A Joint Workshop on IGCC & Co-Production and CO_2 Capture & Storage

WORKSHOP REPORT

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Beijing, China

Report on a workshop jointly organized by the Energy Technology Innovation Policy research group of the Belfer Center for Science and International Affairs at Harvard University's John F. Kennedy School of Government and Chinese Academy of Sciences.

The workshop was held at the Beijing Railway Hotel in Beijing, China from May 23-24, 2007.

Introduction and Motivation

Fossil fuels dominate primary energy supply worldwide, even more so in China and the United States. Coal, oil, and gas have fueled world energy growth for 150 years. Energy supply grew 20-fold between 1850 and 2000. Fossil fuels continued to dominate in 2005, with fossil-fuel dependence at 81% for the world, 82% for China, 88% for the United States.

China and the United States are the world's biggest energy consumers and carbon emitters. The United States is the largest energy consumer and the largest carbon emitter in the world. In 2005, its total energy supply was 106 GJ, and total carbon dioxide (CO_2) emissions were 1700 megatons in carbon equivalent (MtC). China was the second-largest energy consumer and the second-largest carbon emitter in the world. Its total energy supply was 80GJ and total energy-related CO_2 emissions were 1400 MtC in 2005. China and the United States are also the largest and the second-largest coal users in the world, respectively.

Coal dominates electricity generation in China, the United States, and worldwide. Coal's share of overall electricity production is about 40% worldwide, about 50% in the United States, and 80% in China. In 2005, coal consumption in the United States was 1,128 million short tons. The electric power sector consumed 1,039 million short tons, accounting for 92% of total coal consumption. Total installed power generating capacity in the United States in 2005 was 978.02 GW. Coal-fired installed capacity was 313.38 GW or 32.1% of total installed capacity, and natural gas-fired installed capacity was 383.06 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 in recent years, and coal was once again the dominant energy source for electricity generation in 2005. That year, the net generation of electricity in the United States 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. In 2006, China's total installed capacity was up to 622 GW, in which thermal installed capacity was 484 GW, accounting for 77.82% of total capacity in China. Coal-fired capacity provided over 95% of total thermal capacity, which was about 460 GW. Electricity generation was up to 2834 billion kWh, of which thermal electricity generation was 2357 billion kWh, accounting for 83.2% of total electricity generation.

High growth in energy use and electricity generation is likely in China, the United States, and the world over the rest of this century, and high fossil-fuel and coal-dependence is also projected by many to continue. The "Reference" case of the International Energy Agency (IEA) provides a standardized projection of energy. In the reference case, world use of primary energy reaches 2.5 times the 2000 level by 2050, and 4 times by 2100. World electricity generation reaches 5 times the 2000 level by 2100. World CO_2 emissions reach 3 times the 2000 level by 2100. China will pass the United States in CO_2 emissions in 2007 or 2008, and will become increasingly dominant thereafter.

The greatest dangers with this "business as usual" scenario are oil and natural gas supply availability or scarcity, air pollution, and global climate change. The considerable uncertainty over oil and natural gas supply can lead to international tension and conflict over access and terms. Additionally, sudden price increases may result in economic damage. Air pollution due to emissions of SOx, NOx, and soot can lead to health problems amongst the population as well as acid rain. However, global climate change is the most difficult of the three big problems. The Earth is getting warmer, and harm from climate change is already occurring. Increased flooding, droughts, heat waves, powerful typhoons & hurricanes, sea-level rise, damage to agriculture & fisheries (and more) result from climate disruption by CO_2, other greenhouse gases, and soot.

High prices and the economic vulnerability associated with oil and natural gas dependence have motivated interest in coal gasification & liquefaction in many countries. Air pollution, acid rain precipitation, and climate change are increasingly generating interest in cleaner coal technologies, including CO_2 capture and sequestration (CCS). Coal will be central to the energy systems of both China and the United States for decades to come, so it is imperative that the two countries find ways to use the coal without irreversibly harming the environment.

