Joint Workshop on the Cooperation in Clean-Coal Technologies Between the United States and China
Sponsored by the Ministry of Science & Technology, Clean Coal Research Institute, and Energy Technology Innovation Project, Science, Technology, and Public Policy Program, John F. Kennedy School of Government, Harvard University
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WORKSHOP REPORT

Purpose of Workshop

The United States and China are both heavily dependent on coal for their energy systems, and in particular for electricity generation. China is developing a new concept of well-rounded, balanced, and sustainable development, with the goals of:
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- Balancing urban and rural development
- Balancing development among regions
- Balancing economic development with social development
- Balancing the development of man and nature
- Balancing domestic development and opening to the outside world

In a different context, the United States is also wrestling with many of the same dilemmas. One irrefutable fact is that coal will be central to the energy systems of both countries for decades to come, so it is imperative that the two countries find ways to use the coal without irreversibly harming the environment. The purpose of this workshop was to discuss the economic, national security, and environmental challenges and opportunities associated with coal production and consumption, and to identify promising clean-coal technologies that might meet these challenges.

Building on Past Workshops

This workshop is the third workshop sponsored by the following partners: the Energy Technology Innovation Project at Harvard University, the Ministry of Science & Technology, and the China Coal Research Institute. The first workshop was held in October 2002 in Beijing. The second was held at Harvard University in September 2003. A summary of the major findings from the second workshop can be found at http://bcsia.ksg.harvard.edu/energy.

Who Participated?

This workshop had 36 invited participants. They included senior government officials, Mr. Xu Jing and Mr. Zheng Fangneng from the Ministry of Science and Technology.

It was also a convention of China's leading scientists on clean-coal technologies and energy policy, who represented institutions including the Development Research Institute of the State Council, Zhejiang University, Harbin Industry University, Tsinghua University, the Institute of Engineering and Thermal Physics of the Chinese Academy of Sciences, East China University of

Science & Technology, China Coal Research Institute, Thermal Power Research Institute, and State Power Plant Combustion Engineering Technology Research Center.

China's main power-generation and coal-producing firms, including Huaneng Group Co. Ltd., China Electricity Investment Group, Yankuang Group Co. Ltd., and Shenhua Group Co. Ltd, also sent representatives to the workshop.

Professor John Holdren, ETIP Director Dr. Kelly Gallagher, and Research Fellow Dr. Guodong Sun from Harvard University also participated. Dr. Li Wenhua, former Visiting Scholar at Harvard University and Deputy Director of the Beijing Research Institute of Coal Chemistry at the China Coal Research Institute (CCRI), took the main responsibility for organizing the workshop.

Some Key Insights from the Workshop

Energy policy problems in China and the United States

- The United States is the largest energy consumer and the largest carbon emitter in the world. In 2002, its total primary-energy use was 2,293 megatons oil-equivalent (Mtoe) [1], and its total anthropogenic carbon dioxide (CO_2) emissions were 1,581 megatons in carbon equivalent (MtC) [2].
- China was the second-largest energy consumer and the second-largest carbon emitter in the world. In 2002, its total primary-energy use was 998 Mtoe [3] and its total energy-related CO_2 emissions were 906 MtC [4].
- Many factors have made the United States and China the top two energy consumers and carbon emitters. They have the two largest populations [5] and the two largest economies[6] in terms of gross domestic production (GDP) in purchasing-power parity (PPP) terms. China and the United States are also the largest and the second-largest coal users in the world, respectively.
- Rapid economic growth, especially in the rapid expansion of steel, cement, and aluminum industries, has caused a crisis in the coal-electricity generation chain in China. Almost every industry in this chain – from coal mining to transportation to power generation -- reached its maximum capacity in 2003.
- China's electricity industry is undergoing another round of rapid expansion. In 2004, China is likely to build 37 to 40 gigawatts (GW) of new power plants. It is predicted that China's total installed capacity will reach 950 GW by 2020 from 385 GW in 2003. While hydropower, nuclear power, and wind power have been aggressively pursued, coal-fired power plants have – and will continue to dominate the new capacities. Sub-critical or super-critical technologies have been the most commonly used technologies.

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[1] According to BP Statistical Review of World Energy 2003.
[2] According to U.S. EIA Emissions of Greenhouse Gases in the United States 2002.
[3] According to BP Statistical Review of World Energy 2003.
[4] According to U.S. EIA China Country Analysis Brief.
[5] The U.S. and Chinese populations were 286 and 1280 millions in 2001, respectively.
[6] GDP of the United States and China was 9.8 and 5.3 trillion U.S. dollar (PPP, price of year 2000) in 2001, respectively.

