



**Asia-Pacific
Economic Cooperation**

Roadmap to Promote Transfer and Dissemination of Clean Coal Technologies in APEC Region

APEC Energy Work Group

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1. Project's background

In the past decades, global energy demand continues to rise steadily with the economy development. At the same time, issues raised by energy utilization and consumption, including environmental pollution, climate change, human health, political strategy, economic situation and so on, have been recognized as major concerns not only in Asia Pacific but also in the whole world. Nowadays, the Asia Pacific has been assumed a more prominent role as the center of world energy demand. Energy security and efficiency are crucial to the competitiveness of the economies, particularly some regions with energy intensive industries. Despite of diversified energy supply, fossil fuels, especially coal, will continue to play significant roles in the energy mix of Asia-Pacific region in the long term.

Coal, as the most abundant and widely distributed fossil fuel source, is an extremely important fuel in most parts of the world. About 23% of primary energy needs are met by coal, 39% of electricity is generated from coal and 70% of world's steel production depends on coal feedstock. Globally, power and industry account for about 50 percent of all greenhouse gas (GHG) emissions. Carbon Capture, Storage (CCS), including carbon dioxide (CO₂) utilization, can achieve significant CO₂ reduction from power plants (fuelled by coal, natural gas, and biomass) and industrial applications. Industrial applications of CCS can be applied in upstream oil and gas production, cement production, iron and steel production and fertilizer manufacturing, which have few alternative options for emission reduction. Efforts to integrate bio energy with CCS also represent a pathway to negative emission technologies, which suggests that it will become increasingly important in achieving deep decarbonisation. Therefore, carbon emission and air pollutant emission (e.g. SO_x, NO_x, PM), accompanied by coal combustion and utilization, put forward substantial challenges for the development of "clean coal technology (CCTs)", a technology aimed at more efficient combustion of coal with reduced pollutant emissions as well as CO₂ capture, utilization and storage.

This project-'Roadmap to Promote Transfer and Dissemination of Clean Coal

Technologies in APEC Region' responds to APEC Energy Ministers' instruction for the EWG (through their 2014 Beijing Declaration) to promote clean coal technologies (CCTs), so as to enhance cooperation in developing and applying CCTs and to ensure sustainable energy development in APEC region.

2. Project's objectives

The objectives of this project include creating a platform for all APEC economies to participate in the activities of CCTs, and a database providing a technology category list and priority technical review; developing and providing recommendation on promoting technology transfer and dissemination of CCTs; making selected partner beneficiaries clear about the significance and prospects of CCTs and enhancing common understanding among APEC economies on development of Low Carbon Technology.

3. Project's activities

In the first stage from July 2015 to February 2016, two seminars and two video conferences have been organized. Relevant experts, policy-makers, the public, and potential investors and applicants are invited to participate in the face-to-face meeting. One seminar was held on 11 September 2015. Prof Shengping Wang gave a presentation about transfer and dissemination of clean coal technologies in APEC region. About fifty people (including experts of Dr. Xunpeng Shi, Singapore, and Dr. Wuttipong Kongpetsak, Thailand) from APEC region attended this seminar. The other seminar was held on 17 October 2015. About 30 experts of clean coal technologies from China attended this seminar. A discussion was given about how to transfer and disseminate clean coal technology of China to APEC region. The first video conference was held between the experts of clean coal technologies from China and America on 15 November 2015. The second video conference was held between the experts of clean coal technologies from China and Australia on 10 December 2015. The close cooperation of China with

America and Australia in clean coal technology was discussed in the video conferences, respectively. Additionally, the website and database were built up according to the plan.

In the second stage from March 2016 to August 2016, a website about clean coal technologies has been successfully built up (www.apec-cct.com) and database about clean coal technologies in APEC region was also established. The third seminar has been organized in 5-7 August 2016. About 50 experts on clean coal technologies were invited from the top universities and institutes of China and one-third of them were women experts. A discussion was conducted among the topic and Prof Xinbin Ma gave a presentation about transfer and dissemination of clean coal technologies in APEC region. He suggested that cooperation between country and country, institute and institute should be strengthened.

In the third stage from September 2015 to June 2016, a workshop, a seminar and a video conference were successfully held on 3-4 November 2016, 12 April 2017 and 23 March 2017, respectively. The seminar was organized on 12 April 2016. About 10 outstanding Chinese experts in this field were invited to participate the meeting. The video conference was held by Professor at Zhejiang University discussing CO₂ capture by sorbents.