Interest in advanced coal technologies has grown very rapidly in China and the United States (and in the UK and Australia) that can reduce conventional pollutants and mercury (Hg) from coal-electric power plants, can co-produce electricity and H_2, can produce liquid fuels from coal, and can capture and sequester a large part of the resulting CO_2.

In this context, the two main goals of the workshop were (1) to explore how to accelerate the demonstration and deployment of IGCC technology in China, and (2) to catalyze the Ministry of Science and Technology (MOST) and Chinese Academy of Sciences (CAS) to consider launching research on carbon capture and storage (both capture technologies and mapping of geologic storage opportunities).

Building on Past Workshops

This workshop is the first workshop sponsored by the following partners: the project on Energy Technology Innovation Policy (ETIP) at Harvard University, MOST, and the Institute of Engineering Thermophysics at CAS. It is built on the past four workshops sponsored by the following partners: ETIP at Harvard University, MOST, and the China Coal Research Institute. Of these, the first workshop was held in October 2002 in Beijing. The second was held at Harvard University in September 2003. The third was held in May 2004 in Hangzhou. The fourth was held at Harvard University in September 2005. The workshop summaries of the major findings from the workshops can be found at http://energytechnologypolicy.org.

Who Participated?

This workshop had 102 invited participants. They included senior government officials, Mr. Cao Jianlin, Xu Jing, Zhang Zhihong, Wu Ping and Mr. Yuchi Jian from MOST, Mr. Li Jinghai, Xiao Yunhan and Mr. Ji Lucheng from CAS. They also included other government officials from The Administrative Center for China's Agenda 21 at MOST, The High Technology Research and Development Center at MOST, Office of National Climate Change Coordination Committee at

NDRC, Office of The National Energy Leading Group, CAS Shanghai Branch, Division of Energy at CAS, and Division of Comprehensive Planning at CAS.

The workshop also convened China’s leading scientists on advanced coal technologies and energy policy, who represented institutions including the Institute of Engineering Thermophysics of the CAS, Xi'an Thermal Power Research Institute Co., Ltd., National Power Plant Combustion Engineering Research Center of China, Dalian Institute of Chemical Physics, Huazhong University of Science and Technology, Institute of Rock and Soil Mechanics, Peking University, Zhejiang University, Harbin Institute of Technology, Tsinghua University, East China University of Science & Technology, Beijing Research Institute of Coal Chemistry, University of Shanghai for Science and Technology, Institute of Coal Chemistry, Institute of Process Engineering, Guangzhou Institute of Energy Conversion, Energy Foundation, and CAS Shanghai Branch.

China’s main power-generation firms including China Huaneng Group, China Huadian Corporation, China Power Investment Corporation, Dongguan Electricity and Chemicals Industry Ltd., coal-mining firms, including Yankuang Group, Shenhua Group, Lu'an Group, manufacture firms including NanJing Turbine & Electric Machinery (Group) Co., LTD., Power Generation Group,Shanghai Electric, Dong Fang Steam Turbine Works, and Shenyang Liming Aero-Engine Group Corporation, also sent representatives to the workshop.

Professor John Holdren, ETIP Director Dr. Kelly Gallagher, and Research Fellows Dr. Ananth Chikkatur, Aleksandra Kalinowski and Zhao Lifeng from Harvard University also participated. We also had representatives from U.S. Department of Energy, Princeton University, Geoscience Australia, the Australian and UK governments, and BP, and Foster Wheeler.

Dr. Xiao Yunhan, Deputy Director-General of the Bureau of High Technology Research and Development at CAS, the head of the National Joint Expert Group on IGCC and Co-Production Demonstration Engineering for MOST, took the main responsibility for organizing the workshop.

