A Joint Workshop on Promoting the Development and Deployment of IGCC/Co-Production/CCS Technologies in China and the United States

WORKSHOP REPORT

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Report on a workshop jointly organized by the Energy Technology Innovation Policy research group, Harvard Kennedy School; the Chinese Academy of Sciences/Research Center for Energy and Power (CEP); and the National Joint Expert Group for IGCC and Co-Production Demonstration Engineering of China

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Introduction, Background, and Motivation

China is heavily dependent on coal as a primary energy resource. In 2007, primary energy consumption reached 2.66 billion tons of standard coal—about 70% of total primary energy consumption. Primary energy production reached 2.34 tons of standard coal—about 76.6% of the total. Coal accounts for 92.6% of proven energy resource reserves. In recent years, primary energy production and consumption have increased rapidly, and they will continue to increase. In 2030, primary energy consumption will reach 5.27 billion tons of standard coal, almost double 2006. Coal will continue to dominate both production and consumption for decades.

At the beginning of this century, widespread electricity shortages in China prompted a rapid expansion of power capacity, especially coal-power capacity. By 2007, the total installed capacity was up to 713 GW, of which thermal installed capacity was 554 GW, accounting for 77.7% of total capacity in China. Coal-fired capacity was up to about 540 GW. Total electricity generation was up to 3,256 TWh, of which thermal electricity generation was 2,698 TWh, accounting for 83%. Thus, electric power generation depends heavily on coal in China.

According to the latest projection, by 2020 total installed capacity will reach 1,393 GW, of which coal power capacity will be more than 900 GW. The increase in coal power from 2008 to 2020 will be close to 400 GW. Given that generation units usually run for decades, the generation technologies that will be employed will have significant economic and environmental implications in the long term. Based on the economic, environmental, and energy constraints at a certain time, China will have to decide which technologies should be phased out, which ones should be deployed as the mainstream, and which ones should be promoted for future deployment.

As for the United States, oil security is a major concern for China. In 1993, China became a net oil importing country. In 2005, China imported one billion barrels of oil, accounting for 43% of China's total oil consumption. The International Energy Agency (IEA) has forecasted that in 2030 China's primary oil demand will reach 13.3 mb/d. And China is expected to import almost 10 mb/d, as much as the United States imports today. Import dependence will be 74%. Thus, oil security is a major challenge for China.

The improvement of living standards and the development of industry have increased the demand for basic chemical raw materials, such as methanol, DME, and olefin. Because of relatively plentiful coal and scarce natural gas and oil, coal to methanol, DME, olefin, and oil have become significant in China.

China faces an especially daunting set of challenges in the twenty-first century, including generating enough electricity to sustain economic growth, low power-supply-efficiency, further optimization of the power mix, coal supply for power plants, and environmental impacts. IGCC/Co-production/CCS constitute one major approach to meeting these challenges in China.

IGCC is an advanced technology for generating electricity with coal that can substantially reduce air pollutant emissions, water consumption, and solid waste production from coal power plants.

Combined with the production of transport fuels and chemicals, called co-production, the system can significantly enhance energy and material conversion efficiencies. It also provides an important technical pathway for separation and capture of CO_2 emissions, necessary to address climate change concerns, at a relatively low cost.

Currently, the key project "IGCC and co-production demonstration engineering of China" supported by the 863 Program of the Ministry of Science and Technology (MOST) is going forward smoothly. There are 16 projects within the 863 Program concerning IGCC and co-production. One of the project goals is to scale up key technologies for gasification and indirect liquefaction and to retrofit heavy gas turbines for utilizing syngas. Another goal is to develop operation and control technologies and system integration technologies. Finally, all of these technologies will be validated and demonstrated with three IGCC and two co-production demonstration plants. Some of these plants are considering incorporating CCS into the systems in the future.

As China, the United States uses a great deal of coal to generate electricity. In 2005, coal consumption in the United States was 1.128 billion short tons. The electric power sector consumed 1.039 billion short tons, accounting for 92% of total coal consumption. Total installed power generating capacity in the U.S. in 2005 was 978 GW. Coal-fired installed capacity was 313 GW or 32.1% of total installed capacity, and natural gas-fired installed capacity was 383 GW or 39.3% of total installed capacity. Because of the relatively low price of natural gas, it has been the fuel of choice for the majority of new electric power generating units since 1995, and in 2002, natural gas-fired installed capacity surpassed coal-fired installed capacity.

However, because of the continuous rise in the price of natural gas, the use of these natural gas-fired generation units has declined, and coal was the dominant energy source for electricity generation in 2005. That year, the net generation of electricity in the U.S. was 4,055 billion kWh. Coal electricity generation was 2,013 billion kWh or 49.7% of total electricity generation. Natural gas-fired electricity generation was 758 billion kWh or 18.7% of total electricity generation. Coal fired power plants have resurged in electric power generation in recent years, especially IGCC. About 27% of new proposed coal-fired power plants are IGCC. However, the development of IGCC slowed during the last year because of regulatory uncertainty for greenhouse gas (GHG) legislation.

There are two main barriers to the wide deployment of IGCC in the United States now. One is rising capital cost. In 2004, IGCC was slightly more expensive than traditional coal plants. However, the average capital cost roughly doubled from $1,600/kW to $3,300/kW between 2004 and 2007. The other barrier is environmental regulatory uncertainty. Regulation for GHG legislation is a key factor that impacts technology selection and project economics. Currently, in the United States, the federal government supports IGCC via direct funding, tax credits, and loan guarantees. The cost share of the federal government for IGCC demonstration may have a maximum of 50%.

In this context, the three main goals of the workshop were (1) To encourage and facilitate technical cooperation between the United States and China on IGCC/co-production/CCS; (2) For each participant to learn more about what is happening in the other country with respect to developments in IGCC/Co-Production and CCS RD&D, and also with respect to policies for deployment; and (3) To form and/or strengthen personal and professional connections among all the participants.

