

U.S.-China Clean Energy Research Center (CERC)

Joint Work Plan for Research on Clean Coal Including Carbon Capture and Storage

1. Introduction

In November 2009, President Barack Obama and President Hu Jintao announced the establishment of the Clean Energy Research Center (CERC). On November 17, 2009, U.S. Secretary of Energy Steven Chu, Chinese Minister of Science and Technology Wan Gang, and Chinese National Energy Administrator Zhang Guobao signed the U.S.-China CERC Protocol, launching the CERC. The primary purpose of the CERC is to facilitate joint research, development, and commercialization of clean energy technologies between the U.S. and China. The CERC will also build a foundation of knowledge, human capabilities, and relationships in mutually beneficial areas that will emphasize clean energy in both nations.

Within the three current CERC programs, the Clean Coal, including Carbon Capture and Sequestration (CCS), program addresses technology and practices for clean coal utilization and carbon capture, utilization, and storage. Abundant coal resources and widespread use are central to the energy systems and growth aspirations of both countries and present both challenges and opportunities for the two countries in environmental performance and commercial development.

The United States has chosen West Virginia University (WVU) and China has chosen Huazhong University of Science and Technology (HUST) to lead teams of experts from public and private institutions. These teams are designated as the China Advanced Coal Technology Consortium and the U.S. Advanced Coal Technology Consortium (the China ACTC and U.S. ACTC, respectively). These two Advanced Coal Technology Consortia (collectively, the CERC-ACTC) will implement a five-year Joint Work Plan to significantly advance technology in the area of clean coal, including carbon capture, utilization, and storage, in both China and the United States.

2. Vision

The US-China CERC-ACTC advances the coal technology needed to safely, effectively, and efficiently utilize coal resources including the ability to capture, store, and utilize emissions from coal use in both nations.

3. Research Areas

Both teams have identified key research tasks, including the clean coal power generation and transformation, the development of new, low-cost capture technologies, and the development of geological sequestration practices. The CERC-ACTC research program has identified a first set of key projects (see Table 1) where this work can be anchored. The works of the CERC-ACTC are expected to address numerous challenges of both countries. Under the CERC's U.S.-China Protocol and its Intellectual Property Annex, no work on any cooperative activity between the two countries can begin without a mutually agreed upon Technology Management Plan.

1) IGCC with CCS

Combining advanced gasification with CCS in the power sector remains a critical pathway towards low-carbon power generation. Industrial, research, and academic leaders from both countries will work with major demonstration projects (GreenGen and Edwardsport) and best-in-class technologies to considerations to provide the world with robust, transparent cost and performance estimates for this

Table 1: Initial Joint CERC-ACTC Research Projects

No.	China Project Name	China Participants	U.S. Project Name	U.S. Participants	Key Features
1	Studies on near zero emission power-generation technology based on IGCC	NETC-CLCP, CHNG-CERI, CPECC, THU, CEP-CAS, CPIC, SJTU	IGCC with CCS at the million ton scale	Duke Energy, GE, LLNL, IGS, LANL, NETL, WVU: D. Mohler + R. Turtan	Operational study of IGCC operation (best-practices)
			Pilot-scale IGCC research	UWY, GE, LANL: M. Northam + E. Norton	Gasification, gas clean-up, CO ₂ separation w/ many coal types + biomass
2	Large-scale post-combustion CO ₂ capture, utilization and storage technology	NETC-CLCP, CHNG-CERI, CPECC, CPIC, THU	Advanced amine testing platform	Duke Energy, Alstom, WVU, NETL, UKy, B&W, LLNL: R. Smith + SJ Friedmann	Multiple facilities/pilots tests across the US capable of running a suite of tests; instrumentation at flagship facilities;
			Ammonia capture w/ integrated sequestration & scale-up	AEP, Alstom, Ramgen, UKy, NETL, LLNL, WVU: G. Spitznogel + K. Liu	Sequestration and scale-up of facility; Integrated CCS today Chilled ammonia
3	The research on sequestration theory and simulation technology of CO ₂ geological storage and large scale storage strategy	Shenhua, IRSM-CAS THU, NWU, CUMT, Yanchang Petroleum	Sequestration capacity and near-term opportunities: Ordos Basin	UWY, WSGS, WVU, LANL, LLNL, NETL: R. Surdam + T. Carr	Site characterization; modeling; risk assessment; brine treatment;
			Conventional EOR opportunities and practice	WSGS, UWY, WVU, LLNL: D. Mohrbacher	Reservoir characterization and ranking, monitoring planning and design
4	Microalgae bio-sequestration of CO ₂ from flue gas of power plant	ENN, ZJU, CEP-CAS	CO ₂ -Algae bio-fixation and use	Duke Energy, UKy, NETL: R. Smith	Bio-reactor or pond-based algae capture and re-use
5	Theory and equipment development for oxy-fuel combustion	HUST, THU, CPECC, HIT	Theory, development and demonstration of oxyfiring combustion	B&W, Alstom, WVU, LLNL, NETL: K. McCauley + SJ. Friedmann	Oxy-combustion repowering (200MW) with deep saline fm. storage; novel CO ₂ compressors; multiple US facilities for fundamental pilot & coal combustion tests
6	Combined coal pyrolysis, gasification and combustion multi-generation technology	ZJU, CEP-CAS CUMT	Coal-to-Chemicals, with capture & co-gen	LP Amina, WVU, LLNL: W. Latta + I. Celik	Pyrolysis, gasification and oxy-chemical combustion for power & chemical production