Some Key Insights from the Workshop

1. *Alliances for IGCC and Co-Production*

- Government-industry alliances are working well in the United States (FutureGen) and Europe (and starting to work in China), bringing together the complementary skills and resources of the private and public sectors.
- International participation in such alliances is increasing and is very promising as a way to share insights, costs, and risks, and to accelerate progress in all of the partner countries.
- In China, the alliance for IGCC and Co-Production will include academia as well as government and industry, since Chinese firms lack sufficient innovation capabilities.
- Government roles in the alliances:
  a) To advance technology, and not to just replicate existing technology designs and configurations. And one of government goals is to achieve subsequent commercial deployments…not just to build and operate one plant. To establish

program goals, issue the request for proposal, evaluate and select proposals, and have technical oversight of selected projects.

b) To provide co-funding to buy-down the technical and financial risks associated with technology advancements. It is important to note that government co-funding is used to assist industry in advancing the technology. The Government, generally, does not acquire or take ownership of the facility. The government has a stake in completing the mutually agreed work scope, and can step in if the industry partner walks away. To provide other incentives (e.g., tax credits, loan guarantees).

c) Nor does the government want to take an ownership position in the technology or intellectual property. However, the government does want to ensure broader applicability. One example might be requiring the facility to utilize different coal types, and not just local coal. And the government disseminates basic, non-proprietary information.

- Industry roles in the alliances:
  a) To submit qualifying proposals, which advance technology. But, industry has flexibility in structuring the project. Some projects are led by the power company; others are led by the technology developer; and a few by other organizations such as an engineering company or a coal mining company.
  b) To co-fund the projects.
  c) To design, build and operate the facility. To take the ownership of the facility and intellectual property.
  d) To implement subsequent commercialization. If, however, they achieve much commercial success, then the government may require some repayment of Government co-funding.
- The Chinese alliance for IGCC and co-production is intended to coordinate RD&D and provide a platform for international cooperation.
- There are very large benefits to be obtained from public-private partnerships.

2 . *Status and Progress of IGCC and Co-Production*

- Six IGCC demonstration plants are operating worldwide, two in the United States.
- IGCC offers similar efficiency to Ultra-Super-Critical Pulverized Coal (USCPC) plants. USCPC is cheaper, but IGCC offers better control of conventional pollutants, lower water demand, reduced solid waste, the possibility of H_2 co-production, and lower cost to add CO_2 capture (to a new plant). With current technology, cost of electricity from IGCC with carbon capture appears to be less than from PC with carbon capture (comparing new plants built from outset to do this). Cost per ton of avoided CO_2 emission is likewise lower for IGCC with CCS.
- Deployment of IGCC has been slow because of high cost, complexity similar to a chemical plant, lack of CO_2 policy, and (until recently) cheap natural gas.
- Selected commercial IGCC projects in the United States
  a) AEP – one or more 600 MW commercial plants
  b) Working with GE-Bechtel Alliance
  c) Three proposed sites (Ohio, W. Virginia, Kentucky)
  d) Southern Illinois Clean Energy Center – 630 MW