- Although the United States experienced electricity shortages in recent years (notably in California), the most pressing current energy challenge is the increasing price of energy supplies.
- In the longer term, both China and the United States will have to contend with rising energy prices. Neither country is currently regulating mercury or carbon dioxide (CO_2) from power plants. Both countries have regulations to control NOx and SO_2, although the regulations are much more stringent in the United States than in China.
- Governments in both China and the United States support innovation--both domestic efforts and international cooperation--in energy technologies including clean-coal technologies. In the United States, however, investment in energy innovation has steadily declined for many reasons. While there is political support for energy technology innovation in China, the main barrier is the limited resources available for these efforts.

Advanced clean-coal technologies

- Chinese equipment vendors, constructors and electricity-generation companies have mastered sub-critical technologies after about 20 years of experience, and have also accumulated some experience in the supercritical technologies. The development of these capabilities resulted from technology transfer from foreign companies, indigenous R&D efforts, and close cooperation among domestic firms. The central government, which had more control over their operations during that time period than today, has provided consistent support and coordination, proving essential to their success.
- Both the Chinese and U.S. governments are funding research in advanced clean-coal technologies such as Integrated Gasification Combined Cycle (IGCC) and poly-generation technologies (co-production of electricity, hydrogen, and chemicals).
- With the same financing plan, ultra-supercritical (USC) pulverized-coal power plant has a significant lower cost-of-electricity (COE) than a first-generation IGCC power plant. At a coal price of 300 Yuan/ton, COEs of a USC plant and an IGCC plant are about 280 Yuan/MWh [7] and 350 Yuan/MWh [8], respectively.
- Currently, China's equipment vendors, and the electricity industry as a whole, focus their innovation efforts on ultra-supercritical technology because of its high thermal efficiency and large single-unit capacity. China does not have many sites that are suitable for large-scale coal-fired power plants. Ultra-supercritical technology, whose single-unit capacity (600-1,000 MW) is much larger than that of sub-critical and supercritical units (600 MW or smaller), allows power generation companies who are vigorously competing with each other to occupy the sites while rapidly expanding their total capacity.
- When considering the question about which of advanced coal technologies will be appropriate for the long term, there was some debate about the extent to which technologies would be more adaptive to future environmental regulations(especially with respect to carbon dioxide and mercury). Coal gasification-based technologies such as IGCC can be retrofitted to separate and capture CO_2 at lower cost than USC. There were arguments in favor of moving directly to IGCC because in the longer term, it is very likely that carbon dioxide will be regulated in both countries, and IGCC appears to be the only cost-effective coal-based technology that can produce a CO_2 stream of high purity that could be captured and

[7] MWh represents megawatt-hour. 1 MWh is the electricity generated by a 1-megawatt (MW) unit in 1 hour.
[8] Evaluation period is 20 years. Project is financed with 20 percent of equity and 80 percent of bank loan. Annual interest rate of bank loan is 5.7%. After-tax equity return rate is 15%.

sequestered. If IGCC technologies are not adopted, a very large number of valuable power plants will be built that cannot easily be adapted to address the issue of climate change. This could create a "lock-in" effect because countries could be stuck with power plants that are too valuable to scrap, but too costly to retrofit to reduce carbon dioxide emissions.

- China is pursuing research in both direct and indirect liquefaction of coal because of the interest in pursuing greater energy independence. In the United States, government-sponsored research in direct liquefaction was halted during the late 1990s because the government decided there were too many disadvantages to the technology.

Market for clean-coal technologies

- Some participants believed that IGCC technology seemed too distant to be practical today, and recommended that it would be better to focus on eliminating small coal-fired power plants in order to improve the overall energy-efficiency of coal-fired power generation in China. All agreed that the number of small plants needs to be reduced, but there was considerable debate about how fast advanced coal-fired power generation technologies such as IGCC/poly-generation could be moved into the marketplace. Some believed that with a little help from the government, the first generation of IGCC plants could be commercialized immediately in both the United States and China, but others thought it would be too costly for China. Advancing IGCC technology in the United States increases the likelihood that it will also be embraced in China and India.
- China's electricity industry is less interested than the coal industry in adopting more-expensive coal-gasification-based technologies (e.g., IGCC, poly-generation) as a measure to hedge against business risks caused by potential changes in regulatory regimes, especially the possibility that carbon dioxide will eventually be controlled. While China's electricity industry is still regulated, the government has started to introduce more competition into this industry with an eventual goal of full deregulation. More importantly, given the crucial role of electricity in the economy, the power industry always has tremendous political power to influence the decision-making process, and thus is less worried about policy changes.
- Coal gasification technologies have been successfully deployed in China for many years. Most of the current coal gasification applications in China are for chemical production. Similarly, coal gasification is successfully used in commercial applications in the United States.
- Poly-generation technology is favored by China's traditional coal-mining companies for several reasons. First, it offers an excellent opportunity to these companies to move into more profitable businesses including chemical production and power generation. Most of China's major coal mines are located in less-developed regions. Recent reforms that transferred their ownership from the central government to local governments have motivated the latter to adopt strategies that can generate more profit from their coal resources. The central government also adopted policies to encourage small coal-mining companies to merge into large firms so that they can survive in a competitive market. Aggregation also enables the newly formed large companies to adopt complex technology such as poly-generation technology.
- While the coal industry is also very important to China's economy, it has been treated less favorably than the power industry. Perceiving that it has less political power to influence the decision-making process, the coal industry is more sensitive to potential changes in

