Asia-Pacific Economic Cooperation

APEC Expert Workshop on Innovative Systemic Approaches to Enhance Coal-Fired Power Generation Efficiency

EWG 19 2013A

Final Report

APEC Energy Working Group Expert Group on Clean Fossil Energy May 2015

APEC Expert Workshop on Innovative Systemic Approaches to Enhance Coal-Fired Power Generation Efficiency

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Content

I Introduction

This Report is the final report for the APEC project EWG 19 2013A: APEC Expert Workshop on Innovative Systemic Approaches to Enhance Coal-Fired Power Generation Efficiency. This report describes the summary of workshop and CCT Deployment.

1.1 Project Background

The global average net efficiency of coal-fired power plants is below 35%; however, technological advances have enabled coal-fired power plants deploying ultra-supercritical steam (USC) cycles with full environmental controls to achieve up to around 45% (with a resulting average coal consumption of about 280 g/kWh). To put this in perspective, the average coal consumption in China – the world's largest consumer of coal – was 326 g/kWh in 2012, and was substantially lower (i.e., more efficient) than in other developing APEC economies. China's level has been achieved after a more than decade of installing state-of-the-art coal-fired power plants, including many USC units, which is just now happening in other economies. If the global average net efficiency of coal-fired power generation can improve to 45%, CO_2 emissions can be reduced from 1200 gCO_2/kWh to 780 gCO_2/kWh – a 36% reduction. Also, new plant designs using advanced USC steam conditions – made possible by using new higher temperature-rated (>700^oC) metals, can exceed 49% net efficiency.

APEC funding was approved during the second round of 2013 for the APEC/EGCFE project EWG 02/2013A: *An APEC Initiative for Deploying Advanced Clean Coal Technologies*. Its objectives are to assess plans for new coal-based energy facilities in several developing APEC economies; identify the technical, economic and institutional challenges limiting near-term adoption of clean and efficient coal technologies; highlight government policies and incentives needed to accelerate advanced CCT deployment; suggest best practices for application to new and existing power plants; and identify APEC efforts needed to promote CCT deployment.

This 3-day workshop will interface with the recently initiated APEC/EGCFE advanced CCT deployment initiative project (EWG 02/2013A) and will provide additional input and information of value to the final report of that project. The workshop will share proven results of various innovative technologies and best practices, including low-cost measures that are applicable to nearly every coal-fired power plant, to enhance power generation efficiency, reducing coal consumption and CO_2 emissions.

1.2 Objective

Develop workshop materials, identify and arrange expert speakers, organize and hold a 3-day workshop, including site visit if possible to coal-fired power plant employing state-of-the-art technologies and best practices, to share experiences in for efficiency enhancement and in ensuring a safer and more secure power grid in the event of emergency supply disruptions.

Discussions on ensuring a more secure power grid in the event of emergency supply disruptions will be included in the workshop, to contribute to the APEC Energy Security Initiative (ESI) − the principal mechanism through which the EWG addresses the short- and long-term energy security challenges in a sustainable manner in APEC. The ESI comprises a series of short-term measures to respond to temporary energy supply disruptions and longer-term policy responses that are practical and achievable to address the broader challenges facing the region's energy supply. More efficient generation will contribute to longer-term goals by freeing resources for other needs, including grid upgrading/expansion, and building additional generating facilities (including renewable energy). It will make more coal available to other generators, and reduce coal imports by some economies (which will improve their balance of trade), etc.

1.3 Scope of Works

The project was conducted by a consultant team in close coordination with the APEC project steering committee (PSC) charged with the project EWG 02/2013A. Workshop topics include:

- Information on state-of-the-art technology demonstrations and deployments aimed at lower-emission power generation through efficiency enhancement.
- Applicability and transferability of these technologies to existing and future coal-fired power plants in regions where the energy-mix is dominated by coal.
- Systemic and holistic approaches to enhance coal-fired power generation efficiency through innovations in optimizing operating procedures and residual thermal resource recycling.
- Provide timely input to the finalization of the EWG 02/2013A project on advanced CCT deployment.

Government and industry experts were engaged via the PSC and the selected consultant, and appropriate speakers at the workshop identified. Also, EWG delegates has been invited to identify key government and industry representatives in their economies, some of whom presented on either their needs in this area or their work in improving the efficiency of coal-fired power generation in their economy.

Some activities in other international forum on clean coal technologies may have relevance for this project. An example of such activities is the work in progress in the International Energy Agency on high-efficiency, low-emissions (HELE) technologies. The project proponent contacted with the relevant IEA Secretariat officials to ensure an appropriate level of coordination and possible participation.

The APEC consultant team is encouraged to make contact with appropriate IEA and GSEP experts during the course of the work, to exchange information, avoid unnecessary duplication of effort, sharpen the focus, and advance the project towards achieving its objectives.

Representatives of these organizations were invited to participate in the work of the PSC.Industry were potentially be an important player in CCT deployment. Early in the project, it was useful for consultant to interface with relevant coal technology and power generation industry representatives to identify potential expert input and participation from industry to contribute to the project’s success.

The consultant was required to coordinate with the PSC and other EGCFE representatives, especially in the host economy, to identify and select appropriate participants with the right skills sets and expertise and ensure that there is a good mix of both developed and developing economy

participants. The consultant, including many partners, have identified many of the workshop participants. The PSC and EGCFE economy representatives also identified governmental and private sector participants to the workshop. Participants with the right expertise, position, and seniority in both government and industry who would be able to put their learning into practice were targeted to participate in the workshop.

This final report will also recommend ways that this project's results, together with those of the ongoing EWG02/2013A project and of earlier related EWG projects in this area, should be tracked/measured and collected; and what mechanisms might be suggested to collect and analyze this information systematically. Of particular interest in this regard would be any capacity building developments and commercial activities in developing APEC economies that these CCT projects may stimulate.

1.4 Milestones

	Milestones and Deliverables	Due Date (Plant)	Due Data (Actual)
1	Organizational plan for workshop with proposed timetable and agenda	October 2014	October 2014
2	Detailed programs for the workshop including names of confirmed speakers	December 2014	December 2014
3	Workshop successfully held	January – March 2015	March 2015
4	Final report including recommendations for follow-on work	May 2015	May-June 2015

II Workshop Preparation Summary

2.1 Background

According to the RPF (EWG 19 2013A) requirements for the APEC Expert Workshop on Innovative Systemic Approaches to Enhancing Coal-Fired Power Generation Efficiency, China Energy Research Society and Beijing LAD Electric Power Technology Co., Ltd. submitted the report (Bidding Document) on organizing the 2015 Workshop in Shanghai to the APEC Expert Group on Clean Fossil Energy (EGCFE) on 23 February 2014, elaborating the following:

Given climate change and environmental damage, reducing energy consumption and emission is among top priorities in the global agenda. The Chinese government is committed to reducing its carbon emission intensity by 40% from 2005 to 2020, which will bring the carbon emission intensity in China to 45% in 2020. Meanwhile, the total emission of CO_2 will decrease year by year after reaching its peak in 2030.

As the top energy source in the world, coal contributes the largest CO_2 emission and air pollution. Being the biggest consumer of coal, coal-fired power plants must improve energy efficiency to survive and develop along a green path.

By the end of 2014, the total power generated in China amounts to 1.36 billion KW or 5.5233 trillion kWh. Coal-fired power generators account for over 70% of the total number of generators, and coal-fired power accounts for 80% of the total. The average coal consumption is 8834 BTU/kWh.

With the development of renewable resources, it is expected that coal-based power will be reduced. However, China is an exception as coal accounts for nearly 90% of primary energy source that generates the total power of over 1.2 billion kW. In this case, it is simply unrealistic to find any other alternative source to provide such huge electric power. In the foreseeable future, coal-fired power will remain to be the major energy source in China. Thus, it is crucial for the coal-fired power industry to lower emission and reduce energy consumption for sustainable development and environmental protection. Currently, there are three main approaches to reduce emission in the sector:

a) Higher steam parameter (700℃. A 700℃ single reheat set can improve efficiency by 3-3.2% than a 700℃ counterpart, while a 700℃ double reheat set can improve efficiency by 5%. Now many countries are working on this regard. Given limit in materials technologies, high cost and other hurdles, it is hard to commercialize high efficiency supercritical 700℃ units in the short run. At present, CGDC is building the 2nd Phase of Taizhou Power Plant, which employs double reheat high efficiency supercritical technologies, with a temperature at 620℃ through 10-order regenerative heating of extraction steam. The power generators can reach an efficiency of 47.94%, with the coal consumption at 7117 BTU/kWh and CO_2, CS_2, NO_x, and dust emission reduced by 5%. The Waigaoqiao No.3 Power Plant of Shenergy pushed forward with a patented innovation of high/low axis positioning steam turbine power generator. The two-axis generator features the high (middle) axis above the furnace close to the terminal header with overheater and reheater and the (middle) low axis in normal layout, thus eliminating most of expensive high temperature high pressure steam pipes and reducing the resultant pressure and heat loss. According to the thermal balance tests by Siemens, with 600℃ steam parameters, double reheat, and high/low layout, the thermal loss can be further reduced by 5% compared with normal single reheat layout. If combined with the mature energy efficiency innovation of the #3 power plant, the efficiency can reach an unprecedented level of 49%, i.e., 600℃ materials and equipment providing efficiency levels of 700℃ technology.

b) With IGCC technology, Mitsubishi Heavy Industry launched the highest efficiency exemplary units in the world in September 2007. Tests showed 250MW IGCC efficiency at 42.9%, and full workload efficiency at 42%. In 2013, CHNG launched Tianjin IGCC exemplary power plan with three projects passing national certification (250MW IGCC system experiment and

modeling, 2,000-ton/day dry pulverized coal pressure-gasification, and IGCC integrated production system test and control), marking a new level of integrated coal gas and steam recycling power generation in China. However, the project is hindered by high investment and operation cost. There is still big room to improve for sustainable development and operation.

c) Existing technology optimization and partial innovation based on current steam parameters, materials, and cost constraints. This is to leverage all the potential of the production process and try to find a lost cost/risk and fast track towards efficiency improvement. Some Chinese coal-based power plants, as represented by No.3, are doing well along this path. Take No.3 for an example. GM Feng Weizhong is a veteran in electric power innovation, who has produced several globally leading technologies in the coal-based power sector. He has worked hard towards technological breakthroughs with new designs and professional improvement. With new project completion and production online, he has carried out 12 globally unprecedented research projects and 6 nationally leading research projects. He holds 9 patents. #3 has carried out a range of innovative projects, including new sealing, zero energy consumption desulfurization, general heat recycling, elastic heat recycling, SPE control, etc, pushing the energy efficiency envelope along the way. In 2013, the coal-based power generation efficiency reached 7639.5 BTU/kWh, a leading achievement in the world. No.3 has done miracles in terms of clean use of coal, with dust emission at11.63mg/m^3,SO_2 at 17.71 mg/m^3, and NO_x at 27.25mg/m^3, all better than the national emission thresholds. The No.3 experience shows that innovation holds bigger potential for higher efficiency and lower emission and even coal-based power plants can be green.

Thanks to the effective coordination of CERS, Shenhua and CR-Power will gradually implement No.3 innovative technologies in their power plants with over 100 million kW capacity under the technological cooperation agreement with Shenergy. This marks the biggest project for energy efficiency and lower emission ever conducted in the world and will exert a huge impact on the industry both at home and abroad.

An APEC Initiative for Deploying Advanced Clean Coal Technologies was approved, providing funding for the second round of the project EWG 02/2013A in 2013. The Initiative is aimed to assess plans for new coal-based energy facilities in several developing APEC economies, identify technical, economic and institutional challenges to near-term adoption of clean and efficient coal technologies, highlight government policies and incentives to accelerate advanced CCT deployment, suggest best practices applicable to new and existing power plants, and identify APEC efforts to promote CCT deployment. Interacting with the project EWG 02/2013A in the context of advanced CCT deployment, the Workshop focuses on power plant engineering, and hopes to provide additional valued input and information to the final report of that project. While promoting innovative technologies and experiences in the coal-based power plants, this APEC EWG expert workshop has helped improve efficiency and reduce emission, potentially making the coal-based plants as efficient

as their gas-based counterparts. In the future, the workshop will demonstrate the impact on coal-based power plants in lower emission and improved energy efficiency.

2.2 Workshop Teams

2.2.1 Consultant Group

To organize this forum, the organizer has established a Forum Expert Consultant Group consisting of 14 people:

Zhang Cunhao: CAS academician, TWAS fellow, former NNSFC chair, member on CAS Academic division presidium, chair of CAS chemical division, CAST vice chair, member on State Council Academic Degree Commission, and member on IUPAC executive board; leading physicist and chemical scientist; founder of the Chinese chemical laser industry; one of the founders of Molecular Reaction Dynamics research in China.

Li Jinghai: CAS academician, TWAS fellow, SATW overseas fellow, RAE overseas fellow; Chinese Society of Particuology Chair, Vice Chair of CERS, member of editorial board of *Powder Technology* and *Advances in Chemical Engineering*, and international advisor to *Chemical Engineering Science*and *Advanced Powder Technology*; AASA President, 2006-2010; Vice Chair of CAS; Vice Chair of the 8th national congress of CAST.

Ni Weidou: CAE academician, Power Machinery and Engineering expert, and Honorary Doctor of Science of Russia; Former VP of Qinghua University; Current Vice Chair of Beijing Science and Technology Association; Member on CCICED; Chinese side chair of the energy strategy and technology group; leading expert in China in the areas of thermal turbine system and thermal system modeling, simulation, control, and diagnostics.

Huang Qili: CAE academician, electric power expert, and standing member on CSEE, CEI, and CSPE. He contributes key research results in high efficiency and clean combustion as well as pollution control, and was in charge of 71 major technological upgrade projects. His key research results are applied in 20 projects.

Qin Zhongyi: Prof-level senior engineer, former chief engineer of the energy ministry, former deputy GM of Sanxia Group, and former CERS standing Vice Chair

Zhou Dadi: research fellow, CERS standing Vice Chair, energy economics committee chair, China Sustainable Development Institute fellow, Beijing Energy Association Chair, member of energy committee under the 863 initiative, member of the 2nd science committee sponsored by UNEP endowment, chair of the editorial board of *China Energy* magazine, and founder of Beijing Energy Efficiency Center; Chair of China Climate Change Working Group. Member of 2nd Global Environment Science Committee by UNEP; In 2000, awarded by OECD for international climate technology movement.

Yu Xinyang: electric power expert, CERS secretary-general, and former chief engineer of State Electricity Regulatory Commission

Wang Like: Vice Chair of CEPRI, Prof-level senior engineer, IEEE Senior Member, IEC PC118 Secretary, Senior member of CSEE, former Vice Chair of State Grid Nanjing Automation Institute, Chair of State Electric Power Automation Engineering Institute, and director of the National Electric System Automation Engineering Research Center.

Huang Xiang: Prof-level senior engineer and CHD Engineering chief engineer. His main researches include fire power plan energy efficiency, clean combustion, reduced waste, distributed power, wind/hydro/solar power generation, etc. He is the Vice Chair and Secretary General of the Auxiliary Electric Power Committee of China Electrical Equipment Industrial Association, and serves as the editor-in-chief of *Huadian Technologies*.

Feng Weizhong: Shenergy GM, #3 President, and Prof-level senior engineer. His main research includes supercritical power generation. He has completed 12 global leading research projects and 6 domestical leading technologies. As the world-recognized innovation, his high/low axis steam turbine power generation successfully bypassed the 700 degree temperature hurdle and high material costs. With huge contribution to substantial social and economic benefits, he has been invited to speak at conferences in UK, Japan, US, and Poland.

Wang Haifeng: key talent recognized by the 1,000 talents program, current Assistant President of North China Electric Power University, and leading expert of electric system dynamic stability and control with major achievements in FACTS research and electric system dynamic stability analysis; former professor at Queen's University Belfast, director of Electric and Energy System Department, and IET fellow. In 2009, he received the first Sino-UK Science Bridge Award. Currently, he leads the team of electric power system sustainable safety project (Sino-UK cooperation project). The team he leads is part of IET research.

Wang Fan：Director of the Energy Saving & Emission Reduction Center of China Energy Research Society (CERS)

Zhang Kaiyuan: secretariat member of CERS energy efficiency and lower emission, Chair of Guodian Qingxin Co, Ltd, and environmental protection expert

Li Junfeng: secretariat member of CERS energy efficiency and lower emission, and combustion expert; former team leader of the cement kiln medium temperature heat power generation project (a key project during the 8^{th} five-year plan) at the cement institute under CBMA. Overseas study experience with ETH, and a member of the research team under Prof. Lothar Reh. Now chair of Beijing Jiuzhou Gewu Co. Ltd.

An Ting (F): UK Registered Chartered electrical engineer, IET fellow, IET fellowship qualification committee member, Ph.D. of electric engineering of China EPRI and University of Manchester, and key talent of the 1,000 talents program; special designated expert on a national level; chief expert of smart appliance system design, smart grid institute, State Grid Corporation of China.