e) Taylorville Energy Center – 660 MW

f) Duke Energy – 600 MW

g) Mesaba -- 600 MW IGCC

h) Rentech Royster Clark – 600 MW

i) BP-Edison Mission, petcoke-based 500 MW IGCC and CCS with EOR

j) Orlando Gasification – 285 MW KBR Transport gasifier

- China's overall goal is to form clusters of the advanced coal technologies, support the development of China's energy equipment manufacturing industry, and achieve the efficient, clean, and affordable use of coal.
- Goals by Stages in China:
  a) 2010
    - Commercial demonstration power plant
    - Coal gasification based co-production of oils and power system
  b) 2020
    - Installed capacity of IGCC to reach 20,000MWe
    - Synthetic oil and chemical products substitute 50 million tons of crude oil on annual basis
    - Conversion of coal into hydrogen and electricity, and near-zero emission of CO_2
- Technology Development Strategies:
  a) Energy System Integrated Innovation
  b) Step-by-step Strategy
    - Mature individual technologies integration
    - Key technologies breakthrough
    - Near zero emission technologies
  c) Combined Strategy
    - State guide and enterprises voluntary participate
    - Industrial development and technological innovation
    - International cooperation and self creation
- Supported by key technology innovations made by IET, Yankuang has built the first coal gasification-based co-production system with an output of 60MWe and 240 thousands tonnes of methanol per year. The Yankuang plant was a breakthrough for IGCC and co-production in China. This demonstration project came into operation in April 2006, and its success has laid the foundation for long-term development of IGCC and co-production in China.
- A variety of pilot and demonstration projects around China with both corporate and government support are underway or planned pursuant to the overall goal.
  a) Yankuang Group will construct a new co-production plant with capacity of 200 MWe and one million tonnes of synfuel per year.
  b) The Lu'an Group will build a co-production demonstration plant of 60 MWe and 160 thousands tonnes of synfuel per year.
  c) China Huaneng Group will build a 250MWe IGCC demonstration plant in Tianjin.

d) China Huadian Corporation will build a 200MWe IGCC power plant in Hangzhou.
e) Dongguan Electricity and Chemicals Industry Co., Ltd. will build a 200MWe IGCC power plant and retrofit a 120MWe combined cycle power plant into IGCC.

- Research, development, and demonstration of these technologies has been growing in many countries, but much more work will be needed to clarify the full potential.

3. *Carbon Capture and Storage*

- Options for carbon capture in coal-burning power plants are (a) pre-combustion capture of the CO_2 in IGCC plants with shift reaction to H_2 and CO_2; and (b) post-combustion capture in PC power plants.
- Further development of PC/post-combustion options conceivably could close the cost gap, and more R&D should be done to pursue this. Promising options include oxy-firing, chilled-ammonia absorption.
- Until the CO_2 price or policy dictates CO_2 capture and storage, most new plants will be PC. It's important that these be built in a way that allows later retrofit for CO_2 capture when price or regulation makes this attractive.
- Regulations specifying the fraction of coal-electric-generation CO_2 to be sequestered could be considered to get started.
- Fischer-Tropsch coal-to-liquids technology lends itself to low-cost CO_2 capture (~$10/t$CO_2$) and should not be deployed without this component.
- Storage options are oceanic (large capacity but least understood), terrestrial (moderate capacity), and geologic (medium to large capacity).
- Best geologic options, based on current understanding, are enhanced coal bed methane recovery (ECBM), enhanced oil recovery (EOR), depleted oil and gas fields, unmineable coal seams, and saline reservoirs. The largest capacity worldwide is in saline reservoirs.
- Enhanced recovery of oil and gas and enhanced coal-bed methane production bring economic benefits that offset sequestration costs, thus are particularly attractive for early implementation.
- More research is needed on all technical aspects of sequestration -- fundamental processes (e.g., pore behavior), leakage rates and safety, storage capacities, and measurement-monitoring-verification -- as well as on policy aspects including permitting and liability.
- Unlike technology transfer, "geology can't be transferred"; thus geologic assessments of sequestration potential must be done for every region with large CO_2 sources. These assessments are large tasks and for most regions have barely begun.
- CCS will not occur on the needed scale until strong policies make it attractive or require it.

4. *The Role of Policy and International Cooperation*

- Both the Chinese and U.S. governments are funding research in advanced clean-coal technologies such as IGCC and co-production technologies.