government policy. The inherent product-flexibility of poly-generation technology can hedge against such risks.

- Methanol from coal-based poly-generation plants, however, encounters many barriers upon entrance in the automobile-fuel market in China, which is controlled by a few large, vertically-integrated firms.
- Most of China's new power plants were financed with loans from commercial or development banks, or both. The share of equity investment usually is at the lowest level that is allowed by regulation, which is 20 percent. While this practice stimulates the expansion of electricity industry due to the resulting low capital cost, it is commercial and development banks, which are state-owned, that bear most of the financial risks.
- In the United States, because the cost of natural gas has risen so much in the last two years, many of the natural-gas combined cycle (NGCC) power plants are uneconomical to operate. Many of these NGCC plants are being sold at discounted rates, and could conceivably be converted into IGCC plants fairly inexpensively.

The Role of policy and international cooperation

- Appropriate policy changes are needed to both push and pull the advanced technologies into the marketplace. Some of the related laws and regulations include emission standards and coal-quality standards.
- China's central government should take more actions to influence the technology choices for new coal-fired power plants. Many policy instruments are available to facilitate the deployment of IGCC technology. One of them is to increase the minimum equity investment in financing coal-fired power plants that use combustion-based technologies (e.g., ultra-supercritical technology) *or* to lower it for an IGCC plant. IGCC could become competitive with USC in China in terms of the cost-of-electricity if the minimum equity investment for the USC plant is increased from current 20 percent to 40 percent and IGCC is financed with 20 percent of equity and 80 percent of bank loan [9].
- Coal-based methanol producers at the workshop suggested that China's central government should help to clear the market barriers that hinder methanol produced with coal-based poly-generation technology from entering the automobile-fuel market. The newly formed Energy Bureau within the National Development and Reform Commission should take this responsibility.[10]
- One presentation on the Clean Development Mechanism of the Kyoto Protocol was made, and it was noted that China has ratified this Protocol, but the United States has not yet done so. Even so, China has begun to prepare policies related to the implementation of the Clean Development Mechanism, whereby advanced industrialized countries could work on projects in developing countries that reduce greenhouse-gas emissions to obtain credit towards emission-reduction goals. There have been a number of CDM pilot projects in China, and the emission-reduction price of these projects in China is in the range of US$4-5 /ton of CO_2 equivalent (about US$14/ton of carbon). China's electricity industry, however, is a potential opponent of implementing CDM in China because it may want to preserve good CDM opportunities for its own use.

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[9] Annual interest rate of bank loan is 5.7%. After-tax equity return is 15%. All other assumptions are same as those in Footnote 3.

[10] Further study of the chronic health effects from exposure to elevated levels of methanol due to its widespread use as an automotive fuel may be warranted in light of potential adverse health effects from methanol.

- It was noted that there are many common interests between the United States and China with respect to coal, and that there were many reasons to strengthen the cooperation between the U.S. and China on this issue.

Appendix 1: Workshop agenda
Appendix 2: List of invited participants

Group picture

Discussion

Close cooperation

This workshop report was prepared by Dr. Guodong Sun, Dr. Li Wenhua, and Dr. Kelly Gallagher. The interpretations of the presentations and remarks made in the workshop are their own. An electronic copy of this report is also available online at http://bcsia.ksg.harvard.edu/energy.

Dr. Li Wenhua was the principal organizer of this workshop, in coordination with Mr. Xu Jing and Mr. Zheng Fangneng of the Chinese Ministry of Science & Technology, and Program in Science, Technology, and Public Policy Fellow Dr. Guodong Sun. Dr. Sun is the leader of the collaborative research project on clean-coal technologies on the U.S. side, and Dr. Li is the leader of the project on the Chinese side.

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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