The workshop, Roadmap to Promote Transfer and Dissemination of Clean Coal Technologies in APEC Regions, has been successfully held in Tianjin from 3-4 November to 2016. The Lead Shepherd of APEC Energy Work group, Jyuung-Shiauu Chern, and 18 representatives from eight different economies including Australia, Chile, China, Japan, Korea, Malaysia, the Philippines, and Russia, attended the workshop, together with other representatives from famous companies. Prof Xinbin Ma, the project overseer, chaired this conference. Prof Shengping Wang, the project assistant, gave a report about the project progress and achievements in detail.

Experts from different enterprises of China were invited to make report in terms of the application of Clean Coal Technology in different fields. Shiseng Xu, President of the Institute of Clean Energy Technology, China Huaneng Group, Ye Zhuang, Chief Scientist of the Department of Pollution Control and Recycling, State Grid, Lan Zhang, Chief Expert of Shenwu Research Institute, Yulong Zhang, Senior Researcher from Shenhua National

Institute of Low-Carbon Clean Energy , Jinfeng Ma, Professor of Northwest University, and Xiaoli Liu, Researcher from National Development and Reform Commission, attended the conference and delivered speeches on their efforts in the dissemination and research of clean coal technology.

The foreign representatives who made oral presentations included Prof Sang-Eon Park from Inha University (Korea), Mark Christian Marollano, Senior Researcher from the Bureau of Energy Policy Planning, Ministry of Energy (the Philippines), Prof Alan Chaffee from Monash University (Australia), Dr. Danielle Kennedy from Commonwealth Scientific and Industrial Research Organization (Australia), Kensuke Saito, Deputy Head of Coal Department, the Ministry of Economic Trade and Industry (Japan), Keiji Makino, Senior Researcher from the Ministry of Coal Energy Central Strategy and Information (Japan), etc. Their research involved fields of CO₂ capture, storage and utilization, coal-fired power plant, coal-based chemical industry, etc. All attendees provided plenty of constructive suggestions and comments about the research projects as well as the development of sustainable energy in APEC regions. Experts and representatives exhibited intense interests in promoting the cooperation of the development and dissemination of clean coal technology in APEC regions. We believed that consensus achieved in this workshop will benefit the development of sustainable energy in APEC regions, especially in scientific and industrial community.

4. Project's achievements

To summarize our outcomes, firstly the website about clean coal technologies has been successfully built up (www.apec-cct.com), which consists of the following parts: "CCTs" includes a brief introduction of clean coal technologies, such as IGCC, USC, CCUS and utilization of syngas, along with the latest developments in this field; "EVENTS" is a platform for news or notices of some relevant upcoming events and past events; "REPORT" is a collection of workshop documents; "Database" collects the data in the following four aspects---CO₂ emissions per year, coal consumption per year, CO and CO₂ utilization technologies, and emission standard of many countries within the APEC

grouping; "ABOUT US" contains the introduction, objectives, work plan and project oversees of this project; "CONTACT US" provides several contact ways of us. Obviously CCTs website will become a powerful tool to promote transfer and dissemination of CCTs in APEC region and gain public concerns and support. By this website, experts, designers, policy-makers, entrepreneurs and the public can have access to consult the survey report and development plan.

Database about clean coal technologies in APEC region has been successfully established. Database collects the data of the following four aspects---CO₂ emissions per year, coal consumption per year, CO and CO₂ utilization technologies, and emission standard of many countries within the APEC grouping. The establishment of database allows experts, designers, policymakers, entrepreneurs and the public to get valuable information. Also the database helps the policymakers to deploy the advanced efficient energy technologies and promote the transfer and dissemination of CCTs by providing general and specific information.

Four seminars were successfully held in Tianjin on 11 September 2015, 17 October 2015 and 5 August 2016, 12 April 2017, respectively. Also three video conferences were successfully held on 15 November 2015, 10 December 2015 and 23 March 2017, respectively. During the seminars and video conferences, experts and participants from APEC region exchanged valuable information and shared local experience on how to promote transfer and dissemination of clean coal technologies of China to APEC region and provided recommendations on the to-be-deeply-developed CCTs in the Asia-Pacific Region, and also reviewed the outputs of CCTs competition.

The workshop of 'Roadmap to Promote Transfer and Dissemination of Clean Coal Technologies in APEC Regions' has been successfully held in Tianjin from 3-4 November 2016. The Lead Shepherd of APEC Energy Work group, Jyuung-Shiau Chern, and 18 representatives from eight different economies in APEC region attended the workshop, together with other representatives from the famous companies. All attendees presented speeches and provided plenty of constructive suggestions and comments about the research projects as well as the development of sustainable energy in APEC regions.