class of power plant. Pilot testing platform will be constructed via this research work, based on which the technology of CO₂ capture, utilization and storage based on IGCC will be developed and demonstrated.

2) Post-combustion CO₂ capture, utilization, and storage technology

Both CERC teams are addressing directly the difficult problem of steep emissions reductions from the existing coal fleet by analyzing, testing, and demonstrating technologies for post-combustion capture integrated with sequestration at real power plants. Competing technology pathways (amines and chilled ammonia etc.) for cost, ease of retrofit, engineering, and environmental performance will be investigated and demonstration of CO₂ capture, utilization and storage will be carried out in this projects in cooperation with large power generation companies (AEP, Duke, China Huaneng Group and China Power Investment Corporation etc.). We expect this work will lay the groundwork for decision makers in both nations to understand the potential role of post-combustion retrofits in achieving steep reductions, and provide new operational insights to the integration of capture and storage while developing new low-cost post-combustion capture options for market.

3) Sequestration capacity and near-term opportunities

In cooperation with WVU and other US ACTC members, the Shenhua Group will develop related research work focused on CO₂ geological sequestration (CGS) in the Ordos Basin, including the technology and method of potential evaluation of CGS, stimulation technology for CO₂ storage in saline formations, research and application of monitoring technology of CO₂ storage in saline formation, assessment technology of safety and risk of CO₂ storage in saline formation, geological characterization of CO₂ sequestration in aquifers, and related research. Through the above research and the execution of the Shenhua demonstration project, this effort will improve understanding and provide verification of key technologies for CO₂ storage in saline formations and provide the scientific evidence to implement large scale CCS in China and support for CCS development in the US.

4) CO₂-Algae biofixation and use

With high oil productivity, 90 times that of soybean, and high carbon fixation capability, 5~8 times that of equivalent forest biomass (based on ENN's industrial demonstration project in Inner Mongolia supported by Chinese government agencies - MOST, NEA, and NDRC), microalgae have the potential to be an important source of bioenergy in the future and an important and sustainable way of utilizing carbon dioxide as a resource. It has been proved that microalgae can absorb carbon dioxide directly from the flue gas of a coal burning power plant (based on the joint-field test result at Duke Energy's East Bend power plant, carried out by the ENN-Duke team). Based on this solid foundation, the China-US team will work on the industrial demonstration of carbon biofixation using microalgae. The joint research will address the detailed process of utilizing power plant flue gas, post processing, and the utilization of the algal biomass from the process to produce multiple products. The goal is to find a practical, low cost pathway to both absorb carbon dioxide in a sustainable way and turn the biomass produced into a rich source of renewable energy, including biodiesel, through innovations and technology development.

