serve as the IAB's Secretary.
2. Manage the day-to-day activities of the GROUP.
3. Expend funds in support of projects recommended by the IAB.
4. Identify suitable UNIVERSITY faculty and staff as principal investigators for each GROUP research project.

ARTICLE III: GROUP MEMBERSHIP

(A) GROUP Membership and Annual Fees. Any company may become a MEMBER of the GROUP. Membership will be extended to each company which provides financial support in cash to the GROUP in amounts divided equally among the MEMBERS and sufficient to cover one-half of the resources necessary for the anticipated scope of work, such scope of work and fees being determined and fixed by the IAB on an annual basis. FOUNDATION, through the University's Center for Applied Energy Research, will cover the remaining one-half of costs, up to a maximum amount of $1 million per year, and dependent on resources made available for this purpose by the state. Every Member shall be given copies of every other Member's execution of this same Industrial Consortium Agreement.

(B) MEMBER agrees to contribute <u>$200,000.00</u> for the current year (July 1, 2008 – June 30, 2009) in support of the GROUP and thereby becomes a MEMBER. Membership fee payment shall be made to the University of Kentucky Research Foundation as a lump sum payable annually, semi-annually or quarterly. Notwithstanding the forgoing, MEMBER shall only be obligated to pay the membership fee when MEMBER receives approval from the Kentucky Public Service Commission to defer the membership fee costs as a regulated asset for inclusion in future MEMBER rate cases. However, until such payment is received, FOUNDATION is under no obligation to commence work on the project or cover the remaining one-half of costs as provided in Article III (A) above.

(C) Companies wishing to join the GROUP after its establishment and after the Charter Members must indicate their interest in writing to the IAB. The IAB will have the right to accept or reject the request for membership after reasonable consideration by all Members.

(D) The initial membership period covered by this agreement is from July 1, 20<u>08</u>, through June 30, 20<u>09</u>. Membership shall terminate unless MEMBER renews its membership by sending its letter of continuing commitment by June 1 and paying its fee annually, semi-annually or quarterly in each succeeding year. FOUNDATION shall notify MEMBER, as soon as possible, of any reason that might contribute to the failure to perform within the specified performance period even if such reason is beyond the control and without fault or negligence of the FOUNDATION. Checks shall be identified "CARBON MANAGEMENT RESEARCH GROUP" and mailed to:

University of Kentucky Research Foundation
C/o National City Bank
P.O. Box 931113
Cleveland, OH 44193
IRS Tax ID#: 61-6033693

ARTICLE IV: GROUP RIGHTS AND BENEFITS

(A) In consideration of MEMBER's funding, such MEMBER shall be entitled to:

1. Rights to participate in the governance and advisory structure of the consortium as provided in Article II.
2. Access to and use of the technical information and results of the research that is conducted.
3. Access and use for internal company purposes only, without right to sublicense, any inventions, and technologies and other tangible intellectual property that may be conceived or developed in the course of the research as provided in Article VII.

(B) Companies whose request for membership is approved by the IAB will have rights only to intellectual property developed after their membership has been approved and while such membership remains current and paid-up. For avoidance of doubt, upon execution of this Agreement, MEMBER's membership shall be deemed approved by the IAB. The IAB will have the right to place additional constraints or limitations on the rights of new MEMBERS at the time of approval. Constraints not determined at the time of approval will not be subsequently imposed. For avoidance of doubt, the rights of MEMBER granted hereunder shall not be affected absent an amendment to this agreement signed by MEMBER and FOUNDATION.

(C) As a MEMBER, each company will name a Technical Representative who will:

1. Receive all communications from the GROUP;
2. Have access to research data and material;
3. Be invited to participate in the semi-annual presentations of research progress;
4. Have access to the project principal investigators; and
5. Have access to all programs and products developed by the GROUP.

