The Roles of Government in the Innovation and Use of Clean-Coal Technologies in the United States and China

Report on a workshop jointly organized by the Energy Technology Innovation Project, Science, Technology and Public Policy Program, Belfer Center for Science & International Affairs, Kennedy School of Government of Harvard University, and the Department of High Technology of China's Ministry of Science and Technology, and China Coal Research Institute. This workshop was held at Harvard University in Cambridge, Massachusetts, September 4-5, 2003

Goals and objectives

The goal of the workshop was to explore the role of government in the research, development, demonstration and deployment (RD^3) of clean-coal technologies (CCT) in the United States and China. Other primary objectives of the workshop were to identify the most important barriers and incentives for the RD^3 of clean-coal technologies, and to discuss potential policy recommendations.

The challenge

China and the United States are the two largest coal producers and consumers in the world. Each country consumes about 1 billion tons of coal every year -- together, about 45 percent of the world's total. Coal production and consumption are now the causes of some of the most intractable environmental problems in both countries, including air pollution and global climate change. Coal is the most abundant and lowest-cost domestic energy resource in both countries, however, so it will continue to be relied on in both the United States and China in the coming decades. Thus, the development and deployment of clean and efficient coal technologies, at competitive costs, are essential to minimize potential harm to the natural environment and human health.

The innovation process (research, development, demonstration, and deployment) of clean-coal technologies faces many demanding challenges, including technical difficulties, higher costs of the advanced technologies, and the institutional and policy barriers impeding their demonstration and deployment. Clean-coal technologies have great potential to provide large energy, economic, environmental, and national security benefits to the United States and China, and these benefits justify the active involvement of governments in the innovation process. What is less clear, however, is exactly how the government should be involved in the innovation process. This research seeks to determine what are the appropriate roles of government, the market, and various international institutions in the RD^3 of clean-coal technologies.

Who participated in the workshop?

More than twenty leading experts on clean-coal technology were invited to the workshop from U.S. and Chinese governmental agencies, academia, and firms. Their combined experience encompassed the R&D of clean-coal technologies, R&D management, and energy and environmental policies. A list of participants is attached.

What insights came out of the workshop?

This workshop generated many useful insights and suggestions from the distinguished participants. Followings are the major conclusions:

Comparisons and contrasts

- Coal plays a larger role in China's energy supply than in U.S. energy supply, and it accounts for a larger share of China's air pollution than of U.S. air pollution. Thus clean-coal technologies are even more important and urgent for China than for the United States.
- Because China has less liquid-fuel infrastructure in place up until now than the United States has, China has greater flexibility to innovate in synthetic-fuels technologies.
- CCT RD&D in the United States is focused to a greater extent than in China on the longer-term options relating to near-zero emissions, an electric-hydrogen energy economy, and carbon capture and sequestration.
- Because of differences in the systems of government, China is in a better position than the United States to make the lasting policies needed to create stable incentives for using advanced clean-coal technologies, but the United States seems to be more effective at enforcing environmental regulations, including emissions standards.

Status of efforts on clean-coal technologies

- RD&D efforts on CCT are more diverse, more extensive, and more advanced, in both China and the United States, than most people think. Clean-coal technology has been an important part in an array of government-funded programs in China that cover every stage of the RD&D process, namely the National Basic Technology R&D Program ("973" Program) for basic technology research; the National High-Technology R&D Program ("863" Program) for technology research and development; the National Key Technology R&D Program ("Keji Gongguan" Program) for demonstration project.
- China-U.S. communication and cooperation on CCT also have been – and remain – more extensive than most people think.
- Compared to the magnitude of the challenges and opportunities, however, these separate and cooperative efforts on RD&D for CCT are not extensive enough. There are high-leverage opportunities to do more.

Technologies

- CCTs are of many kinds: advanced coal preparation; supercritical & ultra-supercritical steam systems; CFBC and PFBC; advanced stack-gas cleaning; IGCC; carbon capture and sequestration; direct & indirect liquefaction technologies; co-production options, and more.
- All of these are relevant to some degree if the goal is reduction of the "conventional" pollutants from coal burning: SOx, NOx, particulate matters, trace metals.
- If reductions in carbon dioxide emissions are required beyond those achievable through increases in conversion efficiency, then IGCC, carbon capture and sequestration, direct and indirect coal liquefaction, and co-production variants are the most important options.