5. Project's findings

Key findings of the CCTs project is as following: There is strong demand for enhancing cooperation in developing and applying clean coal technologies (CCTs) and ensuring sustainable energy development in APEC region, particularly in developing economies. APEC economy members attended the CCTs workshop are interested in a variety of topics related to CCTs, and APSEC is encouraged to forge ahead with further application and promotion actions of the CCTs outputs obtained in the initial stage. The feedback from the post-workshop evaluations has been very positive, which indicated that participants learned much from the experts' presentations and requested follow-up workshops. Furthermore, the major achievements of this project have been shared with related economy members through CCTs Workshop, APEC and the CCTs website, etc. It will significantly contribute to meeting the need of technologies promotion and dissemination of all APEC members, especially the developing economies.

6. Priority technical review to transfer and dissemination clean coal technologies

After two years' investigation, we found that two Chinese companies (The Shenhua Group and China Huaneng Group) are potential to transfer and disseminate clean coal technologies.

(1)The Shenhua Group of China was set up in October 1995. Being a coal-based large multinational energy company engaged in power generation, railway and port transportation, shipping, coal-to-liquid and coal chemicals with integrated production, transportation and sales operations, Shenhua is also known as the largest and most modern coal enterprise in China and the largest coal supplier in the world. Shenhua Group is mainly engaged in the operation and development of resources such as coal; investment and management in power generation, thermal power, port and railway transportation, shipping, coal-to-liquid and coal chemicals; planning, organization,

coordination and management of subsidiary companies in production and operations.

By the end of 2015, Shenhua Group had 21 wholly owned and holding subsidiaries. It had invested in 54 coal mines and power plants and had a total installed electricity production capacity of 78.51 million kilowatts. It owned 2,155-km of self-operated railways, ports and coal docks with a total throughput of 270 million tons. The group also controlled a shipping company with a fleet of 40 ships. The group's total assets were worth RMB931.4 billion at the end of that year with a registered staff of 208,000. In 2015, Shenhua Group worked as one of the enterprise actively adapted to the new normal situation of China's economy and narrowing its focus on clean energy development strategy and making remarkable achievements in production and operation. The group produced 401 million tons of coal, sold 485 million tons of coal, generated 317.1 kilowatt hours of electricity and transported 364 million tons of freight through its railways. The group also produced 8.07 million tons of major oil-based chemical products. It realized a port throughput of 176 million tons, cargo shipments totaling 67.87 million tons and generated revenues of RMB236.4 billion and total profits of RMB 31.8 billion. The economic contribution rate of the company has topped the coal industry in China for several years. The company is among the most profitable among enterprises of its kind in China while maintaining one of the safest work environments in the world.

The coal industry is the base of the Shenhua Group, the main source of the group's income and the foundation for the group to double its economic aggregate in five years. During the "12th Five-Year Plan," the coal industry of the Shenhua Group will continue to implement the scientific outlook on development, take "building a globally first-class coal mine" as its goal, strengthen its technological innovation and management innovation, promote the transitions from high-risk production to safe production, from labor-intensive production to technology-intensive production, from extensive exploitation to intensive and efficient exploitation, from being guided by indexes to being guided by standards and from experience management to lean management, fully raise the level of its safe, healthy and sustainable development, lead the development of the entire coal industry and make contributions for building the Shenhua Group into an international-competitive and

first-class coal and energy enterprise.

Developing the coal-to-liquids and coal chemical industries is an important strategic measure of China. In past more than 10 years, the Shenhua Group kept changing its development mode, adjusting its industrial structure and improving its integration mode, and has established four main large-scale coal-to-liquids and coal chemical engineering projects, which is the first phase of the first stage of the Ordos Direct Coal-to-liquids Project (direct coal-to-liquids production line of 1.08 million tons per year), the synthetic oil device of the first stage of the direct coal-to-liquids project (indirect coal-to-liquid project of 180,000 tons per year), the Baotou Coal-to-olefins Project (coal-to-polyethylene and coal-to-polypropylene project of 600,000 tons per year) and the coal-to-olefins project of the Shenhua Ningxia Coal Industry Company (coal-to-polypropylene project of 500,000 tons per year). Among all of them, the Ordos Direct Coal-to-liquids Project and Baotou Coal-to-olefins Project are demonstration modern coal-to-liquids and coal chemical engineering projects of China.