ARTICLE V: DESIGNATED REPRESENTATIVES

1. Technical Representative

For MEMBER:
Name
Address
Telephone/Fax/Email

For FOUNDATION
Dr. Kunlei Liu
University of Kentucky
Center for Applied Energy Research
2540 Research Park Drive
Lexington, KY 40511
Tel. 859/ 257-0293
Fax 859/ 257-0220
Kunlei Liu <liu@caer.uky.edu>

2. Administrative Representative

For MEMBER:
Name
Address
Telephone/Fax/Email

For FOUNDATION
Mr. R. David Azbill
University of Kentucky Research Foundation
109 Kinkead Hall
Lexington, KY 40506-0057
Tel. 859/ 257-4826
Fax 859/ 323-1060
David Azbill <rdazbi1@email.uky.edu>

ARTICLE VI: REPORTS

Each MEMBER will receive, in a timely manner a semi-annual research progress report. These and any other reports, as reasonably determined by the IAB, shall be supplied to each MEMBER by the DIRECTOR of the GROUP.

ARTICLE VII: PATENTS AND INVENTIONS

(A) All rights and title to all inventions, improvements and/or discoveries, including software, know how, patent and other intellectual or industrial property conceived, made or reduced to practice in the performance of this agreement (hereafter referred to as "INVENTIONS"), shall belong to the FOUNDATION.

(B) With respect to domestic United States patent applications covering INVENTIONS conceived, made or reduced to practice by FOUNDATION, FOUNDATION will be solely responsible for the costs associated with the preparation, filing, prosecution, and maintenance of those applications and any patents that issue there from. With respect to foreign patents covering INVENTIONS, MEMBERS or other potential licensees may, at MEMBERS' or other licensee's expense, elect to designate countries for the filing, prosecution and maintenance of foreign counterparts to patent applications and patents covering INVENTIONS and FOUNDATION agrees to cause such filings, prosecution and/or maintenance to be effectuated. Alternatively, MEMBER or other licensee may elect to retain its own patent counsel, reasonably acceptable to FOUNDATION, and at its own expense make such foreign filings. All filings shall be submitted to FOUNDATION, in advance, for its review and approval, which approval shall not be unreasonably withheld. Such foreign patent applications shall be filed in the name of FOUNDATION as assignee, title shall be in FOUNDATION.

(C) Subject to IAB restrictions on new MEMBERS, FOUNDATION shall promptly notify all MEMBERS of any INVENTIONS made in the performance of this agreement. Disclosures submitted by FOUNDATION to all MEMBERS shall be identified as confidential.

(D) Subject to IAB restrictions on new MEMBERS and in consideration of the funding made available by MEMBER, FOUNDATION hereby grants to MEMBER and to MEMBER's Affiliates a paid-up, nonexclusive, nontransferable, perpetual license to INVENTIONS conceived, made or reduced to practice by FOUNDATION in the year or years the MEMBER's membership is current and paid-up solely for such MEMBER's and its Affiliates' internal company purposes and not for the direct benefit of any other third party.

(E) No commercial license (including make, sell, or lease license) is granted herein to any MEMBER. However, any MEMBER or other potential licensee may negotiate with FOUNDATION a royalty-bearing, exclusive (if no other MEMBER expresses an interest in licensing same) or nonexclusive commercial license to make, have made, sell or lease INVENTIONS.

(F) If MEMBER elects to exercise the rights identified in the paragraph (D) and (E) above, it must notify, in writing, the DIRECTOR of its intent within sixty (60) days of said INVENTIONS disclosure. Terms that are normal and customary for such agreements will be negotiated in good faith by the FOUNDATION and MEMBER and or other potential licensee. It is expected that negotiation of the definitive license agreement will be completed within the first ninety (90) days after MEMBER's notification.