Economic issues

- Pulverized-coal power plants without flue-gas-desulfurization (FGD) would be the least expensive electricity option in both China and the United States, but they cannot meet air-pollution standards in either country.
- Natural-gas combined-cycle plants have the lowest COE (Cost-of-Electricity) of fossil-fueled options that can meet air-pollution standards in the United States, and this may also be true in China if price of natural gas drops to $2/GJ.
- The next-cheapest option for fossil-fueled electricity generation meeting air-pollution standards is PC with FGD. (EPRI data show IGCC without carbon capture becoming competitive with PC/FGD; most other analyses show IGCC as costlier.) If natural gas costs $5-6/GJ, the COE for PC/FGD becomes less than that of NGCC in the United States.
- If carbon must be captured and sequestered, IGCC becomes the most economical fossil-fueled electricity-generation option.

Institutional and policy issues

- Although many aspects of advanced CCT will benefit from additional R&D, the more difficult problems are those impeding movement to demonstration and deployment.
- China lack of mechanism to help industries hedge the significant financial risks associated with CCT demonstration projects. Government's cost-sharing is far from enough.
- Companies would be reluctant to buy new power plants based on IGCC even if calculations showed these plants to be economically competitive, because IGCC is seen as "not proven" in terms of reliability over the multi-decade period that such plants must operate.
- Higher natural-gas prices and policies to tax or otherwise restrict carbon-dioxide emissions will not be fully effective in overcoming current economic barriers to deploying advanced clean-coal technologies unless decision-makers can be confident that the higher prices and/or carbon taxes and emissions restraints will be permanent.

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- A coherent vision of what the future of coal will be, which should emphasize gasification for both electricity generation and synthetic fuels production. Version 21 Program provides a clear version of the U.S. Department of Energy for the future coal-based power generation technology. If not already exist, a strategic plan of this type in China that define explicitly the problems to be addressed (and not to be addressed) can serve as an effective guide for China's RD&D efforts. This plan should be designed under intensive and rigorous reviews from academia and industry, and is publicly available after it is done.
- A clear and consistent greenhouse-gas emissions policy, including provision for a sequestration infrastructure that incorporates risk and insurance aspects. Greenhouse-gas emissions policy has become one of the most important uncertainty factors that influence not only the RD&D efforts but also the investment decisions on energy infrastructure that has characteristics of long turnover time and path-dependency.
- Financial incentives for the first 20-50 advanced clean-coal power plants, with a second round of smaller incentives for the next 20-50. They provide means to "buy down" to competitive levels the costs of targeted clean-coal technologies, which have learning-curve characteristics.
- A "technology innovation contest" for CCTs, resembling the US DOE's Gas Turbine Initiative of the 1990s.

- International mechanisms for encouraging and financing CCT demonstrations. The 1999 PCAST report entitled “Powerful Partnerships: The Federal Role in International Cooperation on Energy Innovation” recommended two mechanisms to support demonstration projects. They are (1) a Demonstration Support Facility (DSF), preferably at the Global Environmental Facility (GEF), to support demonstration projects that would attract support from the private sector as well as public-sector sources; and (2) an energy-production tax credits to U.S. firms participating in demonstration projects that are carried out under DSF and that meet approved criteria.

Attachments

(1) Workshop agenda; (2) Brief biographies of workshop participants

Workshop participants line up for a photo, September 2003

Proceedings of the clean coal workshop

The Roles of Government in the Innovation and Use of Clean-Coal Technologies in the United States and China

September 4-5, 2003
Kennedy School of Government, Harvard University, Cambridge, Massachusetts