2.2.2 Working Group

Workshop working group members are:

Mr. Wang Fan: CERS standing member, director of CERS energy efficiency and lower emission center, senior engineer of electric power system and automation, and Deputy GM of CHNG Energy Transportation Holdings

Mr. Liu Huihong: CERS Office Director, and Senior Engineer

Ms. Xu Meijuan: secretariat member of CERS energy efficiency and lower emission and Chair of Beijing Geyunlande Company

Mr. Lu Fenghua: secretariat member of CERS energy efficiency and lower emission

Ms. Wang Ping: HN Materials project manager; used to work in international liaison office of Beijing Olympic Organizing Committee; language service manager of 2008 Beijing Olympics, leading a team of 103 persons serving 70 events, including foreign heads of states; high-quality interpretation and translation; 780 projects carried out without customer complaint; training conducted for 2013 YOG volunteers.

Ms. Zhang Xiaoyan: *Energy Review* column editor, *Power Supply and Demand* executive editor in chief, and rich experience in event organizing, editing, and publishing

Ms. Liu Maoying: Beijing LAD electric power technology Co., Ltd Manager of International Dept, translator

Ms. Wang Zhumeng: secretariat personnel of CERS energy efficiency and lower emission, 2D design, media worker, and editor

2.3 Procedures

2.3.1 Call for paper

On November 14th, 2014, we published the call for papers. The topics for thesis and presentations include but not limited to:

I. General Topics

(1). Current Conditions & Future Sustainable Development of Coal-fired Power Plants in China

(2). Opportunities and Challenges: Energy Saving and Emission Reduction in Coal-fired Power Plants in China

(3). Innovation on Thermal Theory and Technical Development of Coal-fired Power Plants (Establishment and Application of General Application of Extraction Energy Technology)

(4). The Influence of Application of High Parameter & High Capacity Coal-fired Units on Improving Efficiency and Reducing Pollution and CO2 Emission

II. Technological Options for Developing High Efficiency and Low Emission Clean Coal Power

(5). Series of Innovative Technologies on Energy Saving and Emission Reduction Implemented in Shanghai Waigaoqiao No. 3 Power Plant

(6). Technology Innovation in China: How to make the Emission of Coal-Fired Units up to the Standards Set for Gas-fired Units?

(7). Super Clean Emission Technology of Coal-fired Power Plants & Benefit Evaluation (Case Study of Three Exemplary Plants including Zhejiang Zheneng Jiahua Power Plant)

(8). Innovative Technology for Saving of Energy and Water in Cooling System of Coal-fired Power Plants

(9). Double-reheat Power Generation Technology in USC (Ultra Super Critical) Units

(10). Innovative Double-reheat Technology for Elevated T-G Unit (1350MWe) in Shanghai Waigaoqiao No.3 Power Plant

III. Clean Utilization of Coal and Clean Coal Technologies

(11). High Capacity & High Parameter CFB Boiler Technologies: Development and

Application

(12). Impact of Quality and Features of Coal on the Energy Saving and Emission Reduction

(13). Development of Coal Pyrolysis Poly-Generation Technology

(14). IGCC Technology: Status, Development & Outlook

(15). Research on Systematic Solutions for Burning High Water Content Lignite

(16). High Efficient Power Generation Technology with Bituminous Coal

(17). High Efficient Power Generation Technology by Getting Water from Lignite

(18). Energy Saving and Emission Reduction of Industrial Boiler: Challenges & Technology Innovation

IV. Innovative Technologies on Environment Protection and Recycle Utilization in Coal-fired Power Plants

(19). Comprehensive Technology for Removing Pollutants in Coal-fired Power Plants

(20). Carbon Capture and Utilization Technology in Coal-fired Power Plants

(21). Innovative Technology on Desulfurization and Denitrogenation in Coal-fired Power Plants

(22). Zero Emission Technology for Waste Water in Coal-fired Power Plants

(23). Environmental Impact of Removal and Emission of Heavy Metal in Coal-fired Power Plants

2.3.2 Organization and Government Approval

In December 2014, the organizer submitted to National Energy Administration the notice of organizing APEC Forum on Innovative Technologies to Enhance Coal-Fired Power Generation Efficiency with *China Energy Research Society [2014] No. 020 Document*.

On March 2nd, 2015, the organizer submitted to Shanghai Municipal Government the notice of organizing APEC Forum on Innovative Technologies to Enhance Coal-Fired Power Generation Efficiency with *China Energy Research Society [2015] No. 07 Document.*

2.3.3 Publication of this Workshop

To support the Workshop, the organizer opened APEC Column on the website of China Energy Research Society for energy-saving and emission reduction, which covered workshop introduction, guest profile, workshop guidance, and latest reports. The column reached over 100,000 clicks.

2.3.4 Workshop Handbook

A Workshop handbook has been prepared, including:

2.3.5 Workshop Compilation

A Workshop compilation has been prepared, including the following contents:

1. Save Coal to Generate More Power / Huang Yicheng
2. Protect Intellectual Property Rights to Support Innovation Development / Zhang Maoyu
3. The Thinking of Clean and Highly-efficient Development of Coal-fired Power in China / Wang Zhixuan
4. Clean coal power generation: current challenges and future opportunities / Andrew Minchener
5. Road Clean and Efficient Utilization of Coal in China / Ni Weidou
6. Innovate into the Future in a Green and Responsible Manne / Zhou Junqing
7. Efficient Clean coal power generation technical advances / Feng Weizhong
8. Introduction to SPC Single-tower Integrated Desulfurization and Dust Removal Deep Purification Technology (SPC-3D)/ Zhang Kaiyuan
9. A Call to Action on High Efficiency Coal to Meet Global Energy and Climate Objectives / Benjamin Sporton
10. Automatic Control Technique for Large-scale Ultra-supercritical Pressure Coal-fired

Power Units / Liu Jizhen

11. The Status and Development Prospect of Circulating Fluidized Bed (CFB)Technology for Power Generation in China/ Yue Guangxi,Mao-Jianxiong,Huang-Qili

12. Enhance application of Siemens large USC steam turbines / Rainer Quinkertz

13. Approaches to Improve the Efficiency of Coal-fired Thermal Power Plants / Wang Fan

14. United States Research & Development for Coal Power Efficiency / Jeffrey N. Phillips

15. Status of Clean Coal Technology for Power Generation in Japan / Keiji Makino

16. Existing and future coal –fired power in Vietnam where the energy mix is dominated by coal / Nguyen Si Mao

17. Current Effective Way to Reduce CO2 Emissions for Coal Fired Power Plants / Mao Jianxiong

18. Status and Trend of Fossil Fuel Power Generation Technology in China / Zhao Min

19. Integrated Optimization System for CCP Plant——F-GEN Clean Coal-fired Power Plant Model / Mark Wu

20. Clean Coal Energy for China / Murray Mortson

21. Energy and Water Reservation Innovative Technology Dry Cooling and Wet Cooling Complementary System of Power Plant/ Li Junfeng

22. Getting Water from Lignite Technology for High-Efficiency Power Generation

——High Efficient Lignite-fired Power Generation Technology Based on Open Pulverizing System with Flue Gas Drying, Fan Mill and Recovery of Water and Heat from the Pulverizing Exhaust. / Pei Yufeng, Guo Xiaoke

23. "High-efficient Subcritical " Comprehensive Upgrading Technique / China Datang Corporation Science and Technology Research Institute Liuyanpeng

24. R&D of Advanced Superalloys for Applications of 700℃ A-USC Boiler Tubes/ Y. Gu, Y. Yuan, X.B. Zhao, J.T. Lu, J.B. Yan, Y.Y. Dang, Z. Yang, H.F. Yin, C.X. Fan

25. Advanced Online Monitoring Technologies / Yang Daming

26. Study on coal staged conversion and clean power generation technology/ Zhongyang Luo, Mengxiang Fang, Qinhui Wang, Xiang Gao, Kefa Cen

27. High efficient, economical and ultra-clean emission technical route of coal thermal power generating unit / Wu Linhu, Ju Jing

28. The LOESCHE High Efficiency Static-Dynamic Separator Technology / LOESCHE Innovative Engineering

2.3.6 All Services Enabled during the Forum

(1) Forum Affairs Group, Logistics Group, External Connection Group, and Publicity Group.

(2) Volunteer Service Team consisting of 30people to provide service for the forum.

(3) Shuttle service between stations, hotels and the Workshop for all representatives.

(4) High-level translation agency, to provide on-site simultaneous interpretation.

(5) Site visit to Shanghai Waigaoqiao No.3 Power Plant.

III About the Workshop

3.1 Brief Introduction

This workshop is an opportunity of cooperation and communication between APEC member countries, regions and organizations, as well as a big event for China's electricity industry. APEC member countries and region representatives, world-famous companies and institutions, China's government authorities, energy (electricity) groups, plan and design institutes, equipment manufacturers, and other stakeholders attended the forum. Key attendees included Mr. Chai Songyue, Director of China Energy Research Society (CERS); Vice Director of Economy Committee under the Chinese People's Political Consultative Conference (CPPCC); Scott, Chair of APEC EWG(EGCFE); Zhou Dadi, CERS Standing Vice Chair and Forum Chairman; CERS Consultant Qin Zhongyi and CERS Secretary-general Yu Xinyang; Zhou Junqin, Deputy General Manager of China Resources (CR) Group and Board Chair and President of CR Power; Academician Ni Weidou; Academician Huang Qili; Liu Jizhen, President of North China Electric Power University; leaders from State Intellectual Property Office, China Development Bank, China Electricity Council and National Energy Administration. Foreign attendees include Andrew Minchener, President of International Energy Agency Clean Coal Center (IEACCC); Benjamin Sporton, Acting Chief Executive of World Coal Association; experts from Electric Power Research Institute (U.S.) and Japan Coal Research Institute; representatives from Philippine, Indonesia, and China Hong Kong. Over 130 representatives attended this forum.

China Resources Power Group, China Galaxy Securities, Beijing SPC Environment Protection Tech Co., Ltd, Siemens, China Development Bank provided generous support to the forum.

Chai Yuesong, President of China Energy Research Society attended the forum and delivered a speech.

Hua Jianmin, Vice chairman of the Eleventh National People's Congress, delivered a letter of congratulation to the forum. Vice Assistant President of Fossil Coal Department under the United States Department of Energy also sent a letter of congratulation.

Wu Xinxiong, Vice Director of Economy Committee under the Chinese People's Political Consultative Conference and President of National Energy Administration attended the forum, listened to reports and attended dinner party.

Zhou Dadi, CERS Standing Vice Chair (forum chairman for Chinese side); Scott, Chair of APEC EWG(EGCFE) (forum chairman); Yu Xinyang CERS Secretary-General; Andrew Minchener, IEACCC President; Mao Jianxiong, Professor from Qinghua University; Wang Fan, Director of the Energy Saving & Emission Reduction Center of CERS (Forum Secretary-general) were the hosts of the forum.

The forum talked about innovative technologies and experiences on enhancing coal-fired power efficiency and clean use of coal, innovative theories and future directions of coal-fired power plants. It also covered new technologies, roadmaps and business modes among APEC member countries and regions as well as across the world, especially in energy saving and emission reduction of coal-fired power generation, climate change and coal emission reduction. During the forum, the organizer arranged a site visit to Shanghai Waigaoqiao No.3 Power Plant, a national coal-fired power plant for demonstration of energy saving and emission reduction.

While preparing the forum, nearly 30 reports and theses were selected after expert assessment for compilation and discussed on the forum. In *Save Coal to Generate More Power*, Huang Yicheng, former Minister of Energy expressed his thoughts as a senior statesman on the development of coal-fired power plants in China, energy saving and emission reduction. Minister Huang believes that it's totally correct for the government to promote nuclear power, hydropower, wind power and solar power, but it's more important and urgent to enhance coal-fired power efficiency and reduce coal consumption. *The Thinking of Clean and Highly-efficient Development of Coal-fired Power in China* by Secretary-General of China Electricity Council Wang Zhixuan, *Road Clean and Efficient Utilization of Coal in China* by Academician Ni Weidou, *Status and Trend of Fossil Fuel Power Generation Technology in China* by Zhao Min, Vice- General Engineer of China Electric Power Planning Institute, *Approaches to Improve the Efficiency of Coal-fired Thermal Power Plants* by Director of the Energy Saving & Emission Reduction Center of CERS talked about the status and future direction of coal-fired power plants in China. *Technical Advances in Efficient Clean Coal Power Generation* by Feng Weizhong, General Manager of Shanghai Shenergy Energy Technology Co., LTD., *Current Effective Ways to Reduce CO2 Emission for Coal Fired Power Plants* by Mao Jianxiong, Qinghua University Professor, *The Status and Development of Circulating Fluidized Bed (CFB)Technology for Power Generation in China* co-authored by Academician Yue Guangxi, Mao Jianxiong and Huang Qili, *Automatic Control Technique for Large-scale Ultra-supercritical Pressure Coal-fired Power Units* by Liu jizhen, President of North China Electric Power University, *Energy and Water Reservation Innovative Technology Dry Cooling and Wet Cooling Complementary System of Power Plant* by Li Junfeng from CERS Energy Efficiency and Lower Emission Secretariat provided innovative technologies and concepts to enhance coal-fired power efficiency and reduce emissions. Foreign experts discussed global clean coal power generation, challenges and opportunities, status of clean coal power technologies in Japan, and status and prospects of coal-fired power plants in Viet Nam. Zhang Kaiyuan, President of Beijing SPC Environment Protection Tech. Co Ltd talked about the latest technologies of single tower integrated desulphurization. Zhou Junqing, Deputy General Manager of China Resources (CR) Group and Board Chair and President of CR Power delivered a keynote speech entitled "Innovative Green Development and Responsibilities Lead Future" on behalf of the group. By introducing advanced technologies in energy efficiency and emission reduction, CR Power was the first to cooperate with Shanghai Waigaoqiao No.3 Power Plant, which demonstrates a sound example by significant rise of the unit fuel efficiency. In the National Demonstration Zone for Circular Economy established by CR Power in Hezhou of Guangxi Province, a "power plant – cement factory – bear factory" circular chain was created to realize comprehensive use of energy and nearly zero emissions. Miao Xinshan, Deputy Director of the Enterprise Bureau of China Development Bank, explained national policies for banks to support energy industry and energy-saving and emission-reduction projects. Zhang Maoyu, Deputy Director of the Patent Division of the State Intellectual Property Office delivered a speech titled "Protect Intellectual Property to Support Innovation and Development."

Proceeding in a fair, respectful and inclusive atmosphere, the high-level forum gathered various elites, new ideas and technologies. All aspects from the collection of theses, art edition, to the design of the back board, advertising page and roll screen, were thoroughly prepared. Supported by high-end site decoration and well-arranged services, all pre-planned schedules were covered, earning the appreciation from all attending Chinese and foreign experts!

In the forum summary, Zhou Dadi, CERS Standing Vice chair, Energy Economics Committee Chair

and Forum Chairman said “this is a high-quality forum,” and “it’s rare to see that a forum could include such comprehensive efficiency improvement technologies for coal-fired power plant, even from international perspective.” “The splendid speeches delivered new and inspiring ideas. I am so glad the forum was well organized under APEC, and it was the best technical conference I have ever attended.” said Scott Smouse, Chair of APEC EWG (EGCFE). ”This forum is superior in all aspects.” said Andrew Minchener, General Manager of the IEA Clean Coal Centre Prof. Keiji Makino, a famous clean coal expert of Japan, said “the site visit to Waigaoqiao No.3 Power Plant was very impressive. Its world-class cleanness, high efficiency and management could match the most advanced coal-fired power plants in Japan.” “Coal-fired power generation doesn’t necessarily lead to air pollution. Current technologies can be efficient and low in emission. If Waigaoqiao No.3 Power Plant is exactly what’s been said on the forum and in other reports, then China is on its way.” said Dr. Jeffrey Phillips Senior Program Manager of EPRI

During the forum, Xiaolan Energy Saving Company and Siemens signed an import contract of 15 small-capacity and high-parameter steam turbine power generators for the “Clean Coal Industrial Boiler CHP Demonstration Project” coordinated by the Energy Saving & Emission Reduction Center of CERS. The project is a demonstration program of energy saving and emission reduction for industrial coal-fired boilers in Guangdong Province.

Well appreciated by all attendees, the two-day forum is beyond expectation and will inject new power to China’s innovation and revolution in electricity industry, promote the national revolution of energy production and consumption, and exert huge influence on the development of global coal-fired power generation industry.

3.2 List of Honored Guests

Chai Songyue

Director of China Energy Research Society (CERS)

Chai Songyue, born in November, 1941, started his career in October 1958. He acted as Governor of Zhejiang Province since January 1998 and was appointed as the Chairman of the State Electricity Regulatory Commission in November 2002. He was a member of the Standing Committee of the 11th Chinese People's Political Consultative Conference (CPPCC) and Deputy Director of the Committee for Economic Affairs of CPPCC in March 2008, and was appointed as the Chairman of the 6th administrative committee of CERS in April, 2009.