Building on Past Workshops

This workshop was organized by the following partners: the Energy Technology Innovation Policy (ETIP) research group at the Harvard Kennedy School, the Research Center for Energy and Power (CEP) at the Chinese Academy of Sciences (CAS), and the National Joint Expert Group for IGCC and Co-Production Demonstration Engineering of China, centered in MOST. The Natural Resources Defense Council also provided input and support. The workshop built upon five previous meetings on the same subject: October 2002 in Beijing, at Harvard University in September 2003, in May 2004 in Hangzhou, at Harvard in September 2005, and in May 2007 in Beijing. Summaries of three of these workshops may be found at:

http://belfercenter.ksg.harvard.edu/publication/19078 (Harvard University, September 2003)

http://belfercenter.ksg.harvard.edu/publication/2103 (Hangzhou, May 2004)

http://belfercenter.ksg.harvard.edu/publication/18340 (Beijing, May 2007)

The workshop series was founded in 2002 by John P. Holdren, former faculty director of ETIP, who is now Assistant to the President for Science and Technology and Director of White House Office of Science and Technology Policy, and Xu Jing, Director-General for the Major Special Projects Office at MOST.

Who Participated?

This workshop had 76 invited participants. They included senior government officials, including Dr. John P. Holdren; Mr. Cao Jianlin, Xu Jing, Zhang Zhihong, and Mr. Ma Linying from MOST; Mr. Jiang Mianheng, Xiao Yunhan, and Mr. Cao Jinghua from CAS. They also included other officials from the U.S. Department of Energy (DOE) and Chinese local governments.

Also participating were leading scientists and experts from both China and the United States on advanced coal technologies and energy policy, representing the Institute of Engineering Thermophysics of CAS, Institute of Rock and Soil Mechanics of CAS, University of Shanghai for Science and Technology, China Huadian Corporation, China Power Investment Corporation, Dongguan Power and Chemical Industry Holding Co., Ltd., Xinxing Pipes Group Co., Ltd., Harbin Power Equipment Co. Ltd., Harbin Boiler Co. Ltd., GCL Engineering Limited, Natural Resources Defense Council, Coal Poly-generation Technologies Lab, Global Research - Shanghai GE, Harvard University, MIT, Stanford University, Princeton University, Schlumberger-Doll Research, GE Energy, ICF International, Duke Energy, ConocoPhillips, Alston & Bird, Shell, and EPRI.

Dr. Kelly Sims Gallagher, Director of ETIP, was the U.S. chair.

Dr. Xiao Yunhan, Deputy Director-General of the Bureau of High Technology Research and Development at CAS, Director-General of CEP, the head of the National Joint Expert Group on IGCC and Co-Production Demonstration Engineering for MOST, was the chair from China.

Main focuses of the workshop:

a) The design, operation, and economics of IGCC/Co-production
b) Technology Policy for RD&D of IGCC/Co-Production/CCS
c) Deployment Policy for RD&D of IGCC/Co-Production/CCS
d) U.S.-China Cooperation on Development and Deployment of IGCC/Co-Production/CCS

Chinese delegation visits in conjunction with the workshop:

1. Meetings in Washington D.C.

In Washington DC, Vice-President Jiang Mianheng from CAS visited US DOE and met with the assistant secretary and directors from National Energy Technology Laboratory (NETL) and Pacific Northwest National Laboratory (PNNL) to discuss specific areas for cooperation on clean coal technology between CAS and U.S. DOE. The specific areas for cooperation included advanced gasification and combustion, gas purification and separation, energy conversion and syngas conversion, materials, computational modeling and virtual simulation, system analysis, and integration, and environmental control technology. CEP, on behalf of CAS, will sign a cooperative agreement with NETL and PNNL in May 2009.

Vice-President Jiang Mianheng and Vice Minister Cao Jianlin from MOST also met with John Holdren to discuss how to strengthen Sino-US cooperation with regard to energy technology and policy. During the visit, Vice-President Jiang also met with several influential U.S. Senators.

2. Visits to Tampa IGCC plant and PSDF

Two plant/facility visits were scheduled, near Birmingham, Alabama (Power Systems Development Facility [PSDF], operated by Southern Company) and Tampa, Florida (Tampa Electric Polk Power Station, operated by TECO Energy).

A 2,250 tons-of-coal per day GE coal-water slurry gasifier is used in the Tampa IGCC power plant, and a radiant syngas cooler is used to recover syngas heat before cleanup. The concentration of coal water slurry is 66%, and 95% concentration oxygen is used as a gasification agent. There are two sets of gas purification systems in the plant. One is wet particulate removal and desulfurization with 100% load at low temperature. The other is high temperature particulate removal and desulfurization with 10% load between 482-538 degrees centigrade. A high temperature filter is used to remove particulate, and a zinc titanium sorbent is used to remove H_2S. The high temperature purification system is for test purposes only. A high pressure independent air separation unit is used to separate air, and all separated N_2 is injected into the combustor chamber. A GE 7221FA gas turbine is used in the combined cycle. The actual net power of the power station is 250MW, and the efficiency is 37.8% (HHV). The improper design of the thermodynamic system of the power station (included heating up syngas, N_2 injection), and the low conversion rate of the carbon in the gasifier, etc, resulted in the actual electricity efficiency of the Tampa power station being greatly lower than the design value of 42% (LHV).

Supported by U.S. DOE, Southern Company has built and run PSDF for several years. The facility includes coal preparation, gasifier, cleanup, and a redesigned syngas-fired gas turbine with a capacity of 50 tons of coal per day. The facility has been used to verify gasification technology, high temperature particulate removal, purification, the syngas-fired gas turbine, and fuel cell. Being a system-level pilot facility of advanced power generation technology, it can test new systems in an integrated manner and semi-commercially and can identify problems with sub-systems interaction that cannot be identified in a non-integrated facility. This facility directly supported the test of a transport gasifier over ten years and helped guarantee the industrialization of gasification technology.

Some Key Insights from the Workshop

1. Central and Local Governments Perspectives on IGCC/Co-Production/CCS

1) Excerpt from Vice Minister Cao's speech

MOST has attached great importance to the development of clean coal technologies. In the science and technology plan, RD&D focuses on coal gasification, liquefaction, co-production, advanced clean coal power generation technology and flue gas desulfurization, and de-nitrification technology. IGCC, co-production, and CCS are the main technical directions for the use of coal and the realization of energy-saving and emission reduction. To date, IGCC is not only the most practical and economical coal-fired power generation technology to realize near-zero emissions of CO_2, but also an effective solution to address other energy and environmental challenges, and to build the world's largest energy consumption and supply system in the next two decades. The RD&D goals of IGCC power generation technology in China are to enhance the competitiveness of clean coal technologies and energy equipment under the support of the national science and technology plan, to reduce the cost of IGCC, and to further provide affordable solutions for the power industry. In support of the science and technology program, in April 2006, we completed the construction of the first 60MW-class IGCC plant and 240,000 tons of methanol co-production demonstration project. It can be said that IGCC in China has become an important option for the development of clean coal technologies.

During the Eleventh Five-Year period, MOST has invested 0.35 billion yuan in the key project of IGCC and co-production demonstration engineering. From the progress of the projects, we are full of confidence in the development of IGCC in China.

2) Excerpt from Vice President Jiang's speech

This workshop program has gained momentum and has now become an important common platform for the academic and industrial communities of both countries to address key energy issues, including in the area of clean coal technology.

Although China has committed much effort to achieve energy efficiency, the optimization of its energy structure, and the change of its mode of economic development, it is basically hard and unrealistic for China to fundamentally change its energy structure in the foreseeable future. As a country that heavily relies on coal for much of its energy, China will have to maintain its course for many years to come. Therefore, to a large extent, a comprehensive clean use of coal will remain a fundamental solution for China to solve its energy bottleneck in the foreseeable future. How to achieve S&T breakthroughs in clean coal technology and how to effectively facilitate its deployment are some of the biggest challenges for the scientific and technological community and industries as well. Given the context of climate change concerns, these issues have become extremely important, with an urgent need to be addressed. This brings us back to the theme of this workshop.

The Chinese Academy of Sciences, being the single largest R&D institution in China, always attaches significant importance to the provision of S&T solutions to national strategic needs and challenges. IGCC, co-production, and CCS are surely the key technology development directions for the comprehensive clean use of coal today and tomorrow. The Chinese Academy of Sciences has put it as one of our top priorities in our energy technology initiative. As a leader in the field in China, CAS has played an important role in research and development of these technologies and has also persistently pursued the course of facilitation, demonstration, and deployment in China.

The United States is in many ways in a similar situation as China in terms of using coal. It also relies on coal for much of its electricity (50%) and has given much attention to R&D on relevant technologies. I know that both the U.S. federal government and some state governments have supported this development and demonstration by various means, such as direct funding, tax incentives, and credit guarantees.

Today we are very pleased to see a gathering of some of the best experts in the field from both countries. We can well anticipate that this workshop will help further facilitate the efforts in both countries in the R&D and demonstration of these technologies.

3) Excerpt from speech of Vice Mayor Shi (Lianyungang Municipal People's Government)

Since the traditional way of utilizing fossil fuels leads to environment pollution and climate change, there must be a change. Considering worldwide demand to solve climate change problems and based on the competitiveness of the energy industry, the approach to development, and the goals of Lianyungang, we have attached great importance to the R&D, engineering, and commercialization of the IGCC/co-production/CCS technology system. With the full support of the Chinese Academy of Sciences, we work together to build “Chinese Academy of Sciences Energy Power Research Center” and “Clean Energy Innovation Industrial Park.”

The engineering and commercialization of IGCC/co-production/CCS technology system matters for the future of human beings. Though the task is tough, the future will be bright. There is challenge, and also there is opportunity. It requires concerted efforts through international cooperation. In order to promote the development of the clean energy industry, we will continue to strengthen international communication and cooperation and try our best to provide an excellent environment for the R&D and deployment of this technology.

4) Excerpt from Director Liang’s speech (State-owned Assets Supervision Commission, Dongguan Municipal People’s Government)

Relevant government departments in Dongguan city will strengthen coordination and enhance communication to promote the development of IGCC in Dongguan by learning from the United States Government departments and the other Chinese provinces. The science and technology bureau, development and reform bureau, State-owned Assets Supervision Commission, and economic and trade bureau will especially work closely together to solve the combined problem of technology and economy and to increase support for technological innovation, take the initiative to help enterprises seek funding and other policy support, and to create a good investment environment for technological innovation and high-tech industrialization. All these efforts will make IGCC industrialization possible and build a technologically advanced, environmentally friendly, efficient IGCC demonstration project to promote cleaner production and comprehensive utilization of resources in Dongguan city.

2. Status and Progress of IGCC and Co-Production

In recent years, with the rise of natural gas prices and varieties of IGCC policies supported by government, coal-fired power stations show signs of recovery, and 28% of the new coal-fired power station planning to be built are IGCC (announced by DOE in February 2008). However, from the second half of 2007, the pace of development has slowed, due to increasing IGCC investment cost and uncertainty about policies for greenhouse gases emissions. (According to the information announced by DOE in June 2008, the number of IGCC power stations scheduled to be constructed has been reduced from 32 to 28.) The following table shows active IGCC projects in the United States.

Active IGCC Projects in the United States

Active Projects	Location	Feedstock	MWe	Gasifier Vendor	CO_2 Capture	Date In Service
Edwardsport IGCC Project	Indiana	coal	630	GE	STUDY	2012
Kemper County IGCC Project	Mississippi	coal	600	KBR	50% EOR	2013
Mesaba Energy Project	Minnesota	coal	600	E-Gas	READY	
Taylorville Energy Center	Illinois	coal	630	GE	YES	2014
Hydrogen Energy California project (HECA)**	California	petcoke	390	GE	2 MTY	2014
Cash Creek Generation*	Kentucky	coal	630	GE	EOR	2012
Summit Power IGCC - Penwell	Texas	coal	600	Siemens	60% EOR	
Sweeny E-Gas™ Project (IGCC or SNG)	Texas	petcoke		ConocoPhillips	YES	
Southern California Edison H_2 for Power**	Utah	coal	500		to meet CA standard	
Future Power PA	Pennsylvani a	coal	150			2011
Ohio River Clean Fuels, LLC***	Ohio	coal/ biomass	250	Shell	YES	2012
Somerset Gasification Retrofit	Massachuse tts	coal/ biomass	120	WPC		2011
Genesee IGCC Project	Alberta	coal	270	Siemens	1.25 MTY EOR	2011
Great Lakes Energy and Research Park ***	Michigan	coal	250	ConocoPhillips	EOR	2012
Hyperion Energy Center (HEC) refinery and IGCC power plant**	South Dakota	petcoke			READY 90%	2014
Hunton Energy Freeport Plant SNG* & IGCC (formerly Lockwood)	Texas	petcoke	400	GE or CoP	100% EOR	2015
Henderson Luminant IGCC Commercial Demonstration	Texas	coal	630		YES	
Morgan 3&4 - Colorado City Luminant IGCC Commercial Demonstration	Texas	coal	630		YES	
*SNG project, **H_2 project, ***CTL project						

China started research on IGCC technology in the 1970s. In 1979, the government planed to build an experimental 10MW IGCC power plant. However, due to certain reasons, this project was stopped. During the Eighth Five-Year, the Ninth Five-Year, and the Tenth Five-Year Plans, the government had financed research on key IGCC technologies and system analysis and optimization. In 1996, U.S. DOE and the National Science and Technology Commission of China organized an America-Sino IGCC Expert Report, in which the authors made clear that the combination of IGCC and co-production will promote the development of IGCC. In 1999, the necessary agencies and departments approved an IGCC demonstration project in Yantai, Shandong Province with an intended installed capacity of 300-400 MW. However, this project has not proceeded as planned, and construction has yet not begun. In 1998, the Institute of Engineering Thermophysics started to develop coal-based co-production technologies. Yankuang took advantage of this technology and has built the first coal gasification-based co-production system. The plant began operation in April 2006. During the Eleventh Five-Year Plan, several IGCC plants will be constructed in China. The following table shows us active IGCC projects in China.

Active IGCC Projects in China

Active Projects	Location	Feedstock	MWe	Gasifier Vendor	CO_2 Capture
Dongguan IGCC Project (repowered)	Dongguan, Guangdong	Coal	2×60	CAS	STUDY
Dongguan IGCC Project	Dongguan, Guangdong	Coal	4×200	CAS	STUDY
Huadian Banshan IGCC Project	Hangzhou, Zhejiang	Coal	200	ECUST	STUDY
China Huaneng IGCC Project (GreenGen)	Tianjin	Coal	250	TPRI	STUDY
China Power Investment Corporation IGCC Project	Langfang, Hebei	Coal	2×400	N/A	8% EOR

3. Technology Policy for RD&D of IGCC/Co-Production/CCS

The United States emphasizes RD&D efforts related to coal, and significant advancements in coal-based electricity generation technologies have been achieved. The Fossil Energy R&D office of U.S. DOE includes basic research and development of coal-related technologies as part of its overall technology demonstration and commercialization efforts. Coal research and development includes the development of more efficient gasification, turbine, and fuel cells technologies, innovations for existing coal power plants, and large-scale CCS injection tests.

Commercial-scale demonstrations of clean coal technologies currently are being carried out in DOE’s Clean Coal Power Initiative (CCPI) and, perhaps, in FutureGen (if it is reconstituted). The CCPI is a 10-year, $2 billion program designed to support the Clean Coal Technology Roadmap milestone, with the government providing up to 50% of the cost of demonstrating a range of promising technologies. The goal is to accelerate commercial deployment of advanced coal technologies to ensure that the United States has clean, reliable, and affordable electricity. CCPI is a follow-on demonstration program to the Clean Coal Technology Demonstration

Program (CCTDP). The development of clean coal technology must encompass a long-term, strategic view, and the United States' 20-year CCTDP project stresses this. The trend of emphasis on advanced power technology in the United States is worth using as a reference for China. DOE anticipates five rounds of solicitations for CCPI.

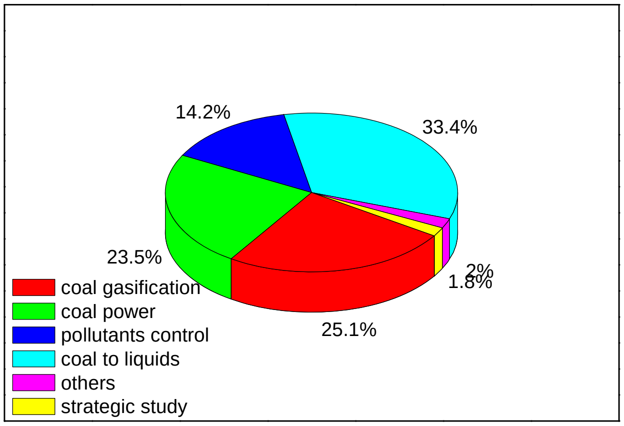
Currently, CCPI active projects for Round I include Increasing Power Plant Efficiency: Lignite Fuel Enhancement, TOXECON Retrofit for Mercury and Multi-Pollutant Control on Three 90-MW Coal-Fired Boilers. The active projects for Round 2 include Demonstration of a 285 MW Coal-Based Transport Gasifier, Southern Company Services, Mercury Specie and Multi-Pollutant Control, Pegasus Technologies, Inc., and Mesaba Energy Project.

The goals of Round 3 are to demonstrate at commercial scale and settings technologies that operate at 90% carbon dioxide capture efficiency, limit increase in COE $< 10\%$ for gasification, $< 35\%$ for combustion and oxy-combustion, sequester $\geq 50\%$ of plant CO_2 output at a scale sufficient to evaluate impact on plant operations, economics, and performance, and capture and sequester or put to beneficial reuse $\geq$ 300,000 TPY of CO_2. Proposals for round 3 are under review; they were due to DOE on Jan. 20, 2009. DOE will award multiple cooperative agreements.

The primary goal of FutureGen is to demonstrate carbon capture and storage technology at multiple clean coal power plants. This program focuses on carbon dioxide separation for CCS. On June 24, 2008, U.S. DOE issued a Funding Opportunity Announcement to invest in multiple commercial-scale IGCC or other clean coal power plants with cutting-edge CCS technology. DOE anticipates $290 million will be available for funding of selected projects through fiscal year 2009, and an additional $1.01 billion is expected to be available in subsequent years, subject to appropriations by Congress. Commercial operation of IGCC power plants equipped with CCS technology is anticipated to begin as soon as plants are commissioned, between 2015 and 2016.

The American Recovery and Reinvestment Act ("stimulus bill," passed in February 2009) appropriated $3.4 billion for Fossil Energy Research, Development, and Deployment. $1.0 billion was for fossil energy research and development programs. $800 million was for additional amounts for the Clean Coal Power Initiative Round III Funding Opportunity Announcement.

On the Chinese side, during the Tenth Five-Year Plan, Clean Coal Technology Subject was involved in the 863 program for the first time, a sign of the beginning of systemic research, development, demonstration, and deployment (RD3) on clean coal technology. Funds for clean coal technology are indicated in the following figure from 2001 to 2005. Funding for coal-to-liquids RD3 is higher than for any other technology, but funding for coal power and pollution control technologies also is likely to be given significant financial support in the next five years.



The 863 program of the Eleventh Five-Year Plan in China was initiated in September 2006. The projects can be divided into three discreet categories: those involving “momentous” projects, key projects, and research themes that are sub-divided according to specific R&D foci. Each category is administrated and managed separately. The research themes are on the frontier of R&D on advanced technologies. Their goal is to enhance innovation ability and acquire independent intellectual property rights. Momentous and key projects emphasize issues of national strategic interest and need for integrated innovation. The goal of momentous projects is to form prototypes of products or technological systems. The goal of key projects is to develop breakthrough core technologies, develop prototypes of single technology products, and resolve important process problems in pilot plants.

In China, the budget for developing advanced coal technologies is larger than ever. During the Eleventh Five-Year Plan, MOST’s budget authority for energy research, development, and demonstration is about 3.5 billion RMB Yuan. The budget authority for coal technology is about 0.7 billion RMB Yuan, accounting for 21% of the total budget. The budget to develop coal gasification-based co-production momentous projects is about 0.35 billion RMB Yuan.

4. Deployment Policy for RD&D of IGCC/Co-Production/CCS

In the U.S., the federal government takes various measures to promote the deployment of IGCC/Co-Production/CCS. They include tax credits and loan guarantees. Section 1307 of the Energy Policy Act of 2005 (EPAct) authorized $1.65 billion in tax credits for clean coal projects:

1) $800 million of credits to support Integrated Gasification Combined Cycle (IGCC) projects for electricity generation. The credits in this category were to be allocated in fairly equal amounts among IGCC projects that use bituminous coal, sub-bituminous coal, and lignite;
2) $500 million to support advanced coal electricity generation projects that utilize innovative technologies other than IGCC;
3) $350 million to gasification projects that support activities other than electricity generation, such as the production of gases used in chemical production.

One billion dollars in tax credits were allocated to support the construction of nine clean coal and advanced gasification projects in 2006, of which two were IGCC projects. One was Duke Energy's Edwardsport IGCC project ($133.5 million). The other was Mississippi Power's Kemper County IGCC project ($133 million). $650 million was available for Round 2 (2007-2008). The award of Excelsior Energy's Mesaba project was $133.5 M. An additional $392 million is available for Round 3. Two IGCC projects will be awarded $133.5 million each.

EPAct also authorized DOE to establish a loan guarantee program to support new or improved technologies that are good for the environment and energy security. DOE's loan guarantee program aims to accelerate the commercialization of innovative, environmentally friendly technologies that will have a real impact on ensuring clean, affordable, and reliable supplies of energy. DOE issued a third solicitation for loan guarantee applicants for advanced fossil energy projects (up to $8 billion) on September 22, 2008. Advanced fossil energy invited projects included Mesaba Energy Project (MEP–I, LLC)'s IGCC Plant, Mississippi Power Company's IGCC Plant, TX Energy, LLC: Coal to Synthetic Gas IGCC Plant.

Additional funds have been appropriated for tax credits in the 2008 Economic Stimulus Bill. $1.25 billion is for clean coal. And $250 million goes to gasification projects. Projects are requested to capture 65% of CO_2. Each metric ton of CO_2 captured and stored or used qualifies for the application of tax credits, $20/tonne CO_2 stored in saline formation or unmineable coal seam and $10/tonne CO_2 used in enhanced oil or gas recovery. Project must sequester more than 500,000 tons of CO_2 during a taxable year.

The Chinese government issued several policy frameworks about energy and climate change in recent years. They are represented by guidelines on its national medium- and long-term program for science and technology development (2006-2020), The Eleventh Five-Year Plan for national economic and social development, The Directory of Key Technologies and Products for which China should have independent intellectual property rights, China's National Climate Change Program, and Special Science & Technology Action in Response to Climate Change. In all these documents, it was mentioned that IGCC/co-production/CCS was the choice for the development of clean coal technology in China. And there are some specific policies to promote the deployment of clean coal technology, but not targeting IGCC/co-production/CCS.

In order to promote the deployment of clean coal technology by industry, central government and local government have formulated a series of industrial policies. For example, for the power sector, the government encourages development of cleaner power generation and combined heat and power, phasing out obsolete technologies, and closing down small-sized plants for efficiency purposes. To control emissions, the government requires that new coal-fired units must be synchronously equipped with FGD, existing plants must have begun to be retrofitted with FGD technology before 2010, and all plants should meet SO_2 requirements before 2015, and calls for the new plants to set aside space for future flue gas denitrification equipment installations.

For the coal sector, the government encourages employing briquette and coal-water mixture, and developing gasification, liquefaction, and clean coal combustion technology. For the manufacturing sector, the government encourages development of desulfurization, dust removal, and denitrification technology and equipment.

The Chinese government also provides clean coal technology projects with necessary fiscal policies. For example, the government offers a preferential price for electricity from power plants with FGD, and gives financial subsidies, low interest loans, and reduction and exemption of taxes to clean coal technology demonstration projects. With more preferential policies, more investment can be drawn from public and private enterprises to promote demonstration and deployment of advanced coal technologies. When the plants that employ advanced coal technologies, such as IGCC and flue gas denitrification, are put into operation, the government can provide a preferential price for electricity from plants.

5. IGCC Design

The four major challenges in IGCC design are better availability, lower capital cost, higher efficiency, and reduction of power and efficiency loss when incorporating CCS. In those aspects, some improvements have been achieved in recent years, such as improved refractory and injector life, enhanced gas turbine availability, and shorter start ups. Larger gasifiers and gas turbines provide economies of scale and lower auxiliary power usage. Some measures have been taken to enhance efficiency, including higher firing temperature gas turbines, lower auxiliary power usage, GT air extraction, separation process for CO_2 at higher pressure, and advanced cycles.

In terms of GT, 7E, 7FA, 9E, and 6FA produced by GE; 6-3000, V94.2, V94.2K, and V94.3 produced by Siemens; and M701D, M701F4 produced by MHI have been applied in IGCC power stations. Planned or commercially offered GT include 7FB, 9FA, 9FB from GE; 5-5000F, 6-4000F, V94 2K from Siemens; and M701F4, M70G, M501 F, M50 G from MHI. Future improvements may include hydrogen-firing without derate and the development G and H class GT. However, to date F GTs still have lower availability than earlier E types. China IGCC Phase 1 demonstration plants currently plan E type GTs. There is a need to move to higher efficiency and larger size 50 Hz GTs and incorporate CCS. The high hydrogen content syngas in the IGCC application with CCS needs demonstration for all manufacturers.

Currently, IGCC design, when incorporating CCS, faces a number of challenges. Emission regulations are not clear. In standard operation and start up, what percent of CO_2 should be captured at what purity? When either CO_2 compressor, pipeline, or sequestration is not available, how to operate the plant? How are CCS costs to be covered? Those issues should be addressed in further research.

6. Insights into Sino-US Cooperation

1) The fast path to deployment of advanced coal technologies is only possible with the help of international cooperation.
2) The single most important energy-cooperation axis is between United States and China.
3) The current state of this cooperation is that it is quite extensive “on paper” (MOUs), but not enough is happening “on the ground”.
4) Need to have specific, concrete ideas for projects.
5) The Harvard-MOST-CAS collaboration can make a big contribution by helping define the specific activities that now should be added.

6) Need to have a common platform for energy dialogue, and these workshops have gained momentum and importance for the energy communities in both countries.
7) Need to study past cooperation projects to see which ones were most effective, and why.
8) Need to think carefully about “coordination” versus “cooperation”. Can we harmonize policies? Coordinate projects and policies?
9) A major educational effort will be needed, at least in the United States, to support enhanced energy cooperation with China.
10) Joint energy RD&D between China and the United States could have the benefit of sharing costs, sharing risk, increasing the speed of learning, and accelerating “buy-in” from governments.

Appendix 1: Workshop agenda

Appendix 2: List of participants

Group picture

Appendix 1: Workshop agenda

Promoting the Development and Deployment of IGCC/Co-Production/CCS Technologies in China and the United States

Joint Workshop
of
Harvard University
Ministry of Science and Technology, People's Republic of China
Chinese Academy of Sciences

Organized by Energy Technology Innovation Policy, Harvard Kennedy School, and Chinese Academy of Sciences/Research Center for Energy and Power (CEP), The National Joint Expert Group for IGCC and Co-Production Demonstration Engineering of China

AGENDA

	April 16, 2009
8:30 AM	**Registration and Light Breakfast Available** **Taubman Building, 5th Floor, Rooms ABC, Harvard Kennedy School**
Morning	**Chaired by Kelly GALLAGHER**
9:00 AM	**Welcome and Opening Remarks** *Kelly Sims GALLAGHER, Harvard University*
9:10 AM	**Opening remarks** *Prof. CAO Jianlin, Vice Minister, Ministry of Science and Technology, China*
9:25 AM	**Setting the Context for Advanced Coal and CCS in the United States and China** *Dr. John P. HOLDREN, Assistant to the President for Science and Technology, Executive Office of the President of the United States*
10:10 AM	**China Energy, Technology Innovation and the Role the Chinese Academy of Sciences Plays** *Prof. JIANG Mianheng, Vice President, Chinese Academy of Sciences*
10:55 AM	**Break**
11:15 AM	**Overview of the Importance of IGCC/Co-Production/CCS** *Ernie MONIZ, MIT*
12:00 PM	**Group Photo in the Taubman Rotunda, Ground Floor**
12:20 PM	**Lunch begins in Allison Dining Room, Taubman 5th Floor**

1:00 PM	**Luncheon Address: Challenges and Opportunities in U.S. and China for IGCC and CCS** *Roberta BOWMAN, Senior Vice President, Duke Energy*
Afternoon	**Chaired by XU Jing**
2:00 PM	**Development Planning by Local Governments** *SHI Yan, Vice Mayor, Lianyungang Municipal People's Government* *LIANG Jianxin, State-owned Assets Supervision Commission Dongguan Municipal People's Government*
2:30 PM	**Technology Policy for RD&D of IGCC and CCS in the United States** *Gary STEIGEL, NETL/DOE* *Sally BENSON, Stanford University (discussant)*
3:15 PM	**Deployment policy for IGCC and CCS in the United States** *Kelly Sims GALLAGHER, Harvard Kennedy School* *Wendy JACOBS, Harvard Law School (discussant)* *Ed LOWE, GE (discussant)*
4:30 PM	**Close**
4:45 PM	**Tour of Harvard University (optional)**
6:00 PM	**Reception in Malkin Penthouse, Littauer Building, Penthouse**
6:30 PM	**Dinner in Malkin Penthouse, Littauer Building, Penthouse**

April 17, 2009

8:30 AM	**Light Breakfast Available** **Taubman Building, 5th Floor, Rooms ABC, Harvard Kennedy School**
Morning	**Chaired by XIAO Yunhan**
9:00 AM	**Panel on Current Challenges and Opportunities in IGCC Design** *Aaron AVAGLIANO, GE Energy* *Neville HOLT, EPRI*
9:45 AM	**Panel on IGCC Demonstration Projects** *Dayong DONG, ConocoPhillips* *MA Zhingming, Hangzhou Huadian Banshan Power Co.* *YOU Wei, Dongguan Power and Chemical Industry Holding Co.* *LIU Jianping, China Power Investment Corporation*
11:00 AM	**Break**
11:15 AM	**Financial Aspects of IGCC and CCS** *Mohammed AL-JUAIED, ETIP Visiting Scholar*

12:00 AM	**Lunch**
Afternoon	**Chaired by Kelly GALLAGHER**
2:00 PM	**Technology Policy for RD&D of IGCC and CCS in China** *ZHANG Zhihong, MOST* *XIAO Yunhan, CAS*
3:00 PM	**Break**
3:15 PM	**Panel on Deployment Policy for IGCC and CCS in China** *LIU Mingzhong, Xinxing Pipes Group Co., Ltd.* *XUAN Wenzhan, Development and Reform Commission of Guandong Province* *CHEN Youlong, the Science and Technology Bureau of Lianyungang Municipality* *LI Xiaochun, Institute of Rock and Soil Mechanics, CAS* *QIAN Jingjing, Natural Resources Defense Council* *Craig HART, Alston & Bird* *XUAN Xiaowei, Harvard Kennedy School and Development Research Center, State Council, PRC*
4:30 PM	**An Agenda for U.S.-China Cooperation on Development and Deployment of IGCC/CCS** *XIAO Yunhan, Chinese Academy of Sciences* *Kelly Sims GALLAGHER, Harvard Kennedy School*
5:00 PM	**Summary and Closing** *Kelly Sims GALLAGHER, Harvard Kennedy School*

Appendix 2: List of participants

List of Participants

	Name	Title	Affiliation
1	AI-Juaied Mohammed	Visiting Scholar (Carbon management)	Harvard Energy Technology Innovation Policy
2	Anadon Laura Diaz	Project Manager (ERD3)	Harvard Energy Research Development Demonstration and Deployment Policy
3	Avagliano Aaron	Gasification Technology Manager	GE Energy
4	Benson Sally	Executive Director, Global Climate & Energy Project	Stanford University
5	Bielicki Jeff	Fellow (CCS, tech policy, climate policy)	Harvard Energy Technology Innovation Policy
6	Blaney John	Senior Vice President, Energy and Resources	ICF International
7	Bowman Roberta	Senior Vice President and Chief Sustainability Officer	Duck Energy
8	Cao Jianlin	Vice Minister	Ministry of Science and Technology
9	Cao Jinghua	Deputy Director-general	Bureau of International Co-operation, Chinese Academy of Sciences
10	Chan Melissa	Fellow (ERD3)	Harvard Energy Research Development Demonstration and Deployment Policy
11	Chen Youlong	Director General	the Science and Technology Bureau of Lianyungang Municipality
12	Chikkatur Ananth	Senior Associate	ICF International
13	Deng Jianfen	Assistant of General Manager /Senior Engineer	Dongguan Power and Chemical Industry Holding Co.,Ltd.
14	Dong Dayong	Senior Project Director, Asia Pacific E-gas Technology	ConocoPhillips
15	Du Meifang	Associate Prof.	University of Shanghai for Science and Technology
16	Gallagher Kelly	Director	Harvard Energy Technology Innovation Policy
17	Gu Huamin	Chairman	GCL Engineering Limited
18	Hart Craig	Counsel, Energy Ingrastructure, Climate Change, and Technology	Alston & Bird
19	Hernandez Milton	Clean Coal – Gas & Power Group	Shell Oil Company
20	Holdren John	Director	Office of Science & Technology Policy in The White House
21	Holt Neville	Technical Executive-Advance Fossil Generation Technology	EPRI
22	Jacobs Wendy	Clinical Professor of Law, Environmental Law and Policy Clinic	Harvard Law School
23	Jiang Mianheng	Vice President	Chinese Academy of Sciences
24	Jones Charles “Skuk”	Fellow (ERD3)	Harvard Energy Research Development Demonstration and Deployment Policy
25	Larson Eric D.	Research Engineer	Princeton Environmental Institute
26	Lee Henry	Co-Principal Investigator	Harvard Energy Technology Innovation Policy

27	Li Wenhua	Lab Manager	Coal Polygeneration Technologies Lab, Global Research - Shanghai GE
28	Li Xiaochun	Prof.	Institute of Rock and Soil Mechanics, Chinese Academy of Sciences
29	Liang Jianxin	Director	State-owned Assets Supervision Commission Dongguan Municipal People's Government
30	Liang Jingchang	Deputy Director General	Economic and Trade Bureau of Dongguan City
31	Liu Hengwei	Fellow (China coal)	Harvard Energy Technology Innovation Policy
32	Liu Jianping	Director	Division of Project Management, Dept. of Planning and Development, China Power Investment Corporation
33	Liu Mingzhong	Chairman	Xinxing Pipes Group Co., Ltd.
34	Lou Margaret	Director, International Technology Cooperation Program	National Energy Technology Laboratory
35	Lowe Ed	General Manager-Renewable Energy Market Development	GE
36	LU Jia	Program Office	Division of Americas and Oceania, Dept. of International Cooperation, Ministry of Science and Technology
37	MA Linying	Deputy Director General	Dept. of International Cooperation, Ministry of Science and Technology
38	Ma Zhiming	Senior Engineer	Hangzhou Huadian Banshan Power Generation Co.ltd
39	Mao Zhongying	Counsel	Consulate-General of The People's Republic of China
40	MENG Hui	Secretary	Executive Office, Ministry of Science and Technology
41	Moniz Ernie	Director	MIT Energy Initiative
42	Morrow Ross	Fellow (Auto Policy)	Harvard Energy Technology Innovation Policy
43	Oliver Hongyan	Fellow (China Auto)	Harvard Energy Technology Innovation Policy
44	Peridas George		Natural Resources Defense Council
45	Qian Jingjing	Senior Research Associate	Natural Resources Defense Council
46	Schwartz Larry	Scientific Advisor	Schlumberger-Doll Research
47	Shang Xianfu	Deputy Director General	the Science and Technology Bureau of Lianyungang Municipality
48	Shi Yan	Vice Mayor	Lianyungang municipal People's government
49	Smouse Scott	APEC EGCFE Chair, International Group Leader	National Energy Technology Laboratory
50	Steelman John		Natural Resources Defense Council
51	Steigel Gary	Gasification Technology Manager	National Energy Technology Laboratory
52	Stowe Robert C.	Associate Director	Harvard Energy Technology Innovation Policy
53	Tang Guohai	Director	the Administrative Committee of LYG Eco. & Tech. Development Zone
54	Vargas Maria	Deputy Director, Office of Systems, Analysis, and Planning	National Energy Technology Laboratory
55	Wang Bo	Fellow (China Climate Policy)	Harvard Energy Technology Innovation Policy
56	Wang Dongliang	Vice Director	Office of LYG Party Committee of the CPC
57	WANG Qiang	Director	Division of Americas and Oceania, Dept. of

			International Cooperation, Ministry of Science and Technology
58	Wang Qiang	Vice Director	the Administrative Committee of LYG Eco. & Tech. Development Zone
59	Wang Dongliang	Vice Director	Office of LYG Party Committee of the CPC
60	Wang Wenqi	Deputy general manager	Huadian Power International Corporation Limited
61	Wu Yiyun	Deputy Consultant-Director	Science and Technology Bureau of Dongguan City
62	Xiao Yunhan	Deputy Director-general	Bureau of High-Technology Research and Development, Chinese Academy of Sciences
63	Xu Jing	Director-general	Major Special Project Office, Ministry of Science and Technology
64	Xu Yuan		Princeton University
65	Xuan Wenzhan	Deputy Director	Development and Reform Commission of Guangdong Province
66	Xuan Xiaowei	Fellow (China Coal)	Harvard Energy Technology Innovation Policy
67	Yang Bin	Deputy General Manager	Xinxing Pipes Group Co., Ltd.
68	Yao Zhurui	Director General	Development and Reform Bureau of Dongguan City
69	You Wei	Chairman	Dongguan Power and Chemical Industry Holding Co.,Ltd.
70	Yu Long	Vice General Manager	HARBIN BOILER Co. Ltd.
71	Yu Yongzhen	Visiting Scholar (Coal, Efficiency)	Harvard Energy Technology Innovation Policy
72	Zhang Zhongxiao	Prof.	University of Shanghai for Science and Technology
73	Zhang Zhihong	Deputy Director-general	Department of High and New Technology Development and Industrialization, Ministry of Science and Technology
74	Zhao Lifeng	Associate Professor	Institute of Engineering Thermophysics, Chinese Academy of Sciences
75	Zhu Anjun	Senior Engineer	Gas Turbine Department, HARBIN POWER EQUIPMENT Co. Ltd.
76	Zhuang Jia		Consulate-General of The People’s Republic of China

This workshop report was prepared by Dr. Lifeng Zhao, Yunhan Xiao, and Kelly Sims Gallgher and drew upon the presentations by participants. The interpretations of the presentations and remarks made in the workshop are the authors' alone. An electronic copy of this report is also available online at http://energytechnologypolicy.org.

Dr. Kelly Sims Gallagher, Dr. Yunhan Xiao, and Dr. Lifeng Zhao were the principal organizers of this workshop. If you have any questions regarding this workshop, previous workshops, or the collaborative efforts on this topic in general, please contact:

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