Agenda

Thursday, September 4, 2003 at Room 415, One Eliot Street Building	
14:00–14:10	Opening remarks from John P. Holdren, Harvard University
14:10–14:15	Opening remarks from Fangneng Zheng, China Ministry of Science and Technology
14:15–14:20	Discuss the agenda, Guodong Sun, Harvard University
14:20–15:40	**Session 1: Energy-Environment-Development-Security Challenges and Clean-Coal Technologies (CCT), Chaired by Mr. Fangneng Zheng** Presentation 1**: John P. Holdren**, Harvard University, Energy-Environment-Development-Security Challenges and Clean-Coal Technologies Presentation 2**: Minghua Du**, China Coal Research Institute, Clean Coal Technology of China
15:40–16:00	Coffee Break
16:00–17:20	**Session 2: Advanced Clean-Coal Technologies, Chaired by Mr. Fangneng Zheng** Presentation 1: **János M. Beér**, MIT, Clean and Efficient Coal-based Electric Power Generation Presentation 2**: Robert H. Williams**, Princeton University, Comparing Direct and Indirect Liquefaction Technologies for Making Fluid Fuels from Coal
19:00pm	Dinner at Faculty Club, hosted by the Science, Technology and Public Policy Program, Kennedy School of Government, Harvard University
Friday morning, September 5, 2003 at Room 415, One Eliot Street Building	
8:00–8:30	Continental breakfast
8:30–9:50	**Session 3: Industry and the Innovation and Use of CCT, Chaired by John P. Holdren** Presentation 1**: Henry Courtright**, Electric Power Research Institute, Industry Innovation and Use of Clean Coal Technology Presentation 2**: Shisen Xu**, Thermal Power Research Institute, The Reform of China's Power Industry and the Application and Development of Clean Coal Generation Technology
9:50–10:10	Coffee Break
10:10–11:30	**Session 4: Government and the Innovation and Use of CCT, Chaired by John P. Holdren** Presentation 1: **Rita A. Bajura**, NETL, A DOE Perspective on Clean Coal Technology Presentation 2: **Fangneng Zheng**, MOST, Clean Coal Technology R&D in China
11:30–13:00	Lunch at Legal Seafood
Friday afternoon, September 5, 2003 at BCSIA Library meeting room	
13:00–15:00	**Session 5: R&D Management and International Collaboration, Chaired by Wenhua Li** Presentation 1**: Guodong Sun** and **Wenhua Li**, Toward a Better Institutional System for the R&D of Clean-Coal Technologies in China Presentation 2**: William Chandler**, Pacific Northwest National Laboratory, U.S.-China Cooperation on Clean Energy and Clean Coal Presentation 3: **Yunhan Xiao,** Chinese Academy of Sciences, An Reevaluation on CCT R&D in China
15:00–15:20	Coffee Break
15:20–16:50	**Session 6: Panel Discussion on policy and institutional changes to facilitate the innovation and use of clean-coal technologies, Chaired by John P. Holdren** Panelists**: Wenhua Li**, Beijing Research Institute of Coal Chemistry **Weiguang Huang**, Chinese Academy of Sciences **Henry Courtright,** EPRI **Karen R. Polenske,** MIT **Henry Lee**, Harvard University
16:50–17:00	Closing Remarks, John P. Holdren, Harvard University

Participants

(in alphabetic order)

Rita A. Bajura is the Director of the National Energy Technology Laboratory (NETL), a national laboratory owned and operated by the U.S. Department of Energy (DOE). As NETL Director, Ms. Bajura oversees the implementation of major science and technology development programs in fossil energy and environmental technologies, including: advanced power generation technologies fueled by coal, natural gas, and biomass; environmental control technologies for the existing fleet of fossil steam plants; ultra-clean fuels for the transportation sector.

János Beér is Professor Emeritus in Chemical and Fuels Engineering, MIT. His research focus on turbulent combustion of gaseous, liquid, and solid fuels; reduction of pollutant emission from flames by combustion process modification.

William Chandler has worked for 29 years in energy and environmental policy, and is currently senior staff scientist and director of Advanced International Studies at Pacific Northwest National Laboratory. Chandler is also an adjunct professor at Johns Hopkins University. Mr. Chandler's international work has included institution building, policy development, and project finance. He led the creation of independent, not-for-profit energy efficiency centers in six nations, including China.

Henry Courtright is the Vice President for Power Generation and Distributed Resources of Electric Power Research Institute (EPRI) in Palo Alto, California. He is responsible for strategic direction and overall group performance for EPRI's technology program in fossil, hydro, renewable and distributed generation. He has 18 years experience, and held many senior positions, in the electric utility industry. He received a B.S. in Mechanical Engineering from the Pennsylvania State University and a Masters in Business Administration from Lehigh University. He is a licensed Professional Engineer in Pennsylvania and California.