5) Research, development and demonstration of oxyfiring combustion

Developing and assessing oxy-fired combustion's economic and environmental potential remain a first order global challenge to the global CCS community. This project brings together flagship projects in

the US (e.g., FutureGen) with centers of excellence in both countries (e.g., Huazhong U., B&W) with the goal of leading to cost and performance breakthroughs in the laboratory and in the field. The work will include challenges to oxyfiring with both US and Chinese coals, potential for biomass co-firing (for negative emissions), retrofit engineering, novel CO₂ compression technology integration, and the potential for co-injection of trace gases with CO₂.

6) Coal co-generation with CO₂ capture

Coal co-generation with CO₂ capture will be one of the main coal utilization technologies. The US and China partners will focus on the research and development of new coal co-generation systems with CO₂ capture including new coal-to-chemical co-generation, new CO₂ capture process, and co-generation system with combined pyrolysis, gasification, and combustion. This project will pursue high conversion efficiency with low cost, footprint reductions, low carbon emission, and pollution control at large coal conversion plants. The technologies developed will be demonstrated successfully at industrial scale for development and sale in both countries.

7) Additional topics

In addition to the research projects identified here, other key areas for collaborative work stand out. We expect that more members and more projects will join in the CERC as well, provided those efforts match the goals and aspirations of the CERC-ACTC team.

4. The US-China team

The US and China have pulled together both the research agenda and the tasks with lead institutions nation-wide to help guarantee the success and value of this collaborative effort (Table 2 and Table 3). These include research institutions, universities, national labs, NGO, and companies with long and successful partnerships working with both sides. The US and China teams have collaborated deeply with each other on many projects and look forward to working together even more closely within the framework provided by the CERC.

Table 2: The US-ACTC CERC team

Consortium Director: Dr. Jerald J. Fletcher, West Virginia University			
Technical Program Lead: Dr. S. Julio Friedmann, Lawrence Livermore National Laboratory			
Universities and Geological Surveys	National Labs	Non-governmental organizations	US Companies
West Virginia U.	Lawrence Livermore Natl. Lab	US-China Clean Energy Forum	Alstom
U. of Wyoming	Los Alamos Natl. Lab	World Resource Inst.	American Electric Power
U. of Kentucky	National Energy Tech. Lab		Babcock and Wilcox
Wyoming State Geol. Survey			Duke Energy, Inc.
Indiana Geol. Survey			GE
			Great Point Energy
			LP Amina
			Ramgen

Table 3: The China-ACTC CERC team

Consortium Director: Dr. Zheng Chuguang, Huazhong University of Science and Technology Dr. Xu Shisen, Huaneng Clean Energy Research Institute		
Chief Scientist: Yao Qiang		
Research Institutions	Universities	China Companies
Huaneng Clean Energy Research Institute	Huazhong U. of Science and Technology	China Huaneng Group
Research Center for Clean Energy and Power, Chinese Academy of Sciences	Tsinghua U.	Shenhua Group
Institute of Rock and Soil Mechanics, Chinese Academy of Science	Zhejiang U.	ENN
	China U. of Mining and Technology	China Power Investment Corp. Group
	Shanghai Jiao Tong U.	China Power Engineering Consulting Corp.
	Harbin Institute of Technology	Shaanxi Yanchang Petroleum (Group) Co., LTD.
	Northwest U.	

5. Summary

The research tasks and projects identified by participants from both the US and China under the CERC-ACTC will help to accelerate the development and deployment of clean coal technology with CCS in both countries. The results will benefit both countries through economic development, reduced emissions, and improved energy efficiency. These kinds of collaborations are essential to build trust between business and governments in order to achieve the goals of each country in harmony with our planet and each other. We hope that the continued work within the CERC as guided by the leaders of the US and China will identify new opportunities for partnership and collaboration through these exchanges.

6) Approvals

The above Joint Work Plan has been jointly developed and reviewed and is hereby approved by the respective authorities in each country, as indicated by the signatures of the appointed CERC-ACTC Directors, below, made this date of January 18, 2011.

For the CERC Advanced Coal Technology Consortium of the United States:

For the CERC Advanced Clean Technology Consortium of the Peoples Republic of China:
