



# CCS activities in China

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## **Introduction**

Climate change is a major threat to the global environment and sustainable development. The international society is focusing on how to cut greenhouse gas (GHG) emissions to mitigate climate change. Carbon Capture and Storage (CCS) is a promising technology that can bring about near zero emissions from use of fossil fuel. It has the potential to capture and store the carbon dioxide (CO<sub>2</sub>) from point source industries and power generation, thereby avoiding emissions into the atmosphere and mitigating global climate change.

Due to its great emissions reduction potential, CCS has attracted global attention. China has carried out a series of activities to promote CCS development. This report provides a comprehensive picture of CCS activities in China, including its role in science and technology planning. A summary of CCS projects funded through the national science and technology programme is included as well as an outline of international science and technology cooperation on CCS and actions by Chinese enterprises.

## **A. Science and Technology Policy**

### **1. The Outline of the National Programme for Medium- and Long-term Science and Technology Development (2006-2020)**

*The Outline of the National Programme for Medium- and Long-term Science and Technology Development* was issued by the State Council on 9 February 2006. The Programme identified guidelines, objectives and general layout for China's science and technology development over the next 15 years. Specific requirements and plans in terms of key areas and priority subjects, frontier technologies, basic research, reforms of science and technology system and building of national innovation system, capacity building, etc, are also clarified. In particular, CCS was highlighted in the Programme as an important frontier technology and the development of efficient, clean and near-zero emissions fossil energy technology was listed as a key component in the advanced energy area.

### **2. China's National Climate Change Programme**

*China's National Climate Change Programme* was issued by the State Council on 4 June 2007, as the first policy document to address climate change, and also the first national climate change program among developing countries. China's objectives, principles, priority areas, countermeasures, positions, and recommended areas for international cooperation for addressing climate change by 2010 are stated in the Programme.

The strategic goal of China, in responding to climate change, is to make

significant achievements in controlling greenhouse gas emissions, to enhance the capability of continuous adaptation to climate change, to promote climate change related science, technology and research and development (R&D) to a new level, to significantly raise public awareness on climate change, and to further strengthen the institutions and mechanisms on climate change. China aims to achieve the above objectives by 2010.

To address climate change, China will be guided by the following principles: to address climate change within the framework of sustainable development, to follow the principle of *common but differentiated responsibilities* of the UNFCCC, to place equal emphasis on mitigation and adaptation, to integrate climate change policy with other interrelated policies, to rely on the advancement and innovation of science and technology, and to participate in international cooperation actively and extensively. Its aim is to strengthen the development and dissemination of advanced and suitable technologies, vigorously develop coal gasification based multi-generation system technology, and carbon dioxide capture, utilization, and storage technologies as policies and measures in the key areas for GHG mitigation.

China will make efforts to realize the specific objectives through a portfolio of legal, economic, institutional and technological instruments to mitigate GHG emissions and improve the capacity to adapt to climate change.

### **3. China's Scientific and Technological Actions on Climate Change**

In order to coordinate climate change-related scientific research and technological development, *China's Scientific and Technological Actions on Climate Change (hereafter referred to as China's S&T Actions)* was issued by the Ministry of Science and Technology (MOST), in conjunction with the other 13 ministries and departments, on 14 June 2007. Making full use of global resources, strengthening international S&T cooperation and enhancing international technology transfer are essential, as a means to address climate change.

The principles of *China's S&T Actions* are: combining government leadership with enterprise participation, combining technological research with policy studies, combining short-term demands with long-term objectives, and combining overall planning with separate implementation. Targets to be met by 2020 include:

- significant improvement in the capacity for independent innovations in research on climate change;
- making breakthroughs in the wider applications of social and economic areas of key technologies related to GHG emission control and climate change mitigation;
- enhancing the adaptive capability of key sectors and typically vulnerable areas in response to climate change;
- improving the ability of S&T to support international cooperation, engagement and decision making on climate change;

- improving S&T infrastructure, research conditions and qualifications of research teams; and,
- enhancing public awareness of climate change and related scientific knowledge.