- Appropriate policies and incentives are needed to push advanced coal technologies (IGCC and co-production) into the marketplace.
- Incentives and policies related to coal in the United States:
  a) The National Commission on Energy Policy December 2004 recommendations on advanced coal technologies:
     Support for first-mover sequestration-capable IGCC facilities is appropriate given this technology's potential for simultaneously addressing economic, environmental and energy security concerns. Thus, the Commission recommended that the federal government:
     i. Provide up to $4 billion over ten years to support the early deployment of roughly 10 GW of sequestration-ready IGCC plants.
     ii. Provide support for the commercial-scale demonstration of geologic carbon storage at a variety of sites with an investment of $3 billion over ten years.
  b) Energy Policy Act of 2005:
     i. The Act includes a number of provisions for tax credits, loan guarantees, loans, and direct grants. These incentives are available for existing, under development, and newly-proposed clean coal and gasification projects.
     ii. The Act enables the U.S. Department of Energy to provide US$200 million annually for nine years, from 2006 to 2014, as loan guarantees, loans, and direct grants, to gasification and other clean coal project developers for a total of US$1.8 billion. Of this amount, at least 70 percent must be used for gasification projects.
     iii. There are 'carve-outs' for specific types of projects to receive direct grants. Portions of the funds must be allocated to projects in the Upper Great Plains, Alaska, and the Western United States. A minimum of five of these projects must use petroleum coke.
     iv. The Act establishes tax credits for up to US$1.3 billion. Of these amounts, up to US$800 million is for IGCC projects, and US$500 million for other advanced coal-based projects. The tax credit for gasification projects for any taxable year is 20 percent of the qualified investment, while the credit for other advanced coal-based project is 15 percent.
  c) In addition, the DOE Carbon Sequestration Program has committed $450 million over the 10 years starting FY2007 to seven regional partnerships to validate capture, transport, injection, and long-term storage of CO_2.
  d) The National Commission on Energy Policy updated its recommendations for climate-change policy in April 2007:
     i. Recommended a mandatory, economy-wide program of greenhouse-gas restraints based on emission caps implemented with tradable emission permits.
     ii. Emissions caps to be based on returning to 2006 emission levels by 2020 and reducing to 15% below 2006 levels by 2030.
     iii. Government sets "safety valve" (ceiling) on permit price, starting in 2012 at $10 per tonne of CO_2 and escalating at 5% per year in real terms.
     The safety valve means that, if the market price reaches this value, the government sells as many additional permits as are demanded at that price.

e) The National Commission on Energy Policy April 2007 recommendations on coal-technology policy:
   i. Emphasize actual deployment of carbon capture and storage (CCS). Projects with CCS should get bonus allowances under a GHG trading program that are at least equal in value to the renewable energy production tax credit.
   ii. Limit public funding or subsidies for any new coal plants going forward to projects that actually include CCS. CCS must be included from the outset in any taxpayer-supported coal-to-liquids projects.
   iii. Explore carbon capture options for non-IGCC plants.
   iv. Direct EPA to develop effective regulatory protocols for long-term carbon storage as soon as possible (recognizing that midcourse corrections will likely be needed as experience is gained).
   v. Ensure that new coal plants built without CCS are not "grandfathered" (i.e., awarded free allowances) in any future GHG trading program.

- Incentives and policies related to advanced coal in China
  a) There is a need for formulation of policy to regulate industry development and deployment of IGCC and CTL.
  b) The Chinese government already provides cleaner coal technology projects with preferential fiscal policies on a case-by-case basis, but there is no comprehensive policy at this time.
  c) China, as a developing country, has not committed itself to a quantitative target in CO_2 emission reductions. So, currently, there are no policies targeting CO_2 reduction exclusively although most of the efficiency policies and programs have the effect of reducing CO_2. Some research has been done about possible carbon policies appropriate for China's situation.
- There are very large benefits to be obtained from increased international cooperation on both the technical and the policy aspects.
- It was noted that there are many common interests between the United States and China with respect to coal, and that the collaboration should be strengthened between the United States and China on this issue.