(G) MEMBER AGREES THAT THE RIGHTS GRANTED IN ANY INVENTION SHALL BE WITHOUT WARRANTY OF ANY KIND EXPRESSED OR IMPLIED INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AND FURTHER INCLUDING NO WARRANTY AS TO CONFORMITY WITH WHATEVER USER MANUALS OR OTHER LITERATURE MAY BE ISSUED FROM TIME TO TIME. MEMBERS FURTHER ACKNOWLEDGE THAT FOUNDATION MAY NOT CONDUCT NOR HAVE CONDUCTED PATENTABILITY OR INFRINGEMENT STUDY, BUT THAT TO THE BEST OF FOUNDATION'S KNOWLEDGE, THE LICENSED RIGHTS WILL NOT INFRINGE, MISAPPROPRIATE OR VIOLATE ANY PATENT, COPYRIGHT, TRADE SECRET OR OTHER PROPRIETARY RIGHT OF ANY THIRD PARTIES.

(H) If Federal Government support is provided to the GROUP, from the start of such support the above patent and invention procedures will be modified to correspond to applicable Federal Government patent regulations provided that Federal Government funding shall not be accepted unless approved by the IAB.

ARTICLE VIII: COPYRIGHTS

FOUNDATION may claim the copyright of data first produced in the performance of this agreement. FOUNDATION shall have the right to use, release to others, reproduce, distribute, or publish any data first produced or specifically used by the FOUNDATION in the performance of this agreement. FOUNDATION hereby grants to MEMBER a paid-up, nonexclusive, nontransferable, perpetual license to reproduce any such data for MEMBER's use.

ARTICLE IX: PROPRIETARY OR CONFIDENTIAL INFORMATION

(A) Should proprietary or confidential information be exchanged under this agreement, each party agrees, absent any special provisions to the contrary, to:

1. Receive and maintain in confidence any and all confidential or proprietary information delivered by one party hereto to the other party;
2. Use confidential information solely for the purpose or purposes for which it was disclosed and for no other purpose whatsoever;
3. As a receiving party , to disclose confidential information to its employees, officers, agents, and representatives only on a need to know basis;
4. Identify <u>in writing</u> all confidential or proprietary information as such at the time of disclosure;
5. Subject to #3 above, not release confidential or proprietary information to any third parties; and
6. To dispose of or return proprietary or confidential information to the disclosing party when requested or upon expiration or termination of this contract.

(B) The period of confidentiality shall be five (5) years from the effective date of this contract.

(C) Confidential information does not include any information which:

1. is already in the public domain or which becomes available to the public through no breach of confidentiality by the recipient;
2. was, as between recipient and disclosure, lawfully in receipt's possession on a non-confidential basis prior to receipt from the disclosure;
3. is received by recipient independently on a non-confidential basis from a third party free to lawfully disclose such information to the recipient; or
4. is independently developed by recipient without use of the disclosure's confidential information;
5. The release of confidential information by the receiving party to satisfy the requirements of federal, state or local laws shall not be a breach of this agreement.

ARTICLE X: PUBLICATION

Subject to limitations of ARTICLE IX, FOUNDATION shall have the right to release information or to publish any information or material resulting from the conduct of the GROUP. FOUNDATION shall furnish the IAB with a copy of any proposed publication or presentation thirty (30) days in advance of the proposed publication or presentation date. Any MEMBER may request FOUNDATION to delay publication for a maximum of an additional sixty (60) days in order that MEMBER may pursue a patent on any Invention described in the manuscript. No delay, however, will be imposed on the filing of any student thesis or dissertation.

ARTICLE XI: CHANGES AND MODIFICATIONS

Any changes to this agreement must be made in writing and must be executed by both parties to indicate acceptance of the modification. Changes that impact the entire consortium must be approved by the IAB.

ARTICLE XII: ASSIGNMENTS AND SUBCONTRACTS

Neither performance nor payment involving the whole or any part of the effort described in this Agreement may be assigned, subcontracted, transferred, or otherwise given or imposed on any other party by FOUNDATION or MEMBER without the prior written consent of the other party.

ARTICLE XIII: MUTUAL RESPONSIBILITIES

(A) Each party will comply with all applicable governmental laws, ordinances, rules and regulations in the performance of this agreement.

(B) Without affecting or limiting any other provisions of this agreement, it is agreed each party's obligation under Article VII may survive the expiration of this agreement.

(C) Each party to this agreement is an independent contractor with each party solely responsible for its own business expenses and employees including but not limited to salaries, benefits, insurances, withholding, worker compensation and taxes. Employees of either party shall not be deemed agents, employees or representatives of the other party.

(D) In the execution to this agreement, the people whose signatures are set forth are duly authorized to execute the agreement and bind the parties.

ARTICLE XIV: ANTITRUST PROVISIONS

In entering into this Agreement, the parties have no intent to discuss any matters which could or might be viewed as prohibited under Antitrust laws. To prevent any inadvertant discussions, in addition to the foregoing, the Parties agree to the following anti-trust provisions:

(A) A written agenda will be prepared for each meeting and the Parties will stick to that agenda. Notes will be taken during each meeting and meeting minutes or other records of what took place during the meeting will be prepared.

(B) The Parties agree not to exchange non-public, competitively sensitive information without appropriate protections/limitations being put in place, including information and data relating to customers, competition, and sales and marketing activities and strategy, such as current or prospective pricing information, price formulas or price strategies; transactional information relating to competitive elements of sales and supply agreements with suppliers or customers; current cost information; or planning documents, including business plans, operating plans, marketing plans or strategic plans.

(C) Requests for information or data will be made in writing and vetted by antitrust-sensitive counsel.

(D) The Parties will refrain from engaging in unnecessary communications, and will limit e-mails and other documents to only those necessary to advance the discussions.

(E) In no event should one or more of the Parties propose, discuss or agree to reduce output, raise prices or diminish the quality of any product or service.

(F) In no event should one or more of the Parties propose, discuss or agree to take or not to take a commercial action with respect to any third party where such action would harm the third party or would otherwise be against a party's economic self-interest.

(G) Each Party will continue to make all commercial decisions independently and unilaterally.

ARTICLE XV: USE OF NAMES

Neither party shall use the name of the other party, and MEMBER shall not use the name of the University of Kentucky, in any news release, advertising or other publication without express written permission of the other party.

ARTICLE XVI: TERMINATION

(A) Either party may terminate this agreement at any time if:

1. The other party materially breaches the terms of this contract; provided that the non-breaching party shall have given the breaching party written notice of such breach and the breaching party shall have failed to cure the same within thirty (30) days after receipt of such notice.
2. There is the loss or departure of key personnel which would jeopardize both the quality and time of performance or would make performance impractical with respect to budget contemplated for this agreement, and a mutually acceptable replacement cannot be found.
3. Performance of any part of this agreement by a party is prevented or delayed by reason of Force Majeure and cannot be overcome by reasonable diligence to satisfaction of either party; or
4. The other party ceases, discontinues or indefinitely suspends its business activities related to the services to be provided under this agreement, or the other party voluntarily or involuntarily files for bankruptcy.

(B) In the event of termination, immediate notice shall be given by the party requesting termination, which should specify both reason and the effective date of termination.

(C) In addition, either party may terminate this contract for any reason with sixty (60) days written notice to the other party.

(D) Upon any termination except for breach of agreement, FOUNDATION shall deliver to MEMBER in the state they exist as of the date of termination all work product, materials, including confidential information and property belonging to MEMBER.

ARTICLE XVII: APPLICABLE LAW

This agreement shall be governed by the laws of the State of Kentucky.

ARTICLE XVIII: ENTIRE AGREEMENT

This agreement is intended by the parties as a final written expression of their agreement and supersedes and replaces any prior oral or written agreement. Any terms or conditions inconsistent with or in addition to terms and conditions herein contained shall be void and of no effect unless specifically agreed to in writing and signed by both parties.

