A Prospectus on the Carbon Management Research Group

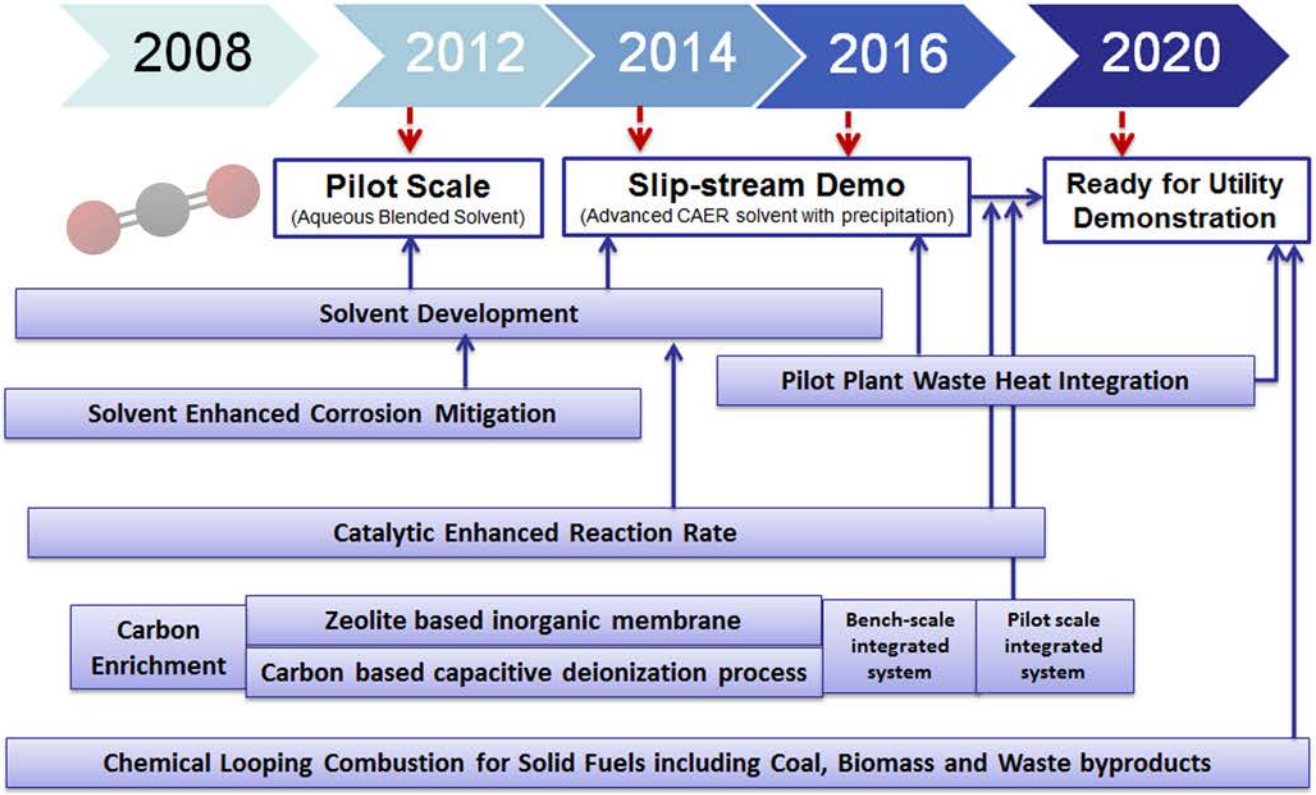
(An industrial, governmental and academic consortium advancing carbon capture and management technologies)

The University of Kentucky's Center for Applied Energy Research (CAER) has a unique position as a conduit between industry and academia. The CAER offers the ability to partner with experienced scientists through specialized, directed research to help answer the growing number of complexities in the power generation, natural gas and chemicals industries as regulations continue to increase. The CAER teamed with Kentucky's major power companies in 2008 to form an industrial-governmental-academic consortium called the Carbon Management Research Group (CMRG). The CMRG began a ten-year research program to develop and demonstrate cost-effective and practical technologies for reducing and managing CO_2 in existing carbon based fuel-fired electric power plants through carbon capture, utilization, storage, and plant efficiency improvement. Its goal is to maintain and strengthen fossil fuel's competitive advantage as a least-cost fuel for electricity production, improve environmental quality, and position CMRG partners with tools to respond to a carbon-constrained economy prior to the imposition of environmental rules.