Appendix 1: Workshop agenda
Appendix 2: List of participants

Group picture

2007 International Workshop on
IGCC & Co-production and CO_2 Capture & Storage

May 23-24, 2007

Railway Hotel, Beijing, China

Agenda

Wednesday Morning, May 23 2007, Conference Room 7, Railway Hotel

Development and Deployment of IGCC and Co-Production Technologies in China

	Chaired by Zhihong Zhang, Vice Director-General of the Department, MOST
8:30-8:40	**Opening remarks from Prof. Jianlin Cao, Vice Minister of MOST**
8:40-8:50	**Opening remarks from Prof. John P. Holdren, Harvard University**
	Session 1: The Roles of the Alliance in the Development of IGCC and Co-Production, Chaired by Zhihong Zhang, MOST
8:50-9:20	Presentation 1**: Jing Xu,** MOST, Brief Introduction to China's Participation in FutureGen
9:20-9:50	Presentation 2: **Thomas A. Sarkus**, DOE, The Roles of the Industrial Alliance in the United States
9:50-10:20	Presentation 3: **Iain W. Wright**, BP, BP's Views on Industrial Alliances in Europe and the United States Regarding Gasification and CCS
10:20-10:40	Tea Break
10:40-11:10	Presentation 4: **Yunhan Xiao**, the National Joint Expert Group on IGCC and Co-Production Demonstration Engineering, IGCC and Co-Production in China
11:10-12:10	Discussion
Questions for discussion	1. Should an alliance be set up in China? 2. What role could it play for the development and deployment of IGCC and co-production technologies? 3. How should it be structured?

Wednesday Afternoon, May 23 2007, Conference Room 7, Railway Hotel

	Session 2: Status and Prospect of IGCC and Co-production, Chaired by Yunhan Xiao
14:00-14:20	Presentation 5: **Qiwen Sun**, Yankuang Group, The Development of Million Tonnes Oils Co-production System
14:20-14:40	Presentation 6: **Yongwang Li**, Synfuels China Co.Ltd., Synfuels China and Its Development in Advanced CTL Process Technologies
14:40-15:00	Presentation 7: **Shisen Xu**, Xi'an Thermal Power Research Institute Co.,Ltd., GreenGen-IGCC Demonstration Plant
15:00-15:20	Presentation 8: **Jianling Deng,** China Huadian Corporation, Progress of 200MW IGCC Demonstration Plant
15:20-15:40	Presentation 9: **Jianfen Deng**, Dongguan Electricity and Chemicals Industry Co.,Ltd., Research，Development，Demonstration and Deployment of IGCC in Dongguan
15:40-16:00	Presentation 10: **Zhongmin Liu**, Dalian Institute of Chemical Physics, CAS, Coal to Chemicals
16:00-16:20	Tea Break
16:20-16:50	Presentation 11: **John P. Holdren** and **Ananth Chikkatur**, Harvard University, Status and Progress of IGCC and Co-Production Technology in the United States
16:50-17:50	Discussion
Questions for discussion	1. What are the remaining IGCC and co-production technical challenges? 2. What policies would spur faster deployment of IGCC and co-production in China? 3. What incentives are needed to develop IGCC in China?

Thursday Morning, May 24 2007, Conference Room 7, Railway Hotel

Towards a Research Agenda on Carbon Capture, Storage and Utilization in China

	Session 3: CO_2 Capture Technology, Chaired by John Bradshaw
8:30-9:00	Presentation 12**: Zhaohui Liu**, Huazhong University of Science and Technology, Status of Oxygen-Fuel Combustion Technology in China
9:00-9:30	Presentation 13: **Zhenzhong Li,** National Power Plant Combustion Engineering Research Center of China, Status of Chemical Absorption Technology in China
9:30-10:00	Presentation 14: **Wendong Tian,** Institute of Engineering Thermophysics, CAS, Research on CO_2 Capture by Oxygen Transfer Material and Carbon Transfer Material
10:00-10:20	Tea Break
10:20-10:50	Presentation 15: **Robert H. Williams,** Princeton University, Status of CO_2 Capture Technology in United States
10:50-11:20	Presentation 16: **Jon R Gibbins,** Imperial College London, UK， An Overview of UK Approaches to CCS
11:20-12:20	Discussion
Questions for discussion	1. What are the research needs and gaps for carbon capture technologies in China? 2. What are the barriers for carbon capture technology development in China? 3. What are the top priorities for carbon capture technology development?