Wu Xinxiong

Vice Director of Economy Committee of CPPCC. He was the Governor of Jiangxi Province, President of SERC, Vice Director of NDRC and President of National Energy Administration.

Zhou Dadi

Deputy Director of China Energy Research Society (CERS)

Zhou Dadi, born in 1946, is the researcher and Deputy Director of CERS, Director of the Committee of Energy Economy; Member of the Chinese Society for Sustainable Development; Chairman of Beijing Energy Society; Senior Advisor of China National Offshore Oil Corporation (CNOOC); Member of the Committee for Energy Experts of the National 863 Plan; Member of the 2nd Science and Technology Committee of the UN Global Environment Facility; Director of the Editorial Board

of Energy of China (magazine), and initiator of Beijing Energy Efficiency Center. His research focuses on energy economy, energy policies and energy systems. With a high reputation in sustainable energy development and global climate change he has an in-depth study on China's energy import policy, energy prices reform, energy structure optimization, and energy efficiency.

Scott M. Smouse

Senior Advisor

Office of Fossil Energy and

Office of Clean Coal and Carbon Management

U.S. Department of Energy

Scott M. Smouse has more than 30 years' experience across nearly every aspect of fossil energy utilization, especially coal-based technologies. In late 2014, he assumed a position as a Senior Advisor in the Office of Clean Coal and Carbon Management in the U.S. Department of Energy's Office of Fossil Energy after nearly 29 years' work at the National Energy Technology Laboratory (NETL) .He has held senior-level positions in several international organizations/initiatives, including the Asia Pacific Economic Cooperation (APEC) and the Asia Pacific Partnership on Clean Development and Climate (APP). Since 2001, he has chaired the Expert Group on Clean Fossil Energy (EGCFE) under the APEC Energy Working Group. In 2012, he completed a 3-month executive exchange program in China under the Office of Fossil Energy's Global Leadership Program.

Qin Zhongyi

Chief Energy Engineer of the former Ministry of Energy,

Exective Deputy Director of China Energy Research Society (CERS)

Qin Zhongyi, graduated from the Power Engineering Department in Tsinghua University in 1962. He previously worked for Harbin Turbine Co., Ltd., Beijing Heavy Electronic Machinery Co., Ltd., and Major Technical Equipment Office of the State Council. The he was a member of the Party group and Chief Energy Engineer of the former Ministry of Energy, Deputy General Manager of China Three Gorges Development Company, and executive Deputy Director of CERS; currently he serves as the Chief Advisor in the Energy Saving & Emission Reduction Center of CERS.

Yu Xinyang

Secretary-General of China Energy Research Society (CERS)

Yu Xinyang was born in September 1946 with a Bachelor's Degree. He is the professor-level Senior Engineer and enjoys special government allowances. His previous positions include Deputy Director of Northeast Electricity Administration, Deputy General Manager of China Huaneng Group, General Manager of Shanghai Municipal Electric Power Company, Chief Engineer of the State Electricity Regulatory Commission (SERC) and advisor of East China Grid Company Limited. He is currently the Secretary-General of CERS.

Miao Xinshan

Deputy Director of the Enterprise Bureau of China Development Bank

Miao Xinshan, Deputy Director of the Enterprise Bureau of China Development Bank and Senior Engineer; he previously worked in Ministry of Water Conservation and Power Energy, Energy Ministration, and China Three Gorges Corporation. He joined in China Development Bank in 2003 and is experienced in financial work in energy and transportation industries and monetary service

to Central Government-led Enterprises.

Zhang Maoyu

Deputy Director of the Patent Division of the State Intellectual Property Office

Zhang Maoyu was born in April 1965 with a master degree in Engineering Degree and Researcher. After the graduation from Tsinghua University majoring in wireless electricity, he joined in work in 1987 and now is the Deputy Director of Patent Division of the State Intellectual Property Office. He has been working on the patent management, participating in research on national intellectual property strategies and the revision of *Patent Law* and has drafted more than 20 relative books.

Wang Zhixuan

Party Member and Secretary-General of China Electricity Council

Wang Zhixuan was born in September 1955 and entered the workforce in February 1982. He is now the Party Member and Secretary-General of China Electricity Council, Member of the National Climate Change Expert Committee, Member of the Consulting Group of the Anti-monopoly Committee of the State Council, Deputy Director of the National Technical Committee on Energy System of Standardization Administration, Director of the National Technical Committee on Power Industry Energy Saving of Standardization Administration, Member of the National Technical Committee on Power Industry Environmental Protection of Standardization Administration, Member of the National Technical Committee on Environmental Management of Standardization Administration, Member of the National Technical Committee on Environmental-friendly Products of Standardization Administration, and Member of the National Technical Committee of the 700 ℃ Ultra-supercritical Coal-fired Power Generation Technology Innovation Alliance.

Zhou Junqing

Deputy General Manager of China Resources (CR) Group

Board Chair and President of CR Power

Zhou Junqing graduated from Tsinghua University majoring in wireless in Electronic Engineering Department and previously worked for the former Ministry of Foreign Economic Relations. She joined CR Group in 1986 and acted as the assistant to General Manager and Deputy General Manager of CR Machinery & Mineral Corporation. She acted as Chairwoman of CR Cement Holdings Limited from February 2008 to October 2011, posted as Deputy General Manager of CR Group in February 2010, and as Chair of the Board in CR Power since October 2011.

Dr. Andrew Minchener OBE

General Manager of the IEA Clean Coal Centre

Dr. Andrew Minchener is the Researcher and Chartered Engineer of the Energy Institute and has over 35 years' experience in fossil fuel and biomass/waste utilization, systems development, energy and environmental consultancy, and contract research and development, with particular emphasis on clean coal and CCS issues in Europe and the Far East. This includes specific expertise in policy/institutional/regulatory analysis, techno/socio-economic analysis, training/capacity building, knowledge transfer and international business development. In recent years he has worked with a number of organizations including the UK Department of Energy and Climate Change, the World Bank, the Asian Development Bank, the International Energy Agency, the European Commission

and the IEA Clean Coal Centre to undertake a wide range of studies covering clean coal utilization and CCS in China and other parts of Asia. With effect from July 2013, he became the General Manager of the IEA Clean Coal Centre, being responsible for all aspects of the Centre's activities and with special emphasis on maintaining a strong international profile for all aspects of clean coal utilization.

Ni Weidou

Former Vice President of Tsinghua University, Fellow of the Chinese Academy of Engineering (CAE)

Ni Weidou was born on October 6, 1932. Currently he is a CAE fellow and an expert at power machinery engineering and President of China Energy Society. He once acted as Vice President of Tsinghua University and Deputy Director of the School Administration Committee, President of Shanghai Shanda University, Vice Chairman of Beijing Association for Science and Technology, and Leader of the Chinese side of the Energy Strategy and Technology Workgroup at China Council for International Cooperation on Environment and Development. He is an expert in the modeling, simulation, control, and fault diagnosis of heat turbine systems and heat power systems.

Feng Weizhong

General Manager of Shanghai Shenergy Energy Technology Co., LTD. & Shanghai Waigaoqiao No.3 Power Plant Co., Ltd**.**

Feng Weizhong was born in December, 1954, and is the General Manager of Shanghai Shenergy Energy Technology Co., LTD. and Shanghai Waigaoqiao No.3 Power Plant, professor-level Senior Engineer, Deputy Director of China Energy Society, and enjoys the State Council special allowance. He has been awarded as the "National Labor Medal" and the following titles: "Shanghai Science and Technology Leading Talent", "Shanghai Outstanding Personnel for Completing Major Projects", one of the "Ten Talented Employees for Technological Innovation", "Outstanding Contributor for China's Low-Carbon Economy", one of the "Ten Figures of the Electric Power Industry Impressed China Most", and a winner of the Science and Technology Innovation Prize of Ho Leung Ho Lee Foundation. During the establishment and operation of Shanghai Waigaoqiao No.3 Power Plant, he took the lead in carrying out over ten major technological innovation activities which helped improve energy efficiency and environmental performance of systems greatly. The systems even outperformed international standards and renewed the world record of lowest coal consumption for 4 consecutive years. He has published about 40 theses from home and abroad and owns more than 20 patents. He has been invited to make speeches in European countries, America, Japan and Australia for several times.

Zhang Kaiyuan

President of Beijing SPC Environment Protection Tech. Co., Ltd.

Zhang Kaiyuan was born in June 1954 and graduated from Nanjing Institute of Technology in 1982. He once acted as Deputy Director of the Office for Electronic Technology of North China Electric Power Research Institute, Secretary of Youth League Committee of Beijing Bureau of Electric Power Industry, Deputy Director of Beijing Electric Power Research Institute and Deputy General Manager of Beijing North China Electric Power Industry Company. In 2001, he was assigned as the Chief Engineer of Beijing SPC Environment Protection Tech Co., Ltd., and then he became the President and General Manager of the company in 2004. Currently he works as the Chairman of Beijing SPC Environment Protection Tech Co., Ltd. and Vice President of the Chamber for

Environmental Service Industry of All-China Federation of Industry and Commerce.

Liu Jizhen

Member of the CPPCC National Committee;
President of North China Electric Power University (NCEPU)

Liu Jizhen was born in August 1951 with a Master's Degree, He is a professor and Ph.D supervisor, and the President of NCEPU. Meanwhile, he is the Member of the Science & Technology Commission of Ministry of Education, Member of the Power Security Expert Committee of State Electricity Regulatory Commission, Deputy Director of Chinese Society for Power Engineering, the executive member of Society For Electrical Engineering, Member of Chinese Association of Automation, Director of the Thermal Automation Standardization Committee, senior member of the Institution of Engineering and Technology (IET), and Member of the 12th CPPCC National Committee.

Benjamin Sporton

Acting Chief Executive
World Coal Association

Benjamin Sporton was appointed Acting Chief Executive of the World Coal Association in November 2014. Benjamin joined the World Coal Association as Policy Director in May 2010 and has been Deputy Chief Executive since May 2012. As Deputy CEO Benjamin is responsible for WCA's strategic and business planning, support to the WCA Board and membership development. Benjamin is also responsible for leading WCA's policy and advocacy work with a particular focus on energy poverty, sustainable development and climate change issues. He is also in charge of leading work responding to coal divestment campaigns. Benjamin is a Member of the International Advisory Committee to the Energy & Environment Foundation of India and an Associate Member of the Coal Industry Advisory Board to the International Energy Agency. He holds an honours degree in politics from the University of Adelaide and has also studied at the University of Buenos Aires and the Australian Institute of Management.

Yue Guangxi

Academician of the Chinese Academy of Engineering (CAE), Energy and Mining Engineering Department

Yue Guangxi graduated from the Department of Power Machinery of Tsinghua University and is a Researcherand Ph.D supervisor. Currently, he is the professor of Thermal Engineering Department of Tsinghua University and Taiyuan University of Technology. In Dec. 2001, he was invited by Turkey's National Science and Technology Commission to deliver a speech on "Coal-fired Circulating Fluidized Bed Technology". He published more than 150 theses, among which 8 theses were collected by SCI and 32 theses by EI. His monographs include: *Circulating Fluidized Bed Combustion Boiler*, second editor, published by China Electric Power Press in 2003; *Operation and Maintenance of Circulating Fluidized Bed Boiler*, second editor, published by China Water Power Press in 2003. In 2009, hHe was elected as a fellow of CAE.

Huang Qili

Advisor of the State Grid, Academician of the Chinese Academy of Engineering (CAE)

Huang Qili is an expert of steam engineering, a CAE fellow and Ph.D. supervisor. He obtained his Bachelor 's Degree from Tsinghua University in 1964 and Master's degree from Nanjing Institute of Technology (now renamed as Southeast University) in 1968. In 1987, he got the Doctor's Degree

in Hokkaido University of Japan. He is now the professor in Department of Energy and Power Engineering of North China Electric Power University, the Chief Engineer in the Northeast Branch of State Grid, and the executive member of Chinese Society of Electrical Engineering, China Energy Association, and Chinese Society of Power Engineering. He won a third prize of the National Award for Science and Technology Progress and seven other the ministerial (provincial) level prizes for progress in science and technology.

Mao Jianxiong

Professor and Former Deputy Director of the Department of Thermal Energy, Tsinghua University

Mao Jianxiong, once acted as Deputy Director of the Department of Thermal Energy, Tsinghua University and engaged in work related to the teaching, research and international exchanges in thermal engineering and clean coal-fired power generation technology. In 1993, he was hired as an advisor for British Coal Science Research Institute and was awarded the Honorary Doctorate of Technology by DeMontfort University of the UK in 1995. He was also elected as a Senior Member of British Energy Society. His teaching and research include: combustion theory and equipment, boiler design and clean coal technology, clean coal-fired power generation technology, supercritical and ultra-supercritical coal-fired power generation technology, and CO_2 collection and storage technology.

Wang Fan

Director of the Energy Saving & Emission Reduction Center of China Energy Research Society (CERS)

Wang Fan was born in 1956 and graduated from Nanjing Institute of Technology (now renamed as Southeast University). He once worked for the Production and Construction Bureau of National Energy Commission, the Energy Bureau of National Economic Commission, and the General Office of the former Ministry of Energy, and served as Deputy Director of the Policy Research Office of Huaneng Group, Chairman and General Manager of Huaneng Engineering Consulting Co., Ltd., Huaneng International Economic and Trade Company, Deputy General Manager of Huaneng Energy and Transportation Industry Holding Co,. Ltd., and Deputy General Manager of Huaneng Supplies Company. Ccurrently, he is the Director of the Energy Saving & Emission Reduction Center of CERS.

Jeffrey Phillips

Senior Program Manager
EPRI

Jeffrey Phillips is a Senior Program Manager at the Electric Power Research Institute (EPRI).He is responsible for EPRI's advanced coal generation research activities including the Fossil Fleet for Tomorrow® program which is focused on developing advanced fossil fuel power plants and the CO2 Capture and Storage (CCS) program that is addressing the technical challenges of capturing CO2 emissions and storing it permanently. Dr. Phillips began his involvement with the Institute in graduate school, providing support to an EPRI-sponsored project as part of his PhD research. He joined EPRI's Coal Fleet program in 2004 after working for 18 years on coal gasification and combined-cycle projects. Before joining EPRI, Dr. Phillips worked for the Royal Dutch/Shell group for ten years. He then worked as a researcher at Molten Metal Technology where he conducted tests on gasifying hazardous wastes. Later he joined Fern Engineering as a vice president and engineering consultant specializing in performance monitoring of combined cycle power plants.

Prof. Keiji Makino

Japan coal energy center

Mr. Keiji Makino graduated from Mechanical Department, Thermal Engineering in Tokyo Institute of Technology in March 1968 with a Master's degre,. In April, 1968, he entered the Research Institute of Ishikawajima Harima Heavy Industries Co. Ltd. (renamed as IHI Company). He was responsible for Basic design of large capacity of supercritical utility boilers in Boiler Division in April 1973 and in April 1983, he was in charge of Design of Combustion Equipment Development, Low NOx Technology, Low NOx Burner Development, Furnace NOx Reduction and Development of Oxy-fuel Technology etc. in Boiler Combustion Dept. In April, 1987, he was mainly responsible for Global Clean Coal Technology, Fluidized Bed Boiler, etc. in Boiler Development Dept. He was appointed as Associate Director in 2002. In 2008, he moved to Japan Coal Energy Center as a Fellow and adviser of Clean Coal Technology, CCS, Global warming etc. Fellow of Japan Society of Mechanical Engineering.

Li Junfeng

President of Beijing GW Process Technology Co. Ltd.

Li Junfeng was born in 1962 and obtained the Master's Degree in thermal power engineering from Southeast University in 1992. He once worked for the Institute of Cement Science of China Building Materials Academy in Beijing, and was the project leader for "power generation through temperature waste heat in the cement kiln" which is a major project of the 8th National Five-Year Plan. In 1997, he studied at the Institute of Process Engineering of the Swiss Federal Institute of Technology and was the researcher at Prof. Lothar Reh's Group. Currently, He serves as Chairman of Beijing Jiuzhou Gewu Process Technology Co. Ltd. and a Board member of Beijing Green Land Energy Saving and Emission Reduction Technology Co., Ltd.

Wu Hai

President of Beijing LAD Electric Power Technology Co., Ltd., ;

President of Forest Power & Energy Holdings, Inc

Wu Hai graduated from Southeast University in 1990, majoring in Electric Engineering. He is now the President of Beijing LAD Electric Power Technology Co., Ltd., and the President of Forest Power & Energy Holdings, Inc. (USA). In 1999, he established Beijing LAD Electric Power Technology Co., Ltd., which was awarded as a Hi-tech company by the local government. The company focuses on the development and promotion of new technologies for system upgrading, efficiency enhancement and emission reduction in coal-fired power plants. In 2003, he invested in VOLK Flow Controls Inc. in Houston Texas, which is now a member of USCBC. In 2011, he established Forest Power & Energy Holdings, Inc., a company dedicated to the exchange, investment and cooperation of technologies between US and China. In the past few years, he worked for the exchange and cooperation in energy industries between US and China, and is devoted to the promotion of Chinese high efficient coal-fired power technologies all around the world.