Benefits from CMRG Participation

- Strategic planning to maintain a low-cost power industry based on coal and other fossil fuels, and preservation of the existing coal-fired electricity generation fleet.
- Insight into technical information that will help identify appropriate post-combustion CO_2-control technologies for the existing power 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.
- Development of advanced technology for next generation electricity and poly-gen, including chemicals and fuels using America's abundant natural resources.
- 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 electric-power industry.

Current Members of the Carbon Management Research Group.



CMRG's Technical Focus

Five primary research areas within CO_2 capture and separation are currently being carried out:

1. Investigation of Post-Combustion CO_2 Control Technologies using CAER's Pilot Plant and Lab-scale Experimental Facilities/setups including secondary gaseous emissions, the development of solvent, catalyst and anti-corrosion coating.
2. Slipstream Investigation of Post-Combustion CO_2 Control Technologies at the E.W. Brown Station Power Plant using the CAER's Advanced Heat Integrated Process.
3. Development of a Chemical Looping Combustion/Gasification for Fossil Fuels
4. Development of a Solvent/Membrane Hybrid Post-combustion CO_2 Capture Process for Existing Coal-Fired Power Plants.
5. Contaminated Liquid Solvent Cleanup

Carbon capture research project funding since CMRG's 2008 inception
(excluding contributions from CMRG Members)

Funding Agency – (Project)	Project funding	Project timeline
DOE – Slipstream (II)	$15,328,100	2011 – 2016
CERC China – Catalyst/CDI (IV)	$2,824,997	2010 – 2015
ARPA-e – Membrane (V)	$2,517,085	2011 – 2013
Wyoming – CLC (III)	$1,489,780	2011 – 2013
DOE – CLC (III)	$755,300	2012 – 2013
Wyoming – Solvent/CDI (VI)	$600,000	2012 – 2014
DOE – Bench-scale Enzyme (VII)	$441,925	2011 - 2014

Project I - Investigation of Post-Combustion CO_2 Control Technologies using the CAER's Pilot Plant and Lab-scale Experimental Facilities/setups. This research is a fundamental study under real coal-derived flue gas conditions and focuses on: scrubber configuration, formulation of new solvents, technologies to enhance CO_2 capture and reduce the energy penalty, process optimization (heat integration), metal corrosion control, solvent holdup characteristics, water balance/management, solvent management, solvent degradation inhibitors, as well as the environmental impact from solvent evaporation and degradation.

Milestones

- Advanced catalytic solvent with 30% mass transfer improvement beyond baseline MEA solvent – *2014*
- Lower-cost Fe-Al coatings capable of similar corrosion abatement to that of Ni-Al coatings while being more cost efficient – *2016*
- Pilot demonstration of new solvent technology – *2017*

Project II - Application of a Heat Integrated Post-combustion CO_2 Capture System with the Hitachi Advanced Solvent into an Existing Coal-Fired Power Plant. The objective of this project is to demonstrate a novel heat-integration scheme utilizing waste heat from the CO_2 capture system (CCS) to improve the plant and CCS system efficiency, which will meet the DOE performance and cost targets of 90% CO_2 capture, 95% CO_2 purity and an increase in the cost of electricity of no more than 35%.

Milestones

- The FEED analysis of CAER heat integrated CCS process – *2013*
- The Slipstream demonstration will collect the necessary information/data on mass and energy balance, solvent degradation (rate and products), and corrosion to provide a full techno-economic and environmental health and safety analysis at a 550-MWe commercial-scale level – *June 2016*

Project III - Development of Chemical Looping Combustion/Gasification for Solid Fuels. Currently, this study is focused on scale-up of work previously done at the CAER involving the use of oxygen carriers in a gasification/combustion reactor where carbon removal as high as 99.7% was obtained. Chemical looping combustion (CLC) is targeted as a next generation power plant technology, which could ultimately prove to be the most cost-effective means for CO_2 control for coal-based power generation.

Milestones

- Cost-effective and high performance oxygen carriers – *2013*
- Proof of concept and bench-scale demo of the CAER process for electricity and chemical production -- 2015
- Design and build a demonstration scale integrated pressurized CLC plant – *2018*

Project IV - Novel Capture Technologies in "US-China Clean Energy Research Center Advanced Coal Technologies Consortium: Clean-Coal Technologies." This project will carry out: (1) membrane barrier-material development and system integration; (2) a hybrid process consisting of catalyzed solvents and post-scrubbing carbon enrichment (capacitive deionization-CDI) for post-combustion CO_2 capture.

Milestones

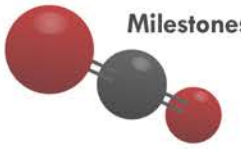
- Demonstration of a pilot-scale integrated system CDI unit capable of stable operation of charge-discharge of carbon-loaded MEA solutions – *2017*
- Synthetic optimization and synthesis of catalyst for use at demonstration facility – *2018*

Project V - A Solvent/Membrane Hybrid Post-combustion CO_2 Capture Process for Existing Coal-Fired Power Plants. A membrane will be used as a catalytic separator, intimately coupling Nanofiltration (NF) separation and catalysis functions. With the implementation of the catalytic membrane reactor, the energy penalty for CO_2 capture can be greatly reduced.

Milestones

- Beginning demonstration of a pilot-scale integrated system membrane barrier unit to the post-combustion CO_2 capture. – *2017*

Project VI – Advanced Solvent for CO_2 Capture and Separation Technology for CO_2 Sequestration to Enhance Utilization and Reduce Emissions from Wyoming Coal. Advanced solvents and impact of degradation will be evaluated. Oxidization inhibitors will be developed to reduce solvent degradation. A hybrid membrane-carbon capacitive deionization process will be used to treat residual wastewater from brine aquifers being used for carbon dioxide sequestration. This unique process will also function along with a parallel operation to enable energy regeneration and lower the overall energy requirements.



Milestones

- Inhibitors capable of effectively mitigating degradation rates from coal combustion flue gas components to high economic and environmental value – *2014*
- Laboratory scale demonstration of membrane capacitive deionization treatment of residual brine aquifer solution with energy recovery technology – *2014*

Project VII – Low-Energy Solvents for CO_2 Capture Enabled by a Combination of Enzymes and Ultrasonics. The overall project will demonstrate an integrated process for CO_2 capture using a carbonic anhydrase promoted potassium carbonate solvent and an ultrasonic regeneration technique to enable non-vacuum based solvent regeneration. The CAER's contribution will be demonstrating that the enzyme can meet the project mass transfer targets in the carbonate solvent and the construction and demonstration of the technology with the integrated process unit.

Milestones

- Construction and demonstration of the process using enzyme and vacuum solvent regeneration – *2013*
- Demonstration of the integrated ultrasonic process using long term process testing – *2014*

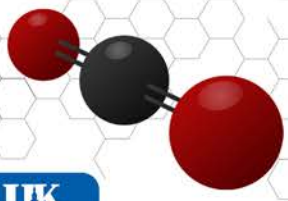
Membership

Premier Member Contribution	Affiliate Member Contribution
$200,000 per annum	$50,000 per annum

Premier members will have access to all research results. Affiliate Members will only have access to information presented in the regular review meetings. Meetings to review these results will take place on a semi-annual (every six months) basis.

Any company may become a member of the CMRG. Membership will be extended to each company that provides financial support in the amounts listed above 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.

If you are interested in participating in CMRG or would like further information, please email, mail or fax your inquiry to:



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