Thursday Afternoon, May 24 2007, Conference Room 7, Railway Hotel

	Session 4: CO_2 Storage and Utilization Technology, Chaired by Kelly Sims Gallagher
13:30-14:00	Presentation 17: **John Bradshaw,** Australian Government, Geoscience Australia, Review of Research Efforts on Carbon Storage Internationally
14:00-14:30	Presentation 18**: Xiaochun Li**, Institute of Rock and Soil Mechanics，CAS, Status and Potential of CO_2 Storage in China
14:30-15:00	Presentation 19: **Aleksandra Kalinowski,** Harvard University, Carbon Storage Mapping in United States and Australia
15:00-15:20	Tea Break
15:20-15:40	Presentation 20: **Dongxiao Zhang**, Peking University, Geological Carbon Sequestration
15:40-16:00	Presentation 21: **Jiangping Ye,** China United Coalbed Methane Corp.Ltd , Prospects of CO_2 Enhanced Coalbed Methane Recovery and Sequestration in Coal Seams
16:00-17:00	Discussion
Questions for discussion	1. What are the research needs and gaps? 2. What are the barriers? 3. What are the top priorities?
17:00-17:30	Chaired by Yunhan Xiao, Vice Director-General of the Bureau, CAS **Closing Remarks** Richard Heap, Manager of the Energy and Climate Change, The Royal Society Prof. John P. Holdren, Harvard University Prof. Jianlin Cao, Vice Minister of MOST

List of Participants

No.	Category	Affiliation	Name	Occupation
1	Officials	MOST	Jianlin Cao	Vice Minister
2		Department of Development Planning, MOST	Jing Xu	Deputy Director-General of the Department

3		Department of High and New Technology Development and Industrialization, MOST	Zhihong Zhang	Deputy Director-General of the Department
4		Division of Energy and Transportation, MOST	Ping Wu	
5		Division of Energy and Transportation, MOST	Jian Yuchi	
6		The Administrative Center for China's Agenda 21, MOST	Jiutian Zhang	
7		The High Technology Research and Development Center, MOST	Hejian Ou	
8		The High Technology Research and Development Center, MOST	Dongmei Shi	
9		The High Technology Research and Development Center, MOST	Lin Wang	
10		Office of National Climate Change Coordination Committee, NDRC	Cuihua Sun	
11		Office of The National Energy Leading Group	Ruipeng Wu	
12		CAS	Jinghai Li	Vice President
13		CAS Shanghai Branch	Zhiyuan Zhu	Vice President
14		Bureau of High Technology Research and Development, CAS	Yunhan Xiao	Deputy Director-General of the Bureau
15		Division of Energy, CAS	Lucheng Ji	
16		Division of Energy, CAS	Hongmei Cao	
17		Division of Energy, CAS	Qing Tang	
18		Division of Energy, CAS	Ling Yuan	
19		Division of Comprehensive Planning, CAS	Lixia Jiang	
20	International Participants	Harvard University	John P. Holdren	
21		Harvard University	Kelly Sims Gallagher	
22		Harvard University	Ananth Chikkatur	
23		Harvard University	Aleksandra Kalinowski	
24		Harvard University	Lifeng Zhao	
25		Department of Energy	Thomas A. Sarkus	
26		Princetion University	Robert H. Williams	
27		Geoscience Australia	John Bradshaw	