Murray Mortson

Chairman and CEO, Airborne International Holdings Corp.

Shareholder and Director, Airborne International Holdings Corp.

Murray Mortson, Canadian, has thirty-four years of experience in the energy industry from all aspects of the engineering contractor, construction contractor and owner's points of view. As a registered professional engineer, Murray has a number of patents and publications on flue gas removal and sodium based technology worldwide. He holds a Bachelor's Degree in engineering

from the University of British Columbia 1980 and is in his late 50's in age. Murray has spent nine years as a construction supervisor in both union and open shop construction environments, eleven years as an engineering contractor and fourteen years in an owner company developing advanced pollution control systems. He has worked on projects in the US, Mexico, China and Canada and other parts of the world. Currently, he is residing in Beijing and working full time to commercialize the Airborne pollution control technology in China.

Yang Daming

President of Beijing CARE-Gen Energy & Environmental Protection Technology LLC.

Yang Daming is the president of Beijing CARE-Gen Energy & Environmental Protection Technology LLC, and has 25 years of experiences in energy conservation and power generation engineering. He was a senior engineer with GP Strategies Corporation in charge of tens of EtaPRO projects, Virtual Plant software development, external and internal training, etc. Before that position, he was a plant engineer with Dynegy Corporation in charge of performance testing and equipment maintenance inspection. In the whole 1990's, he worked in China's energy conservation sector and central government. Mr. Yang owns a bachelor's degree from Tsinghua University and a master's degree from University of Massachusetts Amherst. He lives in Buffalo-Niagara in New York State of USA and likesmusic, photography, skiing, etc.

3.3 List of Speakers and Thesis Topics

<table>
<tr><th colspan="3">APEC Forum on Innovative Technologies to Enhance Coal-Fired Power Generation Efficiency</th></tr>
<tr><td colspan="3">March 25, 2015 Wednesday</td></tr>
<tr><td>ALL DAY</td><td colspan="2">Registration</td></tr>
<tr><td>18:30-20:00</td><td colspan="2">Welcome Dinner</td></tr>
<tr><td colspan="3">March 26,2015 Thursday</td></tr>
<tr><td>8:00-8:30</td><td colspan="2">Registration</td></tr>
<tr><td colspan="3">Part I Opening Ceremony (Moderator:Zhou Dadi)</td></tr>
<tr><td>08:30-08:40</td><td colspan="2">Director of CERS-Chai Songyue-Welcome Speech</td></tr>
<tr><td>08:40-08:50</td><td colspan="2">Chair of APEC EWG(EGCFE) -Scott M.Smouse-Welcome Speech</td></tr>
<tr><td>08:50-09:10</td><td>Protect IP and Support Innovation Development</td><td>Zhang Maoyu; Assistant Commissioner of SIPO</td></tr>
<tr><td rowspan="2">09:10-09:30</td><td rowspan="2">The Thinking of Clean and Highly-efficient Development of Coal-fired Power in China</td><td>Wang Zhixuan;</td></tr>
<tr><td>Secretary-general of China Electricity Council</td></tr>
<tr><td>09:30-09:50</td><td>Innovate into the Future in a Green and Responsible Manner</td><td>Zhou Junqing; Chairman & President of China Resources Power Holdings Co., Ltd.</td></tr>
<tr><td>09:50-10:30</td><td colspan="2">Group Photo & Coffee Break</td></tr>
<tr><td colspan="3">Part II Industrial Analysis (Moderator: Scott M. Smouse)</td></tr>
<tr><td rowspan="2">10:30-10:50</td><td rowspan="2">Clean Coal Power Generation: Current Challenges and Future Opportunities</td><td>Dr. Andrew Minchener;</td></tr>
<tr><td>General Manager of (IEA) Clean Coal Centre</td></tr>
</table>

10:50-11:10	Clean and Efficient Utilization of Coal in China	Ni Weidou; Academician of Tsinghua University
11:10-11:30	Exploration of Development of Clean Coal-fired Power Technologies	Feng Weizhong; General Manager of Shanghai Waigaoqiao No3. Power Generation Co.,Ltd.
11:30-11:50	Introduction to SPC Single-tower Integrated Desulfurization and Dust Removal Deep Purification Technology (SPC-3D)	Zhang Kaiyuan; President of Beijing SPC Environment Protection Tech Co., Ltd
12:00-13:30	**Luncheon**	
Part III Industrial Analysis(Moderator:Yu Xinyang)		
13:30-13:50	Automatic Control Technique for Large-scale Ultra-supercritical Pressure Coal-fired Power Units	Liu Jizhen; President of North China Electric Power University
13:50-14:10	A Call to Action on High Efficiency to Meet Global Energy and Climate Objectives	Benjamin Sporton; Acting Chief Executive of World Coal Association
14:10-14:30	The Status and Development Prospect of Circulating Fluidized Bed (CFB)Technology for Power Generation in China	Yue Guangxi, Academician; Professor Mao Jianxiong; Huang Qili, Academician
14:30-14:50	Enhance Application of Siemens Large USC Steam Turbines	Dr. Rainer Quinkertz; Senior Manager of Turbine R&D Center of Simens
14:50-15:10	Approaches to Improve the Efficiency of Coal-fired Power Plants	Wang Fan; Director of Energy Saving & Emission Reduction Center of CERS
15:10-15:40	**Coffee Break**	
Part IV Technical Session (Moderator: Dr. Andrew Minchener)		
15:40-16:00	United States Research & Development for Coal Power Efficiency	Jeffrey N. Phillips; Senior Program Manager of EPRI
16:00-16:20	Status of Clean Coal Technology for Power Generation in Japan	Prof. Keiji Makino; Japan Coal Energy Center
16:20-16:40	Current Effective Way to Reduce CO2 Emissions for Coal Fired Power Plants	Prof. Mao Jianxiong; Tsinghua University
16:40-17:00	Energy and Water Reservation Innovative Technology	Li Junfeng;
	Dry Cooling and Wet Cooling Complementary System of Power Plant	Expert of Energy Saving & Emission Reduction Center of CERS
18:30-20:00	**Banquet**	
March 27,2015 Friday		
Part V Technical Session (Moderator: Prof. Mao Jianxiong)		
08:30-08:50	Status and Trend of Fossil Fuel Power Generation Technology in China	Zhao Min, Vice- General Engineer of China Electric Power Planning Institute

08:50-09:10	Key Technologies and Engineering Practices for the Synergic Management of Smoke and Gas for Large Pulverized Coal Power Plant	He Yong, Chief Engineer Huaneng Power International Inc.
09:10-09:30	F-Gen Clean Coal-fired Power Plant Model	Wu Hai; President of Beijing LAD Electric Power Technology Co., Ltd.
09:30-09:50	Clean Coal Energy for China	Murray Mortson; President of Airbone
09:50-10:20	**Coffee Break**	
Part VI Technical Session (Moderator: Wang Fan)		
10:20-10:40	R&D of Advanced Superalloys for Application of 700℃ A-USC Boiler Tubes	Yuan Yong; TPRI (China Huaneng Group）
10:40-11:00	“High Efficient Subcritical" Comprehensive Upgrading Technique	Dr. Liu Yanpeng; China Datang Group Science & Technology Institute Ltd.
11:00-11:20	Getting Water from Lignite Technology for High-Efficiency Power Generation	Yao Yufei; Northeast Electric Power Design Institute of CPECC
11:20-11:40	Advanced Online Monitoring Technologies	Yang Daming;President of CARE-Gen, LLC(GP Energy)
11:40-12:00	Summary Speech	Chair of APEC EWG(EGCFE) / Deputy Director of CERS
12:00-13:30	**Luncheon**	
Part VII Site Visit to Shanghai No.3 Power Plant		
13:30-14:10	Trip from Shanghai International Convention Center to Shanghai Waigaoqiao No.3 Power Plant	
14:30-15:30	Site Visiting of Shanghai Waigaoqiao No.3 Power Plant	
15:30-16:30	Technical Communication and Discussion in Shanghai Waigaoqiao No.3 Power Plant	

3.4 List of All Attendees

Attendance at APEC Expert Workshop		
	Name	Organization/Company
1	Wu Xinxiong	Director of Economy Committee of CPPCC
2	Zhang Maoyu	State Intellectual Property Office
3	Miao Xinshan	China Development Bank
4	He Yang	Department of Electric Power NEA
5	Wang Zhixuan	China Electricity Council
6	Ni Weidou	Tsinghua University
7	Liu Jizhen	North China Electric Power University
8	Zhao Min	Electric Power Planning & Engineering Institute
9	Zhang Kaiyuan	Beijing SPC Environment Protection Tech Co., Ltd
10	Chang Zheng	Datang Science and Technology Research Institute
11	Wang Fan	Forum General Secretary
12	Zhou Junqin	China Resources Power Holdings Co., Ltd.
13	Liu Ping	China Resources Power Holdings Co., Ltd.
14	Zhao Houchang	China Resources Power Holdings Co., Ltd.
15	Nie Weimin	China Resources Power Holdings Co., Ltd.
16	Yang Ningsheng	Power Construction Corporation of China
17	Feng Weizhong	Waigaoqiao No.3 Power Generation Co., Ltd.
18	Xi Liqiang	Shenergy Company Limited
19	Xing Xiaoping	Huaneng Lancang River Hydropower co.,LTD
20	Ren Deqing	Jiangxi Energy Research Institute
21	Tang Xiaoping	Guoxin Xingye Consulting
22	Dr. Wilfried Ulm	Siemens
23	Yao Zhenguo	Siemens
24	Wang Baoli	Siemens
25	Chai Songyue	China Energy Research Society
26	Zhou Dadi	Forum Chairman
27	He Yong	Huaneng International
28	Qin Zhongyi	China Energy Research Society
29	Yu Xinyang	China Energy Research Society
30	Liu Huihong	China Energy Research Society
31	Mao Jianxiong	Tsinghua University
32	Huang Qili	State Grid
33	Shen Zhen	Datang Technology Industry Group Co.,Ltd.
34	Scott Smouse	Forum Chairman
35	Andrew Minchener	(IEA) Clean Coal Centre
36	Chen Pei	State Intellectual Property Office
37	Jiang Daoguo	China Development Bank
38	Sun Yan	China Development Bank

39	Jiang Tingjun	Department of Electric Power NEA
40	Liu Zhiqiang	China Electricity Council
41	Song Shizhong	Tsinghua University
42	Niu Yuguang	North China Electric Power University
43	Wang Yuemiao	Beijing SPC Environment Protection Tech Co., Ltd
44	Huang Tianhao	Beijing SPC Environment Protection Tech Co., Ltd
45	Liu Yanpeng	Datang Science and Technology Research Institute
46	Yuan Yong	Xi'an Thermal Power Research Institute Co. Ltd.
47	Zhang Yubo	Xi'an Thermal Power Research Institute Co. Ltd.
48	Li Junfeng	Energy Saving & Emission Reduction Center of CERS
49	Yao Yufei	Northeast Electric Power Design Institute of CPECC
50	Liu Xiaopeng	Guodian Innermogolia Energy Campany
51	Zhang Yi	Guohua Sanhe Power Plant
52	Wang Shiwan	China Resources Power Holdings Co., Ltd.
53	Wang Yi	China Resources Power Holdings Co., Ltd.
54	Cheng Daojun	Shanghai Power Equipment Manufacture
55	Lin Yongxiang	Shanghai Power Equipment Manufacture
56	Wu Guangchen	Shanghai Power Equipment Manufacture
57	Hu Yiyao	Shanghai Power Equipment Manufacture
58	Yin Weifang	Beijing Energy Investment Holding Co.,Ltd
59	Mao Yongqing	Beijing Energy Investment Holding Co.,Ltd
60	Li Yanqing	Tianjin Energy
61	Chang Xuemei	Tianjin Energy
62	Shi Min	Waigaoqiao No.3 Power Generation Co., Ltd.
63	Wang Liqun	Waigaoqiao No.3 Power Generation Co., Ltd.
64	Wei Kang	Waigaoqiao No.3 Power Generation Co., Ltd.
65	Yang Wenhu	Waigaoqiao No.3 Power Generation Co., Ltd.
66	Yao Jing	Shenergy Company Limited
67	Wu Weizhi	Shenzhen Energy
68	Yang Pengfei	Shenzhen Energy
69	Mao Ke	China Huadian Group
70	Jiang Zhiqiang	China Huadian Group
71	Zhao Yonghong	North China Power Engineering Co., Ltd. of CPECC
72	An Ting	State Grid Smart Grid Research Institute
73	Guo Wei	Wiscom System Co., Ltd.
74	Mi Zide	North China Electric Power Research Institute Co., Ltd
75	Miao Yuwang	Yantai Longyuan Electric Power Technology Co., Ltd.
76	Wan Bin	Jiangxi Energy Research Institute
77	Li Wenjun	Shenzhen Qianhai Tianyuan New Energy Co., Ltd.
78	Li Liangren	Shenzhen Golden Highway
79	Chen Yaolong	Beijing Zhongke Runhe Tech.
80	Wang Hongxiao	Suzhou Dong Fang Water Treatment Co., Ltd.
81	Yang Linpei	Maliantai Powerplant

82	Chen Zihong	Houde Investment Fund Management Co., Ltd.
83	Yang Lei	Houde Investment Fund Management Co., Ltd.
84	Shan Xuanhu	China Power Conservation & Environment Protection
85	Shen Deming	Nanjing SCIYON Automation Group Co., Ltd.
86	Shao Yong	Nanjing Greenland Energy Saving Tech Co., Ltd.
87	Wang Haoliang	SEUSUI Energy and Enviro-protection Engineering
88	Li Shaolin	SEUSUI Energy and Enviro-protection Engineering
89	Gao Yuan	SEUSUI Energy and Enviro-protection Engineering
90	Wu Linhu	SEUSUI Energy and Enviro-protection Engineering
91	Wang Danqiu	Nanjing Zonengruihua Electric Co., Ltd.
92	Shao Jianguo	Nanjing Zonengruihua Electric Co., Ltd.
93		Siemens
94	Liu Tiefeng	Siemens
95		Siemens
96	Ma Ziye	Siemens
97	Zhao Ning	China Energy Research Society
98	Li Benfeng	Datang(BeiJing)Energy Management Co.,Ltd.
99	Zhang Guoping	Datang(BeiJing)Energy Management Co.,Ltd.
100	Benjamin Sporton	World Coal Association(London)
101	Keiji Makino	Japan coal energy center
102	Nguyen Si Mao	Hanoi University of Technology(Vietnam)
103	Jeffrey N. Phillips	EPRI
104	Murray Mortson	Airbone
105	Michael Zhao	Airbone
106	Croll Xue	Forest Power & Energy Holdings, Inc.
107	Zhu Mingtao	Forest Power & Energy Holdings, Inc.
108	Yang Daming	CARE-Gen, LLC.(GP Strategies)
109	Xiaoliang Yang	World Resources Institute
110	Hui Yuk-wah	The Hongkong Electric Co. Ltd.
111	Chan Kwok-fai, Calvin	The Hongkong Electric Co. Ltd.
112	Mohd Taupik bin Md Taib	Energy Commision, Malaysia
113	Shamsul bin Ahmad	Energy Commision, Malaysia
114	Johann Jeffrie bin Muhamad Ridzwan	Energy Commision, Malaysia
115	Mark Wu	LAD Enterprise
116	Wang Zhenhe	LAD Enterprise
117	Zhang Yong	LAD Enterprise
118	Wang Linlin	Xinhua News Agency
119	Ma Jiansheng	China Electric Power News
120	Li Qiao	China Industry News
121	Li Qingping	News
122	Xu Meijuan	Total Coordinator

123	Peng Jun	Photographer
124	Wang Lei	Forum Coordinator
125	Wang Ping	Forum Coordinator
126	Wang Zhumeng	Forum Coordinator
127	Xu Yuanyuan	Forum Coordinator
128	Guan Jin	Forum Coordinator
129	Xu Meilin	Forum Coordinator
130	Leo Lu	Forum Coordinator
131	Feng Chen	Forum Coordinator
132	Hua Hong	Forum Coordinator
133	Karen Liu	Translator
134	Wang Suyan	Translator
135	Wang Zheng	Forum Coordinator
136	Ma Jiaku	Forum Coordinator
137	Nan Tianhua	Forum Coordinator

3.5. Media Report

During and after the forum, over 10 newspapers and media reported this event, including:

What's the Most Efficient Coal-fired Power Plant Look Like? (China Business Network)

China Strives to Develop Coal-fired Power Plant and Correct "Improper Use of Coal" (Xinhuanet)

Visit the Most Efficient Coal-fired Power Plant in the World (China Business News)

Waigaoqiao No.3 Power Plant: Only 7667BTU Needed to Produce 1kW/H, World-leading Level (Morning Post)

Expert Interview: Coal is and will continue to be the main power source in China (China Industry News)

Experts Talk over Energy Saving and Emission Reduction of Coal Power in China, and Coal Consumption Can Decrease More (China Electricity News)

IV Major Achievements of the Workshop

The Chinese government, participating experts and scholars around the world reach the consensus that it is a significant move for APEC to hold 2015 APEC Expert Forum on Innovative Systemic Approaches to Enhancing Coal-Fired Power Generation Efficiency in China, where coal-fired power accounts for 60% of the installed capacity and 70% of total power generation. Focusing on enhancing efficiency of coal-fired power generation and reducing emissions of pollutants and carbon dioxide, this forum highlighted exchanges on innovative technology and achieved the significant achievements:

1. Enhancing the efficiency of power generation is the inevitable path for coal-fired power plants.
2. Clean emission is the only choice for coal-fired power plants.
3. To curb carbon emission is humanities' common responsibility.
4. Female participation

4.1. Enhancing Generation Efficiency is the Inevitable Path for Coal-fired Power Plants

In 2013, coal consumption constituted 30% of world primary energy consumption and 66% in China. For a long time coal-fired power plants have accounted for about 80% of China's total generated power. Although power generated from renewable energy sources is increasing in the past decade, coal-fired power plants still accounted for 60% of the installed capacity and 70% of power generation in 2014. The ever more acute conflict between emissions from coal-fired power plants and the environment and low-carbon growth calls for greater cleanness and higher efficiency. Therefore, it is an inevitable choice to enhance the efficiency of coal-fired power generation.

In recent years, China implemented the following major measures to improve the efficiency of coal-fired power plants: 1. Adopting units with large capacity and high parameters. Newly constructed units in China are mostly ultra-supercritical units with a capacity of 60 GW or above. By the end of 2014, there have been 70 ultra-supercritical units with a capacity of 100 GW (compared with 63 units by the end of 2013)and units featuring 25-28 MPa and 600℃have been widely adopted. Among them, two 100 GW ultra-supercritical units of Waigaoqiao No.3 Power Plant are the most effective worldwide with an actual net efficiency of 44.5% (coal consumption at 7667BTU/kWh and a net efficiency of 45.5% under design conditions. 2. Increasing the proportion of cogeneration units and replacing existing coal-fired boilers for heating with cogeneration units. As a result, the proportion of cogeneration units increased from 13.3% in 2000 to 28.9% in 2013. 3. Replacing small units with larger units. The proportion of fossil-fuel units with capacities of 30 GW or above increased from 27.8% in 1995 to 77.7% in 2014. 4. Upgrading of steam turbines of in-service units, such as optimizing the flow path, exhaust heat recovery, and frequency conversion of motors, thus boosting efficiency through innovative technology. 5. Improving the efficiency and cleanness of low-grade coal through technical innovation in and application of CFB boilers. Currently around 100 30 GW CFB boilers have been put into operation. In 2013, the world's first supercritical CFB boiler with a capacity of 600 MW independently developed by China was put into operation in Sichuan Baima CFB Demonstration Power Plant. The efficiency and environmental standards of

CFB boilers meet or in some cases exceed international standards. The average net efficiency of China's fossil-fuel power plants increased from 26.1% in 1978 (thermal efficiency at 28.3%) to 38.6% (thermal efficiency at 41%), i.e., a 48% reduction in fuel consumption per unit power supply due to structural adjustment, technical innovation and scientific innovation. (Because coal-fired units account for around 90% of all fossil fuel units, the average fossil-fuel efficiency approximates average efficiency of coal-fired power plants). The efficiency of China's coal-fired power plants has met advanced international standards. During the Workshop, international experts shared innovative technologies and experience on enhancing the efficiency of coal-fired power generation Workshop. The technologies for energy efficiency and emission reduction of Shanghai Waigaoqiao No.3 Power Plant left deep impression on Workshop experts, which mainly include: all-directional elastic sealing (an elastic cluster-type sealing technology inspired by forest's ability to resist wind. The new sealing component fills the gaps of sealed device and makes up for changes to the gaps through elastic deformation, hence ensuring effective sealing), frequency adjustment through steam bleeding and optimization of steam turbine system (admission replaced by direct and indirect bleeding of steam for power regulation of traditional steam turbines to eliminate throttle losses), zero-energy desulfurization (the basic idea is to recover the thermal energy in the flue gas through a special device before desulfurization for power generation in the thermodynamic system so as to make up for power consumption in the desulfurization system. Power saving technology also helps to balance power saving and power consumption in the desulfurization system to achieve zero-energy desulfurization), all-day-long denitration technology (regenerative technology based on recycling steam from the turbine for heating, catalyst for maintaining effectiveness and long life, zero energy consumption, 24-hour operation), variable frequency power source (centralized variable frequency power supply representing a breakthrough from traditional frequency conversion technologies and concepts. Generators driven by individual speed-control turbines provide variable frequency power for in-plant use. Rotation speed of the turbine is adjusted based on load changes to alter frequency of in-plant power and save energy), general regenerative technology and elastic regenerative technology (expansion of regenerative media from feed water from the boiler in conventional regenerative cycle to water, wind and coal from the boiler), comprehensive control of solid particle (scale) erosion (innovative processes including dry flushing at high degrees of superheat and high-momentum wash of bypath during start-up), start-up of once-through boiler and stable combustion technology (steam bleeding of boiler nearby for water feed and indirect heating during start-up, so that both the wind and the boiler are heated before ignition. The rate of temperature rise is controllable and thermal expansion of the heating surface is even. Steam boilers running dry and rapid oxidation can be eliminated during start-up. Load lower than 20% is achievable for stable combustion in the case of fuel cut off.), fast cut back（FCB）technologies for large units (coordinated unit control and optimization and innovation of bypass and turbine control for FCB in all working conditions. Units can instantly switch to house load operation and islanding operation mode in the case of power grid breakdown and resumes power transmission shortly after fault removal). Shanghai Waigaoqiao No.3 Power Plant is pushing the efficiency of coal-fire units to the limit and is the world's best performer with coal consumption at 7667 BTU/kWh and an emission level on par with natural gas power stations. Data from January to April, 2015 indicates that units at Shanghai Waigaoqiao No.3 Power Plant are cleaner than gas turbine units with emissions of dust, sulfur dioxide and nitric oxide at 0.74mg/m3, 15.11 mg/m3, and 17.20mg/m3 respectively. Average standard coal consumption for the same period, moreover, is 7580 BTU/kWh. While saving energy

and reducing emissions, Shanghai Waigaoqiao No.3 Power Plant's innovative technologies have effectively simplified the system and improved the stability and safety of the facility. Their success in combining energy efficiency, environmental protection and economic benefits paves the road of green and sustainability for coal-fired power plants.

Double-shaft in high and low platform separately placed USC invented by Professor Feng Weizhong of Shanghai Waigaoqiao No. 3 Power Plant features double-shaft placement. Given significant reduction of high-temperature and high-pressure steam pipes, this technology could save piping investment while reducing resistance and heat losses to raise efficiency. This technology breaks the technical constraints of double reheat under 700℃. Drawing on existing 600℃ high-temperature materials and ultra-supercritical technology, this technology can improve the efficiency by 5% with almost the same per unit cost as 600℃ ultra-supercritical unit through double reheating design based on optimized 1350 MW capacity. Together with other energy conservation and emission reduction technologies adopted by Shanghai Waigaoqiao No. 3 Power Plant, Professor Feng's technology makes the designed coal consumption an epoch-making level of 6973 BTU/kWh (net efficiency at 48.92%), far surpassing the net efficiency of the next generation 700℃ ultra-supercritical technology still under development abroad (46% in Japan and 47% in European Union). Once the technology for 700℃ alloys in mature, the design coal consumption will be further reduced to 6556 BTU/kWh (with a net efficiency of 52%).

There is a large number of subcritical and ultra-high pressure units in service in China. By the end of 2013, installed capacity of 300 MW and 600 MW subcritical units was more than 400 million KW, accounting for more than half of the total installed capacity of all fossil fuel units nationwide with coal consumption higher than 8611.8 BTU/kWh. Over 300 ultra-high pressure units had a total installed capacity of about 7000 MW and even higher fuel consumption, dragging the overall efficiency of China's fossil fuel power plants. Under this background, China Energy Research Society is researching solutions for upgrading: 1. Conversion into CHP units with extraction or back pressure for heating; 2. construction of ultra-supercritical coal-fired boilers to replace existing boilers and adding ultra-supercritical units with topping back pressure turbines and the exhaust steam produced will enter existing subcritical or ultra-high pressure units; 3. boosting the admission temperature from 540℃ to 585℃ or 600℃, or even higher so that subcritical equipment can achieve the same efficiency as supercritical equipment; 4. installing devices for coal pyrolysis and gas turbine units in existing power plants for destructive distillation of volatile matter in raw coal. The volatile matter will be purified for units with gas turbines. Residual heat from the flue gas is utilized by the boiler of the gas units to produce steam for power generation. Semi-coke will replace raw coal for existing boilers; 5. conversion of existing ultra-high pressure units into backup units for peak load. After conversion, the boiler would be in a normal standby state with extremely low heat losses and able to rapidly go into stable full-load operation for emergency needs in peak load of the grid. In addition to black start for emergent power supply, the solution could automatically track and compensate for wind and solar power to facilitate the integration of wind and solar power into the power grid. Through above measures, the upgrade of China's subcritical and ultra-high pressure units will reduce coal consumption to less than 8334 BTU/kWh, the same level as supercritical units.

Jeffrey N. Phillips, senior program manager of Electric Power Research Institute, introduced US experience in R& D for coal power efficiency. Based on the application of and research on high-temperature nickel-base alloys, power plants in the United States could improve efficiency and

reduce emissions by raising temperature and assisting the recovery of low-temperature exhaust heat. Mr. Liu Jizhen, President of North China Electric Power University, proposed technologies for automated control of large ultra-supercritical units and integrated control-based optimized operation to address issues with ultra-supercritical units, such as small adjustable range, slow adjustment, compromised security and economic benefits in the case of significant load changing, and deviation from the design conditions due to varied types of coal and mixing of low-grade coal. State parameter-based soft sensing and state reconstruction, non-linear modeling for all working conditions, advanced control, and high-performance control devices as mentioned by Mr. Liu have been applied to multiple 1000MW ultra-supercritical units and the world's first 600 MW supercritical CFB units.

Mr. Yang Daming, President of CARE-Gen of GP Strategies introduced advanced on-line monitoring technologies to increase generation capacity, ensure equipment availability, raise operation reliability and unit efficiency, and reduce emissions.

4.2. Clean Emission is the Only Choice for Coal-fired Power Plants

In recent years, China has witnessed improved pollutant control and integrated resource utilization in coal-fired power plants. In terms of dust control, dust removal technology has been upgraded to high-efficiency electrostatic precipitators, bag filters, and combined electrostatic-bag precipitators. More importantly, technologies as low-temperature electrostatic precipitators have been widely applied, resulting in an increase of average dust control efficiency from 90.6% in 1985 to 99.75% in 2014. Meanwhile, dust discharge was reduced from 291.7 BTU/kWh in 1985 to 6.4 BTU/kWh in 2014. In the control of sulfur dioxide emissions, almost all boilers in power plants have been installed with desulfurization devices, and the percentage for FGD installation reached 91.5% (nearly 30% higher than in the US) since 2005. As a result, emission per kilowatt-hour was reduced from 6.4 g in 2005 to 1.49 g in 2014. Low NO_X combustion technology and SCR technology have been adopted to control NO_X emissions. SCR devices have been installed on a large scale since 2010. By the end of 2014, denitration rate of coal-fired units was 82.5% (33% higher than the US level) and nitric oxide emission per kilowatt-hour was reduced from 3.6 g in 2005 to 1.49 g in 2014. Moreover, dust control, desulfurization, and denitration help to control mercury discharge to meet the discharge limit. With the above-mentioned measures, although the power generation from fossil fuels increased by 16 times from 1980 to 2014, the power sector witnessed reductions of annual soot discharge by 75.4% from 4,000,000 tons to 980,000 tons, sulfur dioxide emission by 54.1% from the peak value of 13,500,000 tons in 2006 to 6,200,000, and nitric oxide emission by 38.2% compared with the peak value in 2011. According to upgrading requirements of standard emissions, China's pollutant emissions will continue to drop in 2015, reaching the world-level in the emission per unit power generation. In terms of integrated utilization of solid waste, production of FGD gypsum rose from 5,000,000 tons in 2005 to the peak value of 75,500,000 tons in 2013, and utilized FGD gypsum rose from 500,000 tons to 54,000,000 tons, with a utilization rate of 72%. Dust production rose from 150 million tons in 2001 to the peak value of 550 million tons in 2013; and utilized dust rose from 97 million tons in 2001 to the peak value of 380 million tons in 2013, with a utilization rate of 69%. In terms of water conservation and waste water control, water consumption for fossil fuel power generation was reduced from 8.6 lbs/kWh in 2001 to 4.4 lbs/kWh in 2013; waste water discharge, moreover, was reduced from 2.89 lbs/kWh in 2001 to 0.22 lbs/kWh in 2013.

In addition to the strictest discharge limits for coal-fired power plants in the world, a large number of coal-fire units will be upgraded in accordance with even stricter requirements from central and local governments to meet ultra-low emission standards for environmental protection. According to the new standards, particles, sulfur dioxide and nitric oxide in discharged flue gas cannot exceed 10 mg/m3 (in some cases 5 mg/m3), 35 mg/m3 and 50 mg/m3 respectively. In terms of carbon emission control, China has set up restrictions on carbon emission per unit GDP and issued Interim Carbon Emissions Trading Measures.

This Workshop also provided innovative technologies and experience in clean emissions of coal-fired power plants.

Beijing SPC Environment Protection Tech Co., Ltd introduced its single-tower integrated desulfurization and dust removal deep purification technology (SPC-3D). Flue gas produces controllable turbulence space with the slurry after passing through the revolving turbulator device. While increasing liquid-solid three-phase mass transfer rate and completing primary desulfurization and dust removal, the technology could realize rapid temperature drop and even distribution of flue gas. The gas continues to go through the high-efficiency spray layer system for secondary thorough removal of SO2 and dust. Then the flue gas enters into the tubular dust and mist removal unit where mist drops and dust are captured by the liquid film on walls under the centrifugal force, thus realizing thorough removal of both dust and mist. Characteristics of SPC-3D include: desulfurization, dust removal and defogging are completed within one absorbing tower; a single tower is adequate to achieve ultra-low emission of flue gas; the efficiency of desulfurization and dust removal meets the most stringent requirements for ultra-low emission. SO2 and dust in flue gas can be below 35 mg/Nm3 and 5 mg/Nm3 respectively. Under normal operation, power consumption of SPC-3D technology is 20%-30% lower than comparable technologies, thus reducing operation costs. Investment in SPC-3D is 40% lower than investment in conventional technology for the same emission standards, thus easing the capital pressure of the enterprise. It is easy to operate as upgrading is conducted in one tower with no need for add-ons, additional power or electrical equipment. In addition, as long as SO2 content is lower than 200 mg/Nm3 and dust lower than 50 mg/Nm3, the flue gas can directly feed into the absorption tower.

Mr. He Yong, chief engineer from Huaneng Power International, Inc. mainly focused on coordinated treatment of pollutants with equipment as nodes along the flow of flue gas. To be specific, materials (rare earth elements) are added to boost the effectiveness of SCR in catalyzing Hg oxidation. Under high Hg catalyzed oxidation, study composition's effect in inhibiting oxidation of SO2 to find out the optimal composition for high Hg oxidation and low conversion of SO2 into SO3. The second type of active component (ex. manganese-based catalyst) is added to expand the thermal window for catalytic reaction. Mr. He also introduced the technology to evenly mix the flue gas.

Mr. Murray Mortson, Chairman of the board of Airborne, introduced the company's unique technology of integrated removal of multiple pollutants from coal (SO_x, NO_x, mercury, fine particulates, etc.) for ultra-low emissions and recycling. The basis of this pollutant removal technology is to use sodium carbonate as the absorbent, a method whose effectiveness has been proved by large units worldwide (the largest being a 3GW unit in the United States). Airborne's technology is capable of regenerating sodium carbonate and producing nitrogen fertilizers as by-products, thus bringing down operating costs and creating additional revenues. This world-leading technology features relatively low investment costs, integrated removal of pollutants (almost all pollutants are removed with one single system, as opposed to the conventional method of using

multiple devices in conjunction with each other), ultra-low emissions, attractive additional revenues and recycling. It can be applied to coal-consuming industries including power plants, steel plants, cement plants, chemical factories, and ceramics factory (coal constitutes 75% of China's energy mix).