Minghua Du is the Director of the Beijing Research Institute of Coal Chemistry. He also serves on the Advisory Committee for Clean-Coal Technologies in the National High Technology R&D Program ("863" Program). He is an expert on coal gasification, and China's energy policy. He holds a PhD degree in Coal Chemistry from China Coal Research Institute.

Robert A. Frosch is a Senior Research Associate in the Belfer Center for Science and International Affairs at Harvard's John F. Kennedy School of Government. He served as the Assistant Executive Director of the United Nations Environment Programme (UNEP), Associate Director for Applied Oceanography of the Woods Hole Oceanographic Institution (WHOI), Administrator of NASA, President of the American Association of Engineering Societies (AAES), and Vice President of General Motors Corporation (GM) in charge of Research Laboratories. He retired from GM in 1993 before joining the Kennedy School of Government at Harvard University. He is a member of the National Academy of Engineering, the American Academy of Arts and Sciences, a Foreign Member of the UK Royal Academy of Engineering, and a fellow or member of a number of professional societies.

Kelly S. Gallagher is Acting Director of the Energy Technology Innovation Project (ETIP) of the Science, Technology, and Public Policy (STPP) Program at the Belfer Center for Science and International Affairs of Harvard's Kennedy School of Government. She has a M.A.L.D. and Ph.D. in International Affairs from the Fletcher School of Law and Diplomacy at Tufts University. Her research interests include energy technology innovation, international energy cooperation, energy policy, climate change, international environmental policy, and technology transfer.

Debyani Ghosh is a Research Fellow in the Belfer Center for Science and International Affairs of Harvard's Kennedy School of Government. She has expertise in policy analysis related to energy-environment systems that include micro and macro-economic policy analysis, global and national policies, regional and sectoral policies, technology policies and socio-economic policy analysis with emphasis on Energy and Environment systems. She holds a Ph.D. from Indian Institute of Management Ahmedabad with specialization in policy analysis of Energy-Environment systems.

John P. Holdren is the Teresa and John Heinz Professor of Environmental Policy and Director of the Program on Science, Technology, and Public Policy in the John F. Kennedy School of Government, and Professor of Environmental Science and Public Policy in the Department of Earth and Planetary Sciences, at Harvard University. He is a member of the National Academy of Sciences, and the National Academy of Engineering. He was a member from 1994 to 2001 of President Clinton's Committee of Advisors on Science and Technology (PCAST). He chaired PCAST panels on protection of nuclear-bomb-materials (1995), the U.S. fusion-energy R&D program (1995), U.S. energy R&D strategy (1997), and international cooperation on energy (1999). He previously co-founded and co-led for 23 years the campuswide interdisciplinary graduate degree program in energy and resources at the University of California at Berkeley.

Weiguang Huang is the Director of the Institute of Engineering Thermophysics, Chinese Academy of Sciences. His research focus on advanced gas turbine technologies.

Henry Lee is the Jaidah Family Director of the Environment and Natural Resources Program within the Belfer Center for Science and International Affairs at Harvard's John F. Kennedy School of Government, Faculty Co-Chair of the School's International Infrastructure Program, and a Lecturer in Public Policy. Before joining the School in 1979, Mr. Lee spent nine years in Massachusetts state government as Director of the State's Energy Office and Special Assistant to the Governor for environmental policy. He has served on numerous state, federal, and private advisory committees on both energy and environmental issues, works with private and public organizations, and has served on several corporate boards. His research interests have focused on electricity and water privatization, environmental management, global climate change, and the political economy of energy.

Wenhua Li chairs the Expert Committee for Clean-Coal Technologies in China's National High Technology R&D Program ("863" Program), Ministry of Science and Technology. He is also the Deputy Director of the Beijing Research Institute of Coal Chemistry. He is an expert on coal chemistry, coal gasification and liquefaction. He holds a PhD degree in Coal Chemistry from China Coal Research Institute.

Pisi LU is a Research Associate in the Department of Chemical Engineering at MIT. His research focus on advanced combustion technologies. He also has many years of research experience in coal combustion technologies with China's Harbin Electric Power Engineering Research Institute, and managed R&D projects in China's Ministry of Science and Technology. He holds a PhD in Mechanical Engineering from the Technical University of Lisbon.