ARTICLE XIX: SURVIVAL

The rights and obligations of the parties set forth in Article VII shall survive termination of this Agreement.

IN WITNESS WHEREOF, the parties hereto have caused their authorized officials to execute this Agreement as of the date(s) set forth below:

MEMBER	**FOUNDATION**
______________________________	______________________________
Typed Name and Title:	Deborah K. Davis, Associate Director
______________________	______________________
Date	Date

KENTUCKY UTILITIES COMPANY
LOUISVILLE GAS AND ELECTRIC COMPANY

Response to First Data Request of Commission Staff
Dated August 19, 2008

Case No. 2008-00308

Question No. 5

Witness: Lonnie E. Bellar

Q-5. Refer to paragraph 14 of the Joint Application. The last sentence states that KU and LG&E have "jointly agreed to provide up to $200,000 a year for ten years."

a. Is it correct to interpret the language of the sentence, plus the absence of certain language from the sentence, to mean that KU's and LG&E's funding commitment to CMRG is not subject to (1) Commission approval of the Joint Application and (2) the types of contingencies identified in Items 2(b) and 3(b) of this request. If the response to either part (1) or (2) is no, explain the response in detail.

b. State the date that LG&E and KU anticipate making their initial contribution to CMRG, whether the $200,000 initial contribution will be in a lump sum or in installments, and whether subsequent contributions, if made, will be at intervals of 12 months or at the beginning of each calendar year.

c. Is it KU's and LG&E's intention to seek rate recovery of the deferred contributions when they file their next general rate applications, based on the level of contributions they have made at that time? Explain the response in detail.

A-5. a. KU and LG&E intend to continue the funding to CMRG. However, KU and LG&E are not contractually obligated to make additional contributions beyond the first year.

b. KU and LG&E plan to make the initial contribution in the form of a lump sum payment during the 3rd quarter of 2008. KU and LG&E expect subsequent contributions will also be lump sum payments and will begin in June of 2009 with the remaining payments being made during the same month of each calendar year.

c. Yes. If the Commission approves the Application in this proceeding, KU and LG&E expect to seek rate recovery of their contributions in their next general rate applications. Specifically, the Companies would defer and amortize these costs over a ten year period upon approval of rates in their next base rate cases.

KENTUCKY UTILITIES COMPANY
LOUISVILLE GAS AND ELECTRIC COMPANY

Response to First Data Request of Commission Staff
Dated August 19, 2008

Case No. 2008-00308

Question No. 6

Witness: Lonnie E. Bellar

Q-6. Refer to paragraph 15 of the Joint Application. With regard to KU's and LG&E's joint contribution of up to $1.8 million to the Kentucky Consortium of Carbon Storage ("KCCS"), provide the following information.

a. State how the $1.8 million contribution to KCCS will be allocated between KU and LG&E.

b. Provide a schedule of the dates that KU and LG&E expect to make these contributions and the amount of each contribution.

c. Is it the intention of KU and LG&E to seek rate recovery through amortization of the regulatory assets resulting from these deferrals at the time of their next general rate applications, based on the level of contributions they have made at that time? Explain the response in detail.

A-6. a. The contribution will be allocated 51.22% to KU and 48.78% to LG&E. This ratio is a combination ratio based on revenue, total assets, and payroll from December 2007.

b. KU and LG&E made an initial contribution of $1,000 to the Western Kentucky Carbon Storage Foundation in July of 2008 for organizational expenses. KU and LG&E anticipate contributing $235,667 in September of 2008 and $1,563,333 in January of 2009.

c. Yes. If the Commission approves the Application in this proceeding, KU and LG&E expect to seek rate recovery of their contributions in their next general rate applications. Specifically, the Companies would defer and amortize these costs over a four year period upon approval of rates in their next base rate cases.

KyPSC-DR-01-007(Duke)

REQUEST:

Refer to paragraph 15 of the Joint Application. Explain in detail the commitment by Duke Energy to study carbon sequestration at its East Bend Generating Station. The explanation should include, at a minimum, a complete description of the study, a timetable for conducting the study, the names of each participant in the study, and a schedule of the expected dates and amounts of contributions by each participant.

RESPONSE:

The U.S. Department of Energy (DOE) established seven regional partnerships of state agencies, universities, private companies and non-governmental organizations (NGOs). These partnerships form the core of a nationwide network to address climate change by assessing the technical and economic viability of various approaches for capturing and permanently storing carbon dioxide through carbon sequestration. Activities undertaken by the partnerships were divided into three phases.

The objective of the Phase I effort was to develop a coherent picture of CO2 sources and sequestration opportunities in the seven regions. Based on this mapping activity, each of the seven partnerships developed recommendations for small-scale field validation tests. The focus of the ongoing Phase II effort is on conducting multiple, small-scale field tests and the focus of Phase III efforts is on conducting large scale field tests.

Duke Energy is a technology coalition partner in the Midwest Regional Carbon Sequestration Partnership (MRCSP). The MRCSP covers eight contiguous states: Indiana, Kentucky, Maryland, Michigan, Ohio, Pennsylvania, West Virginia, and New York. A group of leading universities, state geological surveys, nongovernmental organizations and private companies, led by Battelle, has been assembled to carry out this important research. Battelle is an international science and technology group that focuses on emerging areas of science, develops and commercializes technology and manages laboratories for customers.

As a partner in the MRCSP, Duke Energy is hosting a Phase II field study to test the potential for permanently storing carbon dioxide at our East Bend Generating Station in Rabbit Hash, Kentucky. Various Phase II activities will be spread over a period of about three years. The exact timing of individual activities depends on what is learned during the previous step, as well as on the availability of needed equipment.

Beginning in the fall of 2006, the MRCSP project team began gathering information about the nature of the underlying rock layers to confirm that they were suitable for safely storing carbon dioxide. In addition, a stakeholder communication plan was developed and implemented that included fact sheets, face to face meetings and sending over 1400 invitations to neighbors to attend an open house at East Bend Station to discuss project specifics. In 2007 activities included gathering information to apply for a Class V experimental well permit from EPA Region 4. In 2008 a permit application was submitted and additional information was sent as requested by EPA Region 4. It is anticipated that a public hearing will be held in late 2008. Once a permit is obtained, an injection well (approximately 4000 feet deep) will be installed and well borings will be analyzed. Depending on the outcome of the permitting and well borings analysis, 2,000 tons of CO_2 will be purchased from a local vendor and injected in 2009. Other important activities include continued stakeholder communication and education efforts and the development of monitoring, measurement and verification protocol. All activities should be completed by end of 2009. Duke Energy is providing $400,000 of in-kind services and $350,000 cash to the project.

PERSON RESPONSIBLE: Darlene S. Radcliffe

KENTUCKY UTILITIES COMPANY
LOUISVILLE GAS AND ELECTRIC COMPANY

Response to First Data Request of Commission Staff
Dated August 19, 2008

Case No. 2008-00308

Question No. 8

Witness: Lonnie E. Bellar/Duke Energy Witness/Kentucky Power Witness

Q-8. Other than the funding by the Joint Applicants and the associated matching funds available through the former Governor's Office of Energy Policy (now part of the Department of Energy Development and Independence), are additional funds anticipated from other sources? If yes, identify the potential contributors and, to the extent publicly available, the amount of the funding.

A-8. Yes. KU and LG&E formed the Western Kentucky Carbon Storage Foundation (Foundation) along with Peabody Energy and ConocoPhillips. It is anticipated that Peabody and ConocoPhillips will each make contributions to the Foundation in amounts equal to or greater than the total contribution of KU and LG&E. TVA is expected to contribute $50,000 to the Foundation. In addition, Big Rivers Electric Corporation, East Kentucky Power Cooperative Corporation, and Alcoa have expressed a desire to join the project. An application for a $250,000 grant from the State of Illinois has also been made.