4.3. To Reduce Carbon Emission is Humanities' Common Responsibility

APEC member economies have scored significant progress in reducing carbon emissions from coal-fired power plants. However, to curb carbon emission is still a pressing global issue which requires joint effort from the human society.

China's pilot projects in carbon capture, utilization and storage have experienced great success: carbon capture pilot projects with capacities of between 3,000 to 120,000 tons/year are in full swing; much effort has been made in geological survey for carbon storage; and international research on engineering project-based carbon capture through oxygen-enriched combustion in coal-fired power plants is in progress. Through measures to develop non-fossil fuels and reduce coal consumption and line loss rate, China's aggregate carbon dioxide is reduced by about 6 billion tones between 2006 and 2014 and carbon emission per unit power generation was reduced by 19% in 2014 than 2005.

For years, carbon emission remains the most difficult hurdle for coal-fired power generation. China's carbon emission is estimated to peak in around 2030 and China is trying to speed up the schedule. Given its restriction on coal utilization, control on emission of greenhouse gases is a tough problem for the coal power industry. Therefore, the industry shall continue to raise efficiency and advance the wide deployment of CCUS.

Scott M. Smouse, (EGCFE Chair, Senior Advisor Office of Clean Coal and Carbon Management Office of Fossil Energy U.S. Department of Energy) introduced carbon capture, utilization and storage worldwide at the opening ceremony. He also briefed the audience on Mexico's development of CCS capability, feasibility to deploy CCUS in APEC economies, importance to raise the awareness of carbon capture and storage, and the inclusion of carbon capture into the plan and cost assessment for future coal-fired power plants in APEC economies.

In his presentation titled "High Efficiency to Meet Global Energy and Climate Objectives", Benjamin Sportson, Acting Chief Executive of World Coal Association, said raising coal efficiency was one of the major measures to reduce carbon emission, since 1% increase in thermal efficiency would be equivalent to 2% to 3% decrease of carbon emission. He also noted that with more advanced technologies deployed worldwide, the efficiency of power generation in coal-fired power plants would increase from 33% to 40% while carbon emission would drop by 200 million tons, equivalent to India's annual carbon emission.

Professor Keiji Makino from Japan Coal Energy Center introduced clean coal technologies adopted in Japan's power plants and methods to reduce carbon emissions from coal-fired power plants. Professor Mao Jianxiong from Tsinghua University proposed a roadmap for near zero emission: working on maximum efficiency and co-combustion of biomass and coal, and move towards CCS when appropriate. Currently, the most practical and effective way of carbon emission reduction is to enhance efficiency.

4.4. Female Participation

Having accounted for one sixth of all participants and staff at the Workshop, women are playing an equally important role in boosting efficiency and reducing emissions in coal-fired power generation. Ms. Zhou Junqing is the Chairwoman of the board and President of CR Power Holdings Co., Ltd., whose installed capacity exceeds 40 MW. As the leader of the company, Ms. Zhou heard each presentation and statement and took notes throughout the Workshop. Her earnest and open-minded spirit were praised by the moderator and recognized with a warm round of applause from the audience. Her presentation, moreover, received wide attention.

Ms. Zhou is a symbol of sincerity and wisdom: CR Power Holdings Co.is the first to sign a framework agreement on strategic cooperation with Shenergy in promoting the innovative technology of Shanghai Waigaoqiao No.3 Power Plant. Bearing in mind of risks to promoting new technology at the cooperate level, Ms. Zhou and management personnel and paid three visits to Shanghai Waigaoqiao No.3 Power Plant before choosing CR's Tongshan power plant in Xuzhou to introduce innovative technology of Shanghai Waigaoqiao No.3 Power Plant. Seven technologies from Shanghai Waigaoqiao No.3 Power Plant were adopted and put into operation by the end of November, 2014. More than 277.8 BTU reduction per kilowatt-hour makes the pilot project a successful case of learning from Shanghai Waigaoqiao No.3 Power Plant. The seven technologies, i.e., anti-solid particle erosion, energy efficient steam heating start-up, zero-energy desulfuration, regenerative technology in general, regenerative technology based on recycling steam from the turbine for heating, optimization of air heater, and combination of condensate and feed water for frequency adjustment, are capable of saving energy, reducing emissions and maintaining the effectiveness of the facility through boosting the efficiency of low-load operation and combustion stability. After technical upgrade, each project outperforms Shanghai Waigaoqiao No.3 Power Plant, and the upgrading effect of Tongshan power plant exceeded expectations. Data collected in performance tests by Siemens and Alstom shows a reduction of 13.4 g at 80% of rated load and 18 g at 50% of rated load. Two months after the upgrading, statistics on coal consumption of Unit No. 5 reveal a reduction of 15 g of raw coal. The success in Tongshan Power Plant means that innovative energy-saving technologies from Shanghai Waigaoqiao No.3 Power Plant could be promoted elsewhere.

Under Ms. Zhou's leadership, CR Power Holdings Co. is also minimizing energy consumption and emissions through recycling. It has established the Hezhou Circular Recycling Economy Industrial Park in Guangxi with China Resources Cement and CR Snow. Based on the industry chain of power plant - cement plant- brewery, CR Power built two ultra-supercritical coal-fired power units. The coal ash, slag and FGD gypsum from the power plant are used by the cement plant, which in turn provides limestone powder to the power plant for desulfurization. The power plant will treat and recycle all the water and steam used at the brewery, and co-fire diatomite and yeast slurry. Because of the wastes recycling among different industries, the industry park can achieve a near zero pollutant discharge with total energy saving equivalent to 290,000 tons coal. In addition to the reduction of 730,000 tons carbon emission, 60,000 tons sulfur dioxide emission, and 4250 tons NOx emission, the park generates about 194 million RMB benefits. In 2014, the industry park was named "National Education and Demonstration Park for Recycling Economy" by four Ministries, including the National Development and Reform Commission.

Ms. Zhao Min, deputy chief engineer of Electric Power Planning and Engineering Institute,

presented a paper titled Status and Trend of Fossil Fuel Power Generation Technology in China at the Workshop. Supported by comprehensive data, this paper gives a detailed description of China's current situations and effort in (ultra) supercritical power generation, combined heat and power generation, CFB generation, IGCC generation, pollutant discharge control, carbon capture and storage, optimized design and upgrading of existing power plants. Ms. Zhao's paper also proposes practical solutions to problems facing China's coal-fired power plants.

Women formed a large part of the service team for this Workshop. Xu Meijuan, Wang Ping, Liu Maoying, Wang Suyan, Wang Zhumeng, Wang Lei and many more women were highly appraised by experts and representatives for their contribution in the work and support to this project.

V Further work on Enhancing Coal-fired Power Generation Efficiency and Clean Combustion

5.1 Further Promoting the Innovative Transformations on Energy Saving and Emission Reduction for CCP Plants.

The innovative technologies of energy saving and emission reduction for coal-fired power plants applied in Shanghai Waigaoqiao No.3 Power Plant have been successfully adopted by China Resources Xuzhou Tongshan Power Plant. After 7 technical modifications, Tongshan Power Plant achieved significant results in energy saving and emission reduction by lowering over 10g coal consumption for producing 1 kWh. China Resources Power Group, Shenhua Group and China Datang Corporation all have singed a framework cooperation agreement to promote the innovative technologies of Shanghai Waigaoqiao No.3 Power Plant. All three groups have a coal-fired power capacity of over 200GW, accounting for 1/4 of the whole capacity of China, indicating that a huge impact will be caused on the revolution of energy saving and emission reduction in power industry. In order to accelerate the promotion of new technologies, CERS is looking for the support of National Energy Administration to organize a meeting to address issues of technical exchanges, policy supports and business modes.

5.2 Initiating the Pilot Project of "High-Low-Split-Shaft High Efficient USC Power Generation Technologies".

The "high-low-split-shaft highly-efficient USC power generation technologies", invented by Professor Feng Weizhong of Shanghai Shenergy Energy Technology Co., Ltd, features a unique "high-low-split-shaft technology" which can significantly shorten high-temperature and high-pressure lines, not only helping cut line costs, but also bringing down drag and heat loss. It raised unit efficiency and broke through double reheat and 700℃ technical bottlenecks. Based on the current 600℃ high-temperature materials and USC technology, as well as optimized 1350MW capacity and double reheat design, this technology can raise unit capacity by 5% and reducing coal consumption for power generation to the remarkable 251g standard coal/kWh without increasing the manufacture cost of unit. The net efficiency of unit is 48.92%, much higher than the next-generation 700℃ USC unit being developed by foreign countries. National Energy Administration already entrusted China International Consultant Co.,Ltd. to discuss about Technical Program of New Highly-efficient Clean Coal Power Generation of Shenergy Energy Technology Co., Ltd. On 13 April 2015, National Energy Administration entrusted Electric Power and Engineering Institute to evaluate the program of "high-low-split-shaft advanced clean power generation project" submitted by Shenergy Energy Technology Co., Ltd. The overall feasibility of the demonstration project was assessed from the perspective of location and layout, national policies, coal-fired power industry and balance of electric power and energy. The conclusion was submitted in written form along with the experts' suggestions on facility location. The project has been launched.

5.3 Expanding Industrial Boiler CHP Pilot Projects.

The "systematic solution of energy saving and emission reduction for industrial boilers" proposed by CERS on the forum has been widely adopted in pilot projects with the support of authorities. Back-pressure CHP will be developed based on "ordering-electricity-by-heat" principle. The coal consumption for power supply of back-pressure unit can reach 160g standard coal, equivalent to half of the average coal consumption of coal-fired power plants across the country. There are about 6million t/h industrial boilers in China. If all of them adopt back-pressure, the whole capacity can increase by CHP 600,000-900,000 MWe, which is even more than all the current capacity of top 5 coal-fired power groups in China. All of these capacities are located in load centers, so the power generation matches the use of power by industrial users who can directly consume the power. Without the necessity of building long-distance grid and the trouble of losing power on transmission lines, the effect of energy and water saving is very remarkable.

5.4 Implementing "One Belt And One Road" Strategy by Studying and Exporting Highly-efficient Power Generation Products and Technologies.

With China's economy rapidly growing, the manufacture leader in the world will be able to provide more technologies and equipment to the world. By applying the mature innovative technologies and experiences of Shanghai Waigaoqiao No.3 Power Plant in the manufacture of large power generation equipment, we can export the most efficient power generation equipment and technologies to the countries on the Silk Road economic belt. We will organize a consortium consisting of investors, technology providers, design companies and equipment manufacturers to invest and build power plants in countries and regions on the Silk Road economic belt, with the capital of Asian investment banks and China Development Bank. We can also help developed countries such as the United States or Britain modify power plants or build demonstration power plants, to make our contributions to the efficiency improvement and clean use of coal in coal-fired power plants in the world.

5.5. Assisting NDRC in compiling Guidance on Promoting Clean Coal Power Generation.

Since last year, National Energy Administration released action programs to improve coal power efficiency and reduce emission, such as National Program of Upgrading and Modification Actions for Energy Saving and Emission Reduction in Coal-fired Power Plants (2014-2020) and Program of Actions on Clean and Efficient Use of Coal (2015-2020). To accelerate the implementation of those action programs, NDRC is entrusting CERS to draw up Guidance on Promoting Clean Coal Power Generation, which is progressing now. Guidance on Promoting Clean Coal Power Generation defines the special position of coal power in the big picture of energy use in China, the relationship between coal power and clean energy, the significance, necessity and leading role of coal power in coal use, the function and significance of developing clean coal power to environmental protection and carbon emission, the relationship between coal power and haze, market revolution of electric power, and the influence of economy (power price) on the clean development of coal power. China

will also work out incentive policies and measures for energy industries related to clean coal power generation.

VI The Summary of Speeches during the Workshop

Topic of Speech: Save Coal to Generate More Power
Speaker: Huang Yicheng, Former Minister of Energy
Key points: Coal-fired power plants in China accounts for 70% of electricity installed capacity and generate 80% of electricity. To lower CO_2 emission and change the structure of power sources, we need to lower the proportion of coal-fired power by vigorously developing nuclear power, hydropower, wind power, solar power, and biomass power. However, as the majority of power plants in china are coal fired, it is hard to change the situation in a short term. Therefore, we should strive to reduce coal consumption to realize the goal of generating more power with the same amount of coal. To this end, coal fired plants should be upgraded in the following four aspects. Ⅰ. Upgrade existing power plants and set up new ones with available technologies and management experience. Ⅱ. Take advantage of the latest technologies to upgrade 200MWe generator units and even smaller ones. Ⅲ. Develop more efficient power generator units, and raise steam parameters. Ⅳ.Transform industrial boilers, and develop CHP to save coal.

Topic of Speech: Expert Group on Clean Fossil Energy (EGCFE) Overview
Speaker: Mr. Scott M. Smouse, EGCFE Chair, Senior Advisor, Office of Clean Coal and Carbon Management, Office of Fossil Energy, U.S. Department of Energy.
Key points: Mr. Smouse made an overview of "APEC Expert Group on Clean Fossil Energy (EGCFE)". Who introduced "what is APEC" and "Energy Working Group (EWG)", as well as what the "Expert Group on Clean Fossil Energy (EGCFE)" is doing:
Coal-Based Power Generation and Conversion - Saving Water.
APEC Forum: Improving the Energy Efficiency of Coal-fired Power Plants & Reducing the Air Pollutants Discharge.
Initiative for Deploying Advanced Clean Coal Technologies (CCT Deployment Initiative): Phase 1.
Comprehensive Integration and Optimization of Coal-Based Clean Power and Chemicals Multi-Generation (CBMG).
Maximizing the Energy Efficiency and Clean Utilization of Low Rank Coals through Innovative Technologies in APEC Economies.
Comprehensive utilization of coal resources through recycling technology.
Best Practices in Environmental Monitoring for Coal-Fired Power Plants: Lessons for Developing Asian APEC Economies.
Technology Status and Project Development Risks of Advanced Coal Power Generation Technologies in APEC Developing Economies.
Carbon Capture, Utilization and Storage:
APEC Expert Workshops on CCUS-EOR.
CCS Capacity Building in Mexico.
Feasibility of accelerating the deployment of CCUS in developing APEC economies.
Increasing the Knowledge and Awareness of Carbon Capture and Storage: Capacity-Building in the APEC Region - Phase V .
Promoting Technologies of CCUS in APEC Developing Economies.
Permitting Issues Related to Carbon Capture and Storage for Coal-Based Power Plant Projects in

Developing APEC Economies.
Assessment of the Capture and Storage Potential of CO_2 Coproduced with Natural Gas in South-East Asia.
Planning and Cost Assessment Guidelines for Making New Coal-Fired Power Generation Plants in Developing APEC Economies CO_2 Capture Ready.
Unconventional Gas:
APEC Unconventional Gas Census Expert Workshop (EWG 16 2011).
APEC Unconventional Natural Gas Census (EWG 01/2013).
Fossil Fuel Subsidies:
Phasing Out Fossil Fuel Subsidies to Reduce Waste and Limit CO2 Emissions while Protecting the Poor (EWG 11/2010).
Mr. Smouse concluded that: Coal-Fired Power Generation Efficiency of APEC economies has gained big increase in the last years:
Coal-fired power generation efficiency around world ranges from low of 26% in India to high of 43% in France (net LHV basis, 2010 data).
U.S. and Japan's coal-fired power plant efficiency has been flat.
China dramatically improved its efficiency by closing many small, old inefficient units while building new, large, more efficient units.
Korea dramatically increased its efficiency by building new more efficient units.

Topic of Speech: Protect intellectual property, support innovation development
Speaker: Zhang Maoyu, Assistant Commissioner of SIPO
Key points: Stimulation of innovation development: IP, IP Situation of energy and electric power industry, IP and development of coal fired power industry. Innovation environment of China has been improving, the Outline of National IP strategy was released in 2008, Further implementation of National IP strategy active plan (2012-2020) was started from 2014. The amount of patent application and patent valid of China has been fast growing. IP situation of energy and electric power industry, the relationship of IP & development of coal fired power industry.

Topic of Speech: The thinking of clean and highly-efficient development of coal fired power in china
Speaker: Wang Zhixuan, Secretary general of china electricity council
Key points: Development status of the clean and highly-efficient use of coal fired power in china and major achievements. The role and functions of coal fired power in energy revolution. The prospect of coal fired power in china. Coal is the dominant source of China's energy consumption and electric power consumption. Laws regulations and policies structure of thermal power plant environment protection. Main reasons for the clean and highly efficient use of coal fired power are: requirements on the efficiency and coal consumption of coal fired power units, emission control requirements and CO_2. The main measures of the highly efficient use of coal fired power wre introduced. Some policy suggestions were proposed.

Topic of Speech: Clean coal power generation: current challenges and future opportunities
Speaker: Dr. Andrew Minchener, OBE general manager, IEA clean coal center
Key points: Overview of the IEA clean coal center activities. Coal within the global energy mix.

HELE challenges to reduce carbon intensity. Clean coal power flexibility. Advanced HELE drivers through to 2030. Clean coal technology must be the way forward to ensure efficient use of coal with low environmental impact. Focus is on the power sector, but also needs to address key non-power sectors. Many non-technical challenges to be overcome. Role of IEA clean coal center to provide independent, objective advice on all aspects is increasingly important.

Topic of Speech: Road for clean and efficient utilization of coal in china
Speaker: Ni Weidu, Academician of Chinese Academy of Engineering, Prof. of Tsinghua University
Key points: Severe situation of energy and environment. Clean and efficient transformation of coal. ways of clean coal technology, advanced coal fired power generation technology, e.g. Shanghai Waigaoqiao Third power plant. IGCC. Coal based poly-generation technology. How to make good use of 100~129 billion tons of standard coal in China from 2015 to 2050. Clean coal technology is doomed to be the most important solution for the reduction of CO_2 emission in China after 2030. The unchanging situation of coal in China is that coal remains to be the main energy resource in China now and future.

Topic of Speech: Innovate into the future in a green and responsible manner
Speaker: Ms. Zhou Junqing, President of China Resources Power HLGs Co. Ltd.
Key points: CRPH's innovation green development practices are highlighted by " 3 optimizations": optimize business portfolio & installed capacity mix under innovative models to establish a pattern of green development, optimal designs with high starting points, to ensure top quality environmental facilities for new generation units. Optimize technologies for high standard operations to promote the green revolution over traditional energy. Ms. Zhou shared with audiences that the practices and experiences of what CR power has been doing in green development through energy conservation and emission reduction. CR power acknowledge that the trinity of "development, construction and operation" by the "3 optimizations" with an aim at green growth through energy conservation and emission reduction, is just CR's responsibility and undertaking to the community.

Topic of Speech: Exploring on the development of high efficiency green coal fired power technology
Speaker: Feng weizhong, Shanghai Waigaoqiao third power plant Co. Ltd.
Key points: The main approaches to develop high efficiency coal fired power. Higher temperature and pressure of steam, IGCC, better maintenance on the plant. Coal should not be a dirty energy, it can be made to be a more clean, more environmental friendly energy. A series innovative technology for improving efficiency and reducing pollutants emission have been developed and implemented in Shanghai Waigaoqiao third power plant Co. Ltd., which has improved the power generation efficiency of the plant to be 46.5%, and has reduced the pollutants emission to be: $NO_X < 17gm/Nm^3$, $SO_2 < 18mg/Nm^3$, Soot $< 8mg/Nm^3$. The next generation of coal fired power plant technology was shown that the two stage USC with high position back pressure turbine and lower position Subcritical turbine could left the net power efficiency to be 49% when the steam temperature is 600℃, and even 52% when the temperature is 700%.

Topic of Speech: Introduction to SPC single tower integrated desulfurization and dust removal deep purification technology (SPC-3D)

Speaker: Zhang Kaiyuan, Beijing SPC environment protection tech. Co. Ltd.
Key points: Main features of SPC-3D technology, integration, high efficiency, low energy consumption, lower investment, simple operation, high flexibility, short engineering term. It has been applied in several power plants, e.g. Yungang power plant. The SPC-3D technology best satisfies actual needs of enterprises, which can save energy by 16%. At the meantime , it can control the exit pollutants density to below 35mg/Nm^3 of SO_2 and 5mg/Nm^3 of soot. Compared to the investment of conventional technology, SPC save cost by 40%, and the engineering time for upgrading a conventional facility is only 1 month, the operation cost is only 20~30% of that of a conventional technology. Complete elimination of the "gypsum rain" band generated by the wet desulphurization system

Topic of Speech: A call to action on high efficiency coal to meet global energy and climate objectives
Speaker: Benjamin Sporton, World coal Association
Key points: coal is a key energy resource in the ongoing global fight to address energy poverty. As the world population grows, coal will continue playing an essential role in global energy supply. Cleaner coal technologies have addressed environmental challenges. Efficiency improvements can significantly contribute to CO_2 emission reductions. The potential impact is significant in a global context. A global platform to drive HELE technology is needed. Which is why we are presenting the PACE concept: a global platform for accelerating coal efficiency.

Topic of Speech: Key technologies of automation equipment control system for large scale USC power generator units
Speaker: Liu Jizheng, President of North China power University
Key points: A state-of-art automation control system has been developing to improve the work condition efficiency of 1000MW power units. In 2006, the major project automation control system was listed by the State Council as one of the 16 major equipment localization. In 2011, the localized automation control system was put into use in the 2*1000MW USC power units of the State Power Jianbi power plant, after the power units started operation, the units has been continuously running for 230 days, which was the best record of the same units. The automation system has passed through the check before acceptance of the State Energy Bureau and China Mechanic and Electric Engineering Association, the acceptance conclusion is that the design idea of the control system is advanced, complete function, high availability, generally the level has matched civil top level, a part of the system has matched the international top level.

Topic of Speech: The status and development prospect of circulating fluidized bed (CFB) technology for power generation in china
Speaker: Yue Guangxi, Miao Jianxiong, Huang qili
Key points: it is very significant for CFB technology in china to control emissions and to convert low grade coal of mining and washery waste to power. China has grasped 300MW subcritic CFB technology from design to manufacture, installation and operation. For 600MW SC CFB boiler, which is a good example to show how china could develop such a big size SC CFB by going through the cooperation and innovation between manufacturer, university, and research institute. Both 600MW SC CFB and energy saving CFB are advanced technology with world leading level.

Development direction of CFB: CFB technology originally is a low cost technology for SO_2 and NO_X emission control, but the most new serious emission limits issued in 2013 came up an unprecedented challenge for CFB technology. Another challenge for CFB is the new requirement of cost consumption for power generation. So today, CFB in China is facing the challenges for both emission and efficiency. Based on these challenges, the development of CFB in China during the 13-five-year-plan(2016-2020) will focus on the projected 600MW USC CFB technology with low cost ultralow emission, energy saving and high efficiency, which can compete with SC PC boiler for energy saving and emission control.

Topic of Speech: Enhance application of Siemens large USC steam turbine
Speaker: Rainer Quinkertz
Key points: Siemens modular steam turbine portfolio serves as proven design basis for further development of USC technology. (Advanced) Double reheat application significantly drives efficiency and feasibility has proven i.e. only design development required. 700℃technology still requires research to prove feasibility. Flexibility features for SPP ensure competitiveness in changing market environment (growing share of renewables). (advanced) double reheat is the next evolutionary step for USC power plants.

Topic of Speech: Approaches to improve the efficiency of coal fired thermal power plants.
Speaker: Wang Fan, Energy saving % emission reduction center of CERS
Key points: CERS is putting great stresses on the following aspects to improve the efficiency of coal fired thermal power plants. The first to promote the demonstration projects of split cylinders arrangement and high efficiency USC power generation technologies. The second is to promote innovative energy conservation technologies and upgrade existing power plants with new technologies. The third is to promote cogeneration of heat and power with industrial boilers and construction of clean coal fired DES. The spilt cylinders arrangement and high efficiency USC power generation technology can increase the power generation efficiency by 5% without any additional cost, so that at steam temperature 600℃, the net power efficiency reaches 48.92%, account for standard coal consumption 251g for per kWh. By upgrading existing power units with state-of-the-art technologies, the coal consumption rate of subcritical power units could be reduced to below 300g/kWh. By building DES with industry boilers, more than 600 million kW power capacity would be set up in the future, these CHP adopt back pressure turbines, so the coal consumption rate of power generation could be as low as 160g/kW./

Topic of Speech: United States research & development for coal power efficiency
Speaker: Dr. Jeffrey N Phillips, senior program manager, Electric power research institute
Key points: coal power plant heat rate can be improved by increasing the temperature at which heat is recovered in the boiler, –requires use of nickel alloys now Beijing tested by US department of energy and state of Ohio consortium. Heat rate can also be improved by recovering low temperature heat. United States experience shows that using more coal power does not have cause dirtier air, -EPRI has assisted Great River Energy (GRE) in the developing of the Dry Fining process which upgrades low rank coal using temperature heat. United States experience shows that using more coal power does not have to cause dirtier air,-Highly effective emission controls for NO_X, SO_2, particulates and mercury are now well proven.

Topic of Speech: Status of clean coal technology for power generation in Japan
Speaker: Keiji Makino, Senior follow, Japan coal energy center
Key points: A comprehensive introduction on clean coal technology in Japan. Coal should be used as a main fuel in the future, however, consideration should be paid to reduce air pollution and GHG emission in order to continue using of coal. Now high efficiency coal power generation is essential. Coal power accounts for 22% of total power supply in Japan, coal power have been operated almost fully for base load. Japan's coal policy is that : coal will continue to be important part of energy source diversification in Japan, ensure sustainable power supply, and promotion of utilization – efficiency improvement. Coal fired power generation capacity in Japan is 37.7GW. New Isodo power plant Unit No.1&2 USC 600MW will demo net efficiency of 45%, reduce CO_2 by 17%, the pollutant emission will be lower that SO_2(10ppm), NO_X(13ppm), PM(5ppm).

Topic of Speech: Exiting and future coal fired power in Vietnam where the energy mix is dominated by coal
Speaker: Prof. Dr. Sc. Nguyyen Si Mao, Hanoi University of Science and technology Vietnam
Key points: A comprehensive introduction of coal fired power industry in Vietnam. In the present report the essential subjects of the production of electricity, production of coal in the energy balance of supply and demand in Vietnam for over 20 years. In this in-depth analysis of the advantages and difficulties face by the use of the development of Thermal power plants. Introduce some properties of Vietnam coals using in Vietnam thermal power plants. Introduce some operating parameters of the coal fired power plants in Vietnam, the existence and efficient operation of power plants. And some orientations of coal firing thermal power plants in the future development plans of electricity to 2030. Discuss cooperation possibilities to use advanced technology in the project development of new coal thermal power project as well as the upgrading of coal thermal power plants coming. Restructuring and divestiture strategy for Vietnam electricity generation companies. Some recommendation was proposed.

Topic of Speech: Current effective way to reduce CO_2 emissions for coal fired power plant
Speaker: Mao JianXiong, Prof., Tsinghua University
Key points: As the largest energy consumer and CO_2 emitter, how to fulfill China's promise to achieve peak value of CO_2 emission by 2030, China is facing big challenge to reduce CO_2 emission, especially for coal fired power sector. For the major ways to reduce CO_2 emission from coal fired power plants, CCS is the only technology which can reduce over 90% CO_2 emission, but not only CCS has not been commercialized and need more development and demonstration, but also due to its high energy penalty and high cost, for China with such a big coal power capacity, when and how to use CCS to reduce CO_2 emission in large scale are very much uncertain at present. Co-firing biomass is limited by resources and depended on incentive policy. It is also uncertain to use co-firing biomass for CO_2 reduction today. Therefore, the only realistic and feasible way to reduce CO_2 emission is to improve efficiency for coal fired power generation as high as possible. Shanghai Waigaoqiao 3 power plant has demonstrated that for steam cycle power plant, even for 1000MWe USC unit with very high efficiency, there is still a big potential for further improve net efficiency drastically to reduce CO_2 emission. Since WGQ3 was put into operation in 2006, its net efficiency has been improved from design figure of 41.6% to 46.5%, and specific net coal consumption

reduced from design figure of 295 gce/kWh to 276 gce/kWh. The reduction of coal consumption was 19 gce/kWh, which is equivalent to reduce specific CO_2 emission for 50 gCO_2/kWh, total average generated electricity for WGQ3 is 12 billion kWh per year., which means the annual reduction of total coal consumption for WGQ3 is 228000 tons of standard coal and annual reduction of CO_2 emission is 600000 tons of CO_2, WGQ3 ‘s experience is the direction of CO_2 reduction for USC power plant.

Topic of Speech: Status and trend of fossil fuel power generation technology in China
Speaker: Zhao Min, Electric power planning & Engineering Institute
Key points: Overview of China’s power industry. Status of coal fired power industry in China, problems and solution of coal fired power industry. Development tendency of China’s coal fired power industry. China’s installed coal fired power generation capacity was 862 million kW in 2013, it is estimated that by the end of 2020 the capacity would reach 12200 million kW. China has been promoting the optimization and upgrading of fossil fuel power plants, the average coal consumption keeping on decreasing to be 321g/kWh by the end of 2013, and the amount of 1000MW power units has been 63. Pollutants emission control will follow more strict rule, the limits:dust(5mg/Nm^3),SO_2(35mg/Nm^3), NO_X(50mg/Nm^3)

Topic of Speech: Integrated optimization system for CCP plant ---F-GEN clean coal fired power plant model
Speaker: Mark Wu
Key points: An introduction of F-GEN clean coal power plant model, and technology transfer, as well as business model. The LAD company was founded in 1999 in Beijing, which is devoted to the R&D, introduction, and promotion of high tech products in coal fired power plant. Provide overall and professional solutions of energy saving and emission reduction for coal fired power plant.

Topic of Speech: Clean coal energy for China
Speaker: Airborne China ltd.
Key points: Airborne process converts pollution into fertilizers, pollution removals of SO_2, SO_3, NOx, dust and Hg are near 100%. The technology is economical and profitable in China. Airbone developed an integrated multi-pollutants control technology that removes SO_X, NO_X, Mercury, PM, etc, from coal combustion. The pollutants removal system are sodium based which have globally been proven to be highly efficient at mega scale (up to 3 GW in US). Airbone has patented a sodium regeneration technology that drastically lowers operation costs co-producing ammonium based fertilizers which is an additional revenue product.

Topic of Speech: Energy and water reservation innovation technology dry cooling and wet cooling complementary system of power plant
Speaker: Li Junfeng
Key points: At a power plant with dry cooling and wet cooling unit parallel operated, in summer, a part of the load of dry cooling unit is transferred to wet cooling unit. In winter, a part of the load of wet cooling unit is transferred to the dry cooling unit, so that coal is saved in summer, and water is saved in winter.

Topic of Speech: Getting water from lignite technology for high efficiency power generation
Speaker: Pei yufeng, Northeast electric power design institute
Key points: GWFL is an integrated innovation technology which combined boiler body system, coal drying and pulverizing system, and exhaust water recovery system scientifically. Getting water from lignite (GWFL) for high efficiency power generation technology has been developed out, which couples coal fired power generation technology with lignite drying and heat and water recovery technology. GWFL is s an integrated innovative technology which combined boiler body system, coal drying and pulverization system, and exhaust gas water recover system. Which can achieve "Zero water makeup" for lignite air cooling units and reduce coal consumption of power generation.

Topic of Speech: High efficient subcritical comprehensive upgrading technique
Speaker: Liu Yanpeng, China Datang group
Key points: A new solution to upgrade the sub-critic power units to higher efficiency is introduced, which reduce coal consumption of per kWh by more than 15g. A comprehensive upgrading and reforming technique for subcritical power units has been developed at China Datang Corporation Science and Technology Research Institute, which will escalating main and reheat steam temperature of subcritical units from 540℃ to 570℃, and the steam pressure remain unchanged. The boiler and steam turbine will be retrofitted. The engineering would be finished at the end of Oct of 2015.

Topic of Speech: R&D of advanced superalloys for application of 700℃ A-USC boiler tubes
Speaker: Y. Gu, etc, R&D center, TPRI
Key points: an introduction the R&D of the superalloys which is used as boiler tubes at 700℃ at TPRI. Targets of the alloys for A USC component is that 100000 hrs at 700℃/100MPa.

Topic of Speech: Advanced online monitoring technologies
Speaker: Yang Daming, GP Strategies corporation
Key points: an introduction of EtaPRO, techonology and economy. The EtaPRO technology can bring benefits to the customers of reducing fuel consumption by 1~3% while reducing carbon emission. Payout occurs usually in less than 2 years, detect early faults & impending failures before critical, shift from unplanned maintenance to planned outages, protect EFOR by early detection, be aware of unidentified problems & hidden threat.

Topic of Speech: Study on coal staged conversation and clean power generation technology
Speaker: Luo Zhongyang, etc. Zhejiang University
Key points: coal staged conversion and clean power generation technology has greater significance to China. One hand, it was suitable to the comprehensive utilization of coal to improve efficiency, on the other hand, it can get some oil, and gas, as well as to ease the tremendous burden of environment problems caused by coal burning. From the realistic and strategic view point of coal staged conversion and clean power generation, the technology is related to the coordinated development of Chinese society, economy, energy and environment. Development of coal staged conversion and clean power generation technology is expected to have significant economic environmental and social benefits.

VII CCT Deployment Discussion

At present, clean coal technology development and project development, in many APEC economies, are to be concerned increasingly, some of the mature clean coal technology have won the market recognition, which are applied in coal-fired power plant, also some advanced clean coal technology is being researched in laboratory, or carried out industrialization demonstration projects. All these clean coal technology and project progress and information should be traced and collected by a specifically responsible team under the leadership of the clean coal workgroup of APEC organization, and the team should analysis the project information and timely dissemination the project information and the analysis to the member states and regions, so that all of the member states and regions could share the CCT results, thus the popularization and application of clean coal technology could be speed up.