Yunfei Luo is an Engineer from the Beijing Research Institute of Coal Chemistry, and is an Assistant to Dr. Minghua Du. Her research focuses on coal liquefaction technology.

Karen R. Polenske is a Professor of Regional Political Economy and Planning at MIT. For the past 30 years, she has conducted research on energy, environmental, and transportation issues in the United States and, for the past 17 years, in China. She is currently conducting research on energy-efficient, low-pollution technologies in town, village, and state-owned enterprises in China and on the socioeconomic impact of Yellow Dust Storms in North China. She head of two Alliance for Global Sustainability (AGS) research teams with participants from in collaboration with the Chinese Academy of Science, Northeastern University (Shenyang, Liaoning Province), University of Tokyo, and other universities in China, Japan and Korea.

William Rosenberg is a Research Fellow in the Belfer Center for Science and International Affairs of Harvard's Kennedy School of Government. His career spans 14 years as corporate lawyer and energy and environmental consultant, 11 years as real estate developer and venture capitalist, and 13 years of public service. He was appointed to head EPA's Clean Air Program, by President Bush after the '88 election. As part of Roger Porter's working group that drafted, negotiated, and implemented the Clean Air Act Amendments of 1990 ("CAAA"), he was responsible for making market based programs work within EPA's regulatory framework.

Guodong Sun is a Research Fellow in the Belfer Center for Science and International Affairs of Harvard's Kennedy School of Government. He coordinates on the Harvard side the collaborative research and outreach efforts on clean-coal technologies with China Coal Research Institute and Ministry of Science and Technology. He is also the E7 Scholar in Sustainable Energy Development, and Adjunct Research Fellow in the Carnegie Mellon Electricity Industry Center at Carnegie Mellon University. His current research focus on advanced energy technologies, energy strategies, and energy policy for China. He worked for the Energy Research Institute (ERI) of China's State

Planning Commission, where he conducted research, managed research projects, and advised central government on matters of energy and global climate change policy. He holds a bachelor degree in Thermal Turbomachinery and a Master degree in System Engineering from China's Tsinghua University, and a doctoral degree in Engineering and Public Policy from Carnegie Mellon University.

Robert H. Williams is Senior Research Scientist at Princeton Environmental Institute, Princeton University. His research span a wide range of topics relating to advanced energy technologies, energy strategies, and energy policy, for both industrialized and industrializing countries. He leads the Energy Systems Analysis Group at Princeton. He is also involved in a collaborative research project involving Princeton and Tsinghua Universities that is exploring clean energy technologies and strategies for China.

Yunhan Xiao is the Deputy Director of the Institute of Engineering Thermophysics, Chinese Academy of Sciences. He also serves on the Expert Committee for Clean-Coal Technologies in China's National High Technology R&D Program. He is the Chief Scientist of a sub-program on total energy system under China's Basic Technology R&D Program ("973" Program), and advisor to China's Clean Energy Action. His research areas include coal-based poly-generation system, China's energy policy. He holds a PhD degree from Tsinghua University.

Shisen Xu is the Director of the Division of Research and Development in the Thermal Power Research Institute, which is now a research consortium of five China's largest power generation companies. He also serves on the Expert Committee for Clean-Coal Technologies in China's National High Technology R&D Program. Dr. Xu is an expert on coal combustion, coal gasification. He also has many years of experience in R&D management. He holds a PhD degree from Xi'an Jiaotong University.

Fangneng Zheng is a Director of the Division of Energy and Transportation in China's Ministry of Science and Technology. He is in charge of China's R&D efforts for clean-coal technologies.

This workshop report was prepared by Dr. Guodong Sun, largely based on the closing remarks presented by Professor John P. Holdren of Harvard University. The interpretations of the presentations and remarks made in the workshop are of their own. A electronic copy of this report is also available online at http://bcsia.ksg.harvard.edu/energy. Workshop presentations can be made available electronically as well.

Dr. Guodong Sun was the principal organizer of this workshop, in coordination with Energy Technology Innovation Project Visiting Scholar, Dr. Li Wenhua of the China Coal Research Institute. 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, or the collaborative efforts in general, please contact:

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