VERIFICATION

State of Ohio)
) SS:
County of Hamilton)

The undersigned, John G. Bloemer, being duly sworn, deposes and says that I am employed by the Duke Energy Corporation affiliated companies as Director, Analytical Engineering; that on behalf of Duke Energy Kentucky, Inc., I have supervised the preparation of the responses to the foregoing information requests; and that the matters set forth in the foregoing response to information requests are true and accurate to the best of my knowledge, information and belief after reasonable inquiry.

John G. Bloemer

John G. Bloemer, Affiant

Subscribed and sworn to before me by John G. Bloemer on this 28th day of August 2008.

Anita M. Schafer

NOTARY PUBLIC

My Commission Expires:

NOTARY PUBLIC STATE OF OHIO

ANITA M. SCHAFER
Notary Public, State of Ohio
My Commission Expires
November 4, 2009

VERIFICATION

State of Ohio)
) SS:
County of Hamilton)

The undersigned, Darlene S. Radcliffe, being duly sworn, deposes and says that I am employed by the Duke Energy Corporation affiliated companies as Environmental Technology & Fuel Policy Director; that on behalf of Duke Energy Kentucky, Inc., I have supervised the preparation of the responses to the foregoing responses to information requests; and that the matters set forth in the foregoing response to information requests are true and accurate to the best of my knowledge, information and belief after reasonable inquire.

Darlene Radcliffe

Darlene S. Radcliffe, Affiant

Subscribed and sworn to before me by Darlene S. Radcliffe on this 27th day of August 2008.

Anita M. Schafer

NOTARY PUBLIC

My Commission Expires:

NOTARY PUBLIC STATE OF OHIO

ANITA M. SCHAFER
Notary Public, State of Ohio
My Commission Expires
November 4, 2009

237572

VERIFICATION

STATE OF KENTUCKY)
) SS:
COUNTY OF JEFFERSON)

The undersigned, **Lonnie E. Bellar**, being duly sworn, deposes and says that he is the Vice President, State Regulation and Rates for E.ON U.S. Services Inc., that he has personal knowledge of the matters set forth in the responses for which he is identified as the witness, and the answers contained therein are true and correct to the best of his information, knowledge and belief.

Lonnie E Bellar

LONNIE E. BELLAR

Subscribed and sworn to before me, a Notary Public in and before said County and State, this 29th day of August, 2008.

Tammy J. Elzy (SEAL)
Notary Public

My Commission Expires:

November 9, 2010

VERIFICATION

STATE OF KENTUCKY)
) SS
COUNTY OF FRANKLIN)

The undersigned, Errol K. Wagner, being duly sworn, deposes and says that he is the Director, Regulatory Services for Kentucky Power Company, that he has personal knowledge of the matters set forth in the responses for which he is identified as the witness, and the answers contained therein are true and correct to the best of his information, knowledge and belief.

Errol K Wagner

ERROL K. WAGNER

Subscribed and sworn to before me, a Notary Public in and before the said County and State, by Errol K. Wagner, this the 29 day of August, 2008.

Notary Public

My Commission Expires:

January 4, 2010

VERIFICATION

STATE OF KENTUCKY)
) SS
COUNTY OF FRANKLIN)

The undersigned, Timothy C. Mosher, being duly sworn, deposes and says that he is the President and COO for Kentucky Power Company, that he has personal knowledge of the matters set forth in the responses for which he is identified as the witness, and the answers contained therein are true and correct to the best of his information, knowledge and belief.

Timothy C Mosher

TIMOTHY C. MOSHER

Subscribed and sworn to before me, a Notary Public in and before the said County and State, by Timothy C. Mosher, this the 29 day of August, 2008.

[signature]

Notary Public

My Commission Expires:

January 4, 2010