Taizhou power plant is the world's first 1000 MW ultra-supercritical double reheat unit. To improve its efficiency, the project used technology combined by plasma ignition, double reheat, MGGH for air, condensed water, 10-stage steam reheat, 2-stage external steam cooler and steam at 1.0 Mpa/600/610/610°C. And the flue gas clean-up methods integrated the methods of reducing or eliminating NO_x, SO₂, PM to form a system. Then Zhuang showed a chart of the plant performance giving the emission level of NO_x, SO₂, PM. The capital investment is 3,777 RMB/kW; the power generated was 10 billion kWh; the return on investment is about 7%.

(2) China Huaneng Group is a key state-owned company established with the approval of the State Council. With registered capital of 20 billion Yuan, the Company is mainly engaged in the following business: development, investment, construction, operation and management of power sources; production and sale of power and heat; development, investment, construction, production, and sale of businesses and products related to finance, energy transportation, renewable energy, and environmental protection; industrial investment, operation and management.

The Company takes power industry as its core business, adheres to the Green Development philosophy, and continues to speed up structural adjustment. The Company strives to optimize the development of coal-fired power, vigorously develop hydropower, actively develop wind power, solar power and other forms of new energy, endeavors to develop nuclear power, and continues to develop natural gas-fired power, so as to increase the proportion of low-carbon and clean installed capacity, and constantly enhance the efficient and clean utilization of conventional energy. In 2012, the Company added 4295MW of low-carbon and clean installed capacity, accounting for 40.9% of the total newly-added installed capacity, up by record high of 8.7 percentage points YOY. By the end of 2012, the Company had 28.3GW of low-carbon and clean installed capacity, accounting for 20.95% of the total, maintaining a leadership position in the industry.

The company strengthens study of coal market trends, tries to seek for high quality coal resources by strengthening the construction of power transmission and coal transportation channels, and gives priority to the development of large-scale coal bases and coal power bases in Eastern Gansu, Xinjiang, Eastern Inner Mongolia, and Eastern Yunnan. In 2012, Gaotouyao and Weijiamao open-cut mines were put into trial operation, and Liuxiang coal mine completed the trial operation. Besides, the construction of Hetaoyu and Linglu coal mines made positive progress, and Shaozhai and Chicheng coal mine projects gained government approval. Twelve coal mine projects of the Company were listed into the National Twelfth Five-year Plan for the coal industry, with the total capacity of 49.4 million tons per year. Huaneng Hulunbuir Energy Company and Huating Coal Company were ranked top 50 coal enterprises in China; Shanzhai Coal Mine was evaluated as Top Coal Mine in China; Yimin Open-cut Mine, Lingquan Mine and Jingshigou Mine were evaluated as national advanced coal mines.

CO₂ capture technology of China Huaneng Group is advanced. The GreenGen Project was near zero emission coal fired power plant with pre-combustion CO₂ capture. The GreenGen Program was made of three stages: (1) Stage1, IGCC; (2) Stage 2, R&D for key technologies, improve IGCC technology; (3) Stage 3, Green Gen demo engineering. For the stage1, the flow sheet of GreenGen I and the first 250MW IGCC in China, the first 2000t/d dry coal powder gasifier in China, whose design, construction,

commission and operation were by China Huaneng Group, owned more than 5680 hours operation in 2014-2016. For the GreenGen Phase II, it included the technology of pre-combustion capture by MDEA and the equipment like absorber and pipelines. 200Nm³/h Membrane Separation was presented as well.

The other project is the post-combustion CO₂ capture projects. It has a long history of the research and development on post-combustion CO₂ capture of CHNG. Firstly, the first PCC unit in China included R&D on CO₂ capture for PC power station in use, chemical absorption process design and evaluation, continuous running and parametric operation study and pilot plant for new absorption solvent. The second PCC Unit is in Shanghai, a 120,000 t/a Post-Combustion CO₂ Capture and Refining Utilization Project in 2009. The third PCC unit is for NGCC Station. It had the first CO₂ capture pilot plant both for natural gas and coal based power station in China and it was built by CERI in 2012 (1000tpa). The last stage is R&D on new solvent, HNC-5 solvent tested in Shanghai PCC unit since 2015 Capture showed a reduction of 65.22CNY/t in the operation cost by using HNC-5.

7. Prospectives

It is so challenging to figure out what is the best practice considering the technology, financing and commercial models, since the degree and status of development are quite different for different member economies and the high-tech CCTs industry develops very fast in APEC region during the recent years. In addition, different APEC member economies might have quite different climate conditions, residential life styles, energy structure, natural energy resources and electricity price, thus the best practice for CCTs and construction to a specific economy doesn't necessarily fit to another. Therefore, we intend to spend more time on developing more templates to ensure the research could cover as many as possible APEC member economies. We hope to further transfer and dissemination of the clean coal technologies in APEC regions.