An analysis of deployment issues are discussed in this section.

7.1 Generic Issues for Developing APEC Economies

Technology	Deployment issue
CCS	CCS is high energy consumption, high cost, and high water consumption system, and a large set of equipment, which will decrease power efficiency by 10%, cost by 65$/t, and increase water consumption by 100%. CCS equipment requires large space and area for installation. A CCS set will occupy a bigger area than that of the whole equipment of a power plant. CCS A on line monitoring system must be installed to ensure the safety of CO_2 sequestration
IGCC	China Huaneng Group has set up an IGCC demo project in Tianjin, in 2014 the Tianjin IGCC power plant was operated by 5000 hours, up to new, the net efficiency has reached 45%. Next step: To continuously improve the performance of the main equipment and systems in IGCC technology, improve the availability and reduce the cost. To develop large capacity, high performance, wide adaptability and wide adaptability of coal gasification furnace To develop new type of air separation

	technology with higher efficiency, larger scale and lower cost. To develop larger capacity gas turbine with higher beginning temperature, the higher the efficiency of 52%. To develop high temperature gas purification equipment. To optimize IGCC Technology systematically and integrated. To develop a poly-generation energy system by combination of other industries with IGCC power generation. An important development direction of IGCC system is that with IGCC and coal gasification technology as a leader, the plant is to produce electricity, heat, and a variety of chemical products.
700 USC coal fired power generation technology	China Huaneng Group has being set up the first test platform. To develop 700 ℃ ultra supercritical superheater / reheater tube of high temperature alloy. High temperature alloy is the most important material basis for developing 700 A-USC coal and electricity technology. The safe and reliable operation of 700 DEG ℃ A-USC thermal power units serving under higher temperature and pressure creep properties of materials, welding performance, antioxidant and corrosion performance, fatigue performance and organizational structure of the stability of proposed more stringent requirements.
USC PF	High efficiency supercritical ultra-supercritical (USC) pulverized coal firing power generation technology should be the main coal fired units. To develop high temperature, high pressure steam system. To develop larger capacity power unit.
USC CFBC	The first USC CFBC coal firing boiler has been set up at Baima power plant by China Dongfang boiler group co. ltd at Feb. 24 of 2013, and it was full loaded at April 14 of 2013. The boiler efficiency is 91.67%, higher efficiency is expected. The NOx emission and SO_2 of flue gas lower

	than 200mg/Nm^3 and 400mg/Nm^3, respectively. More operation test and optimization work should be done.
Cross-compound Arrangement of Elevated Turbine-Generator Unit Technology	The concept design has been finished, the first unit is projected be set up at Shanghai Waigaoqiao No.3 power plant before 2018, which net efficiency will reach 48.92% with turbine inlet steam temperature of 600℃ ,and the power output is 1350MWe.
Getting Water from Lignite Technology for High-Efficiency Power Generation	Water shortage is a bigger challenge for power industry in China, to get water from coal can save large amount water. The concept design has been done, a demo project is needed to verify the technology.

7.2 China – specific Issues

Technology	**Deployment issue**
CCTs (generic)	China's energy resources and its consumption structure, make that China's current status of relying on coal can't be changed in a short time. From the reality that China's pressure of environmental protection continues to increase, also combining the increasingly severe environmental protection requirements, China has made various effective environmental protection measures regarding energy consumption and pollutants reduction, China has being promote CCT innovation and international cooperation, as well as taking the initiative in using various effective green environmental protection measures, thus to make conventional coal fired power plant as a highly efficient, clean and environmental-friendly green energy and continue to serve for human kind. China National Development and Reform Commission, the Ministry of environmental protection, the National Energy Bureau, the three ministries jointly issued the "coal and electricity energy saving and emission

	reduction and upgrading of the action plan (2014 - 2020)" (hereinafter referred to as "action plan"). The action plan has proposed that the national new coal-fired generating units average power supply coal consumption of less than 300 grams of standard coal / kWh (hereinafter referred to as the "g / kWh"); by 2020, existing coal-fired generating units of average power supply coal consumption of less than 310 grams / kilowatt. In the implementation of more stringent energy efficiency standards for environmental protection of the premise, to 2020, and strive to make the coal accounted for a ratio of total energy consumption is decreased to be less than 62%, coal of power plants accounts for total coal consumption, the proportion increased to more than 60%. In the eastern region of China, new coal-fired generating units for the discharge of atmospheric pollutants concentration should reach the gas turbine set emission limit values, in the central region, new units close to or to reach gas turbine set emission limit values, and in the western region new units are encouraged to close to or reach the emission limits of gas turbine.
USC PF	To develop 700℃ of steam parameter power unit To develop Cross-compound Arrangement of Elevated Turbine-Generator Unit Technology, and a demo project with capacity of 1350MW in being projected at Shanghai Waigaoqiao No3 power plant. To building more USC PF units in near future so that small and lower efficiency power units can be replaced, big one replaces small one.
USC CFBC	The 600MW USC CFBC unit has been set up, and put into operation. Systematically optimization is being undertaking.
IGCC	Huaneng Tianjing IGCC demo project has been optimized and more experiences will be collected, to prepare for the next generation

	IGCC
CCS	Huaneng CCS pilot plant has been set up at Beijing thermal power plant.
CHP	There is a large amount of industry steam and hot water demand for some 6 million tons per hour, cogeneration of heat and power can by-produce a large amount of electricity with much lower coal consumption. CHP has been encouraged by China, but not enough.

7.3 Generic Technology Issues

7.3.1 USC

As more and more USC units are set up in China, the specific coal consumption of power in China has been decreased from more than 360g/kWh to less than 321g/kWh.

To realize USC unit of higher temperature and pressure steam parameter, international cooperation is necessary, APEC fossil fuel group could contribute to the international cooperation for higher efficiency USC development.

7.3.2 IGCC

China has set an IGCC demo plant in Tianjing, the emissions performance and efficiency have met the expectations, the efficiency has reached 45%, but two major barriers has influenced IGCC, first is cost, second is reliability.

7.3.3 CCS

Up to now, CCS is a kind of energy intensive, expensive, and land costly CO_2 capture approach, it is hard to gain public acceptance, and it's hard to compete with other kind of CO_2 reduction technology.

VIII Conclusions and Recommendations

8.1 Summary

China have planned to promote coal firing power generation efficiency by more than 10% over the next 20 to 30 years, to meet the expected decrease of CO_2 emission, as well as to promote ultra-low air pollutants emission program. So CCT is urgently needed by Chinese market.
Although more and more renewable energy sources and nuclear power will be adopted by China, coal is expected to remain as dominant important energy sources in the coming decades.

8.2 Conclusion

This workshop is all about efficiency. In the last day and a half we have 25 excellent presentations, covering a wide range of topics including upgrading existing plants, such as reforming subcritical plants to supercritical or ultra-supercritical plants, designs for new state-of art plants, all supercritical 600C and higher with double reheat technology. And also, we heard research on the next generation technologies, such as advanced ultra-supercritical materials over 700C. We also have a few presentations on environmental issues, emission control technologies, and an effort to reduce cost and eliminate waste. We also have heard coal drying technology to improve overall plant efficiency.
As Professor Mao explained in his second presentation, all these efforts have been driven by the need to not only conserve energy resources but address the biggest remaining challenge to continue long-term use of coal, which is climate change. That means the efficiency to reduce CO_2 emission is critically important. The coal community worldwide must continue to work to events like this various forum, not only APEC but the IEA Clean Coal Center leadership forum and many other venues and organizations to share our information about the latest technology developments, to share information on best practices, and to begin to collaborate more deeply on advanced research technologies which is critical to the continued use of coal.
It must pointed out that pushing efficiency is not the final answer, we must also continue to work and redouble our efforts to reduce the cost carbon capture storage, because many organizations worldwide have looked at it and said that we cannot reach our climate goals without CCS and in fact coal with CCS is critically important to reaching climate goals.

8.3 Recommendations

APEC should support China in deploying more CCTs to improve the power plant efficiency and reduce coal consumption, as well as reduce CO_2 emission.
APEC should support member countries and regions with educations programs on the latest generation of CCTs, through workshops and some training courses to consider the next generation of coal-based energy facilities.

Annex A: Technical Data of Shanghai Waigaoqiao No.3 Power Plant in 2014
Annex B: Status of power plants with over 1000MWe capacity in China

Annex A: Technical Data of Shanghai Waigaoqiao No.3 Power Plant in 2014

Coal consumption: Coal consumption at 7722.3 BTU/kWh for an aggregate load of 73.88%, on par with the annual plan.

Power consumption：aggregate power consumption at 2.93% after taking desulfurization and denitration into consideration, 0.57% lower than the annual plan.

Environmental protection：average emissions of two units were: SO_2 29.04mg/m³, NO_X 24.25mg/m³, rate of denitration 99.75%, composite denitration efficiency 86.92%；dust 10.41mg/Nm³

Total for 2015:

Coal consumption:7580.3 BTU/kWh, aggregate power consumption:2.47%, SO_2:15.11mg/Nm³,NO_X:17.2mg/Nm³, and dust 8.41mg/Nm³.

Annex B: Status of power plants with over 1000MWe capacity in China

No.	Power Plant	Nameplate Capacity MWe	Commissioning Year	Fuel Type	Nominated Main Steam Pressure (MPa)	Nominated Main Steam Temperature (℃)	Boiler Manufacturer	Turbine Manufacturer	Motor Manufacturer
1	Huadian Laizhou Power Generation Co., Ltd.	1050	2012	Bituminous coal	25.5	600	Dongfang Boiler	Dongfang Turbine	Dongfang Electric Machinery
2	Huadian Laizhou Power Generation Co., Ltd.	1050	2012	Bituminous coal	25.5	600	Dongfang Boiler	Dongfang Turbine	Dongfang Electric Machinery
3	Tianjin SDIC Beijiang Power Plant	1000	2009	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
4	Tianjin SDIC Beijiang Power Plant	1000	2009	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
5	Huadian International Zouxian Power Plant	1000	2006	Bituminous coal	25	600	Dongfang Boiler	Dongfang Turbine	Dongfang Electric Machinery
6	Huadian International Zouxian Power Plant	1000	2007	Bituminous coal	25	600	Dongfang Boiler	Dongfang Turbine	Dongfang Electric Machinery
7	Suizhong Power Generation Co.,Ltd	1000	2010	Bituminous coal	25	600	Dongfang Boiler	Dongfang Turbine	Dongfang Electric Machinery
8	Suizhong Power Generation Co.,Ltd	1000	2010	Bituminous coal	25	600	Dongfang Boiler	Dongfang Turbine	Dongfang Electric Machinery

9	Guodian Jianbi Power Plant	1000	2011	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
10	Guodian Jianbi Power Plant	1000	2012	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
11	Guohua Xuzhou Power Generation Co.Ltd	1000	2011	Mixed coal	26.25	600	93.5	STP	SGP
12	Guohua Xuzhou Power Generation Co.Ltd	1000	2011	Mixed coal	26.25	600	93.5	STP	SGP
13	Jiangsu Xinhai Power Generation Co.,Ltd.	1000	2012	Bituminous coal	27	600	Shanghai Boiler	STP	SGP
14	Jiangsu Changshu Power Company Limited	1000	2013	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
15	Xuzhou China Resources Power Co.,Ltd.	1000	2010	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
16	Xuzhou China Resources Power Co.,Ltd.	1000	2010	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
17	Taizhou Power Plant	1000	2007	Bituminous coal	25	600	Harbin Boiler Company	Harbin Turbine Company (HTC)	Harbin Electric Machinery
18	Taizhou Power Plant	1000	2008	Bituminous coal	25	600	Harbin Boiler Company	Harbin Turbine Company (HTC)	Harbin Electric Machinery
19	Huaneng Jinling (Coal-fired) Power Plant	1000	2009	Bituminous coal	26.25	600	Harbin Boiler Company	STP	SGP
20	Huaneng Jinling (Coal-fired) Power Plant	1000	2012	Bituminous coal	26.25	600	Harbin Boiler Company	STP	SGP
21	Beilun Power Plant	1000	2008	Bituminous coal	26.25	600	Dongfang Boiler	STP	SGP
22	Beilun Power Plant	1000	2009	Bituminous coal	26.25	600	Dongfang Boiler	STP	SGP

23	Zhejiang Jiahua Power Generation Co., Ltd	1000	2011	Bituminous coal	26.25	600	Harbin Boiler Company Ltd	STP	Shanghai Turbine Co., Ltd.
24	Zhejiang Jiahua Power Generation Co., Ltd	1000	2011	Bituminous coal	26.25	600	Harbin Boiler Company Ltd	STP	Shanghai Turbine Co., Ltd.
25	Huaneng Yuhuan Power Plant	1000	2006	Bituminous coal	26.25	600	Harbin Boiler Company	STP	SGP
26	Huaneng Yuhuan Power Plant	1000	2006	Bituminous coal	26.25	600	Harbin Boiler Company	STP	SGP
27	Huaneng Yuhuan Power Plant	1000	2007	Bituminous coal	26.25	600	Harbin Boiler Company	STP	SGP
28	Huaneng Yuhuan Power Plant	1000	2007	Bituminous coal	26.25	600	Harbin Boiler Company	STP	SGP
29	Zhejiang Guohua Zheneng Power Company Limited	1000	2009	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
30	Zhejiang Guohua Zheneng Power Company Limited	1000	2009	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
31	Tongling Power Plant	1000	2011	Bituminous coal	25.36	600	Shanghai Boiler	STP	SGP
32	Shanghai Shangdian-Caojing Power Generation Co., Ltd	1000	2010	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
33	Shanghai Shangdian-Caojing Power Generation Co., Ltd	1000	2010	Bituminous coal	26.25	600	Shanghai Boiler	STP	SGP
34	Huaneng Qinbei Power Generation Co. Ltd	1000	2012	Meager coal	25	600	Dongfang Boiler	Harbin Turbine Company (HTC)	Harbin Electric Machinery

35	Huaneng Qinbei Power Generation Co. Ltd	1000	2013	Meager coal	25	600	Dongfang Boiler	Harbin Turbine Company (HTC)	Harbin Electric Machinery
36	Pingdingshan Power Generation Branch of China Power Investment Henan Power Co., Ltd.	1000	2011	Bituminous coal	25	600	Dongfang Boiler	Harbin Turbine Company (HTC)	Harbin Electric Machinery
37	Pingdingshan Power Generation Branch of China Power Investment Henan Power Co., Ltd.	1000	2010	Bituminous coal	25	600	Dongfang Boiler	Harbin Turbine Company (HTC)	Harbin Electric Machinery
38	Hubei Hanxin Power Generation Co., LTD.	1000	2012	Mixed coal	26.25	600	Dongfang Boiler	STP	SGP
39	Huadian Corporation Ningxia Lingwu Electric Power Co., Ltd.	1000	2011	Bituminous coal	25	600	Dongfang Boiler	Dongfang Turbine	Dongfang Electric Machinery
40	Huadian Corporation Ningxia Lingwu Electric Power Co., Ltd.	1000	2011	Bituminous coal	25	600	Dongfang Boiler	Dongfang Turbine	Dongfang Electric Machinery
41	Guohua Yuedian Taishan Power Generation Co.,Ltd.	1000	2011	Bituminous coal	26.25	600	Shanghai Boiler	STP	Shanghai Turbine Co., Ltd.
42	Guohua Yuedian Taishan Power Generation Co.,Ltd.	1000	2011	Bituminous coal	26.25	600	Shanghai Boiler	STP	Shanghai Turbine Co., Ltd.
43	Guangdong Datang International Power Generation Co., Ltd.	1000	2010	Bituminous coal	25	600	Harbin Boiler Company	Harbin Turbine Company (HTC)	Harbin Electric Machinery

44	Guangdong Datang International Power Generation Co., Ltd.	1000	2010	Bituminous coal	25	600	Harbin Boiler Company	Harbin Turbine Company (HTC)	Harbin Electric Machinery
45	Guangdong Yudean Jinghai Power Generation Co., Ltd.	1000	2013	Bituminous coal	25	600	Dongfang Boiler	Dongfang Turbine	Dongfang Electric Machinery
46	Guangdong Yudean Jinghai Power Generation Co., Ltd.	1000	2013	Bituminous coal	25	600		Dongfang Turbine	Dongfang Electric Machinery
47	Haimen Power Plant of Huaneng Power International Inc.	1000	2009	Bituminous coal	25	600	Dongfang Boiler Group Co., Ltd.	Dongfang Turbine	Dongfang Electric Machinery
48	Haimen Power Plant of Huaneng Power International Inc.	1000	2009	Bituminous coal	25	600	Dongfang Boiler Group Co., Ltd.	Dongfang Turbine	Dongfang Electric Machinery