28		the (Australian) Department of Industry, Tourism, and Resources.	John Karas	
29		BP	Iain W. Wright	
30		Imperial College London	Jon R Gibbins	
31		Imperial College London	Jia Li	
32		The Royal Society	Richard Heap	
33		Foster Wheeler Energy Ltd	Tim Bullen	
34	Chinese Speakers	Yankuang Group	Qiwen Sun	
35		Synfuels China Co.Ltd.	Yongwang Li	
36		Xi'an Thermal Power Research Institute Co.,Ltd.	Shisen Xu	
37		China Huadian Corporation	Jianling Deng	
38		Dongguan Electricity and Chemicals Industry Ltd.	Jianfeng Deng	
39		Dalian Institute of Chemical Physics	Zhongmin Liu	
40		Huazhong University of Science and Technology	Zhaohui Liu	
41		National Power Plant Combustion Engineering Research Center of China	Zhenzhong Li	
42		Institute of Engineering Thermophysics	Wendong Tian	
43		Institute of Rock and Soil Mechanics	Xiaochun Li	
44		Peking University	Dongxiao Zhang	
45		China United Coalbed Methane Corp. Ltd	Jianping Ye	
46	863 Experts	Beijing Research Institute of Coal Chemistry	Minghua Du	
47		Harbin Institute of Technology	Shaohua Wu	
48		University of Shanghai for Science and Technology	Zhongxiao Zhang	
49		Institute of Coal Chemistry	Yitian Fang	
50		Dalian Institute of Chemical Physics	Shudong Wang	
51		Shen Hua Group Corporation, Limited	Xiangkun Ren	
52		Xi'an Thermal Power Research Institute Co., Ltd.	Yi Zhao	
53		Tsinghua University	Qiang Yao	
54	the National Joint Expert Group on IGCC	Zhejiang University	Zhongyang Luo	
55		NanJing Turbine and Electric Machinery (Group) Co., LTD.	Weining Liu	

56	and Co-Production Demonstration Engineering	East China University of Science and Technology	Fuchen Wang	
57		Power Generation Group, Shanghai Electric	Yigong Zhou	
58		Tsinghua University	Ningsheng Cai	
59	Representatives from Industry	Yankuang Group	Xin Wang	
60		Yankuang Group	Jun Li	
61		Lu'an Group	Xingbin Liu	
62		Lu'an Group	Xiang Guo	
63		China Huadian Corporation	Dongxiao Zhang	
64		China Huadian Corporation	Xinrong Yan	
65		China Huadian Corporation	Han Qiu	
66		China Huaneng Group	Shidong Ji	
67		Shen Hua Group Corporation, Limited	Feng Yang	
68		Global Research - Shanghai GE	Wenhua Li	
69		NanJing Turbine and Electric Machinery (Group) Co., LTD.	Mabao Lou	
70			Jiaqiang Yang	
71			Shimin Zhang	
72		Dong Fang Steam Turbine Works	Lijin Zhao	
73		Shenyang Liming Aero-Engine Group Corporation	Kejie Chen	
74		China Power Investment Corporation	Guanghua Li	
75			Jianhua Yao	
76			Jiandong Li	
77			Jinchuan Lu	
78			Qizhao Li	
79			Yamin Hu	
80	Representatives from CAS	Institute of Engineering Thermophysics	Wei Qin	
81			Junqiang Zhu	
82		Dalian Institute of Chemical Physics	Yiming Cao	
83			Liang Wang	
84			Xuelun Hong	
85			Sheng Wang	
86		Institute of Coal Chemistry	Yizhuo Han	
87			Wei Wei	
88		Institute of Process Engineering	Guangwen Xu	

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90			Huiquan Li	
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This workshop report was prepared by Dr. Lifeng Zhao and drew upon the summary presentation by John P. Holdren. The interpretations of the presentations and remarks made in the workshop are the author's alone. An electronic copy of this report is also available online at http://energytechnologypolicy.org.

Dr. Yunhan Xiao was the principal organizer of this workshop, in coordination with Dr. Kelly Sims Gallagher of ETIP at Harvard University, and ETIP Fellow Dr. Lifeng Zhao.

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