In terms of technological development for GHG emission controls and climate change mitigation, there will be a focus on CO<sub>2</sub> capture, utilization and storage technologies, through developing key technologies, designing a technology roadmap for CO<sub>2</sub> capture, utilization and storage; and by engineering and carrying out a technical demonstration project.

#### **4. Outline for CCS technology development**

MOST is currently developing an outline for CCS technology development in China, which will be an important document on CCS technology policy. The aim of the outline is to define the objectives of CCS technology in the near future (up to 2030), and identify key tasks for future 5-year plans. This document is now in the process of finalization and is expected to be issued in the second half of 2009.

#### **5. Participation in international organizations**

##### *(1) CSLF*

The Carbon Sequestration Leadership Forum (CSLF) is a Ministerial-level international climate change initiative that focuses on the development of improved cost-effective technologies for the separation and capture of CO<sub>2</sub>, and for its transport and long-term safe storage. The mission of the CSLF is to facilitate the development and deployment of such technologies via collaborative efforts that address key technical, economic, and environmental obstacles. The CSLF will also promote awareness and champion legal, regulatory, financial, and institutional environments conducive to such technologies. The CSLF has currently 22 members, comprised of 21 countries plus the European Commission. China is a member of CSLF and MOST represents China in the activities under the framework.

##### *(2) Global CCS Institute*

The Global Carbon Capture and Storage Institute (Global CCS Institute) is a bold new initiative aimed at accelerating the worldwide commercial deployment of at-scale CCS. Announced by the Australian Government in September 2008, the Global CCS Institute was formally launched in April 2009 and became an independent legal entity in July 2009. The Chinese Government is one of the founding members and the Huaneng Group has signed up to the Global CCS Institute as the representative of Chinese industry.

## **B. Research Projects**

### **1. National Key Technology R&D Programme**

During the 10<sup>th</sup> and 11<sup>th</sup> five-year periods, the Key Technologies R&D programme has supported strategic studies on CCS by Chinese research institutions. In particular, studies have addressed the applicability of CCS in China and its potential impacts on the energy system and GHG emissions reduction.

## **2.National Basic Research Programme (973 program)**

### **Project 1: Utilizing Greenhouse Gas as resources in Enhanced Oil Recovery (EOR) and Geological Storage**

Utilizing greenhouse gas in EOR brings notable economic benefits as well as the social benefits of CO<sub>2</sub> emission mitigation. Challenges and technical difficulties arise when considering the heterogeneity of Chinese oilfields, the high viscosity of crude oil, the high miscible pressures that arise between crude oil mixed with CO<sub>2</sub> etc. This project looks to explore four key scientific issues:

- (1) Geological issues associated with CO<sub>2</sub> storage;
- (2) Physical and chemical issues during CO<sub>2</sub> injection and storage;
- (3) Nonlinear flow mechanics during the CO<sub>2</sub> injection process;
- (4) Issues of CO<sub>2</sub> capture and corrosion prevention.

The expected outputs of the project are: to establish a long-term CO<sub>2</sub> geological storage technology system applicable to China's situation; to bring about the social benefits from CO<sub>2</sub> emissions mitigation and economic benefits of efficient CO<sub>2</sub> utilization; to develop and advance theories for multiphase and multi-component phase flow during CO<sub>2</sub> separation and concentration; to cultivate a team of professional and technical personnel engaged in development and implementation of CO<sub>2</sub> emission reduction and efficient utilization; and to establish independent intellectual property combining CO<sub>2</sub> emission mitigation with efficient utilization to bring China to a leading position globally.

PetroChina, Institute of Geology and Geophysics Chinese Academy of Sciences, Peking University, China University of Petroleum (Beijing), Huazhong University of Science and Technology, Tsinghua University and the Jilin oilfield are jointly responsible for the following eight research topics:

- Topic 1: Standard setting and evaluation of the potential for CO<sub>2</sub> storage to fit China's geological characteristics;
- Topic 2: Geological theory of CO<sub>2</sub> subsurface storage;
- Topic 3: Theory and technology of monitoring and predicting CO<sub>2</sub> storage processes;
- Topic 4: Research on multiphase and multicomponent phase theory during CO<sub>2</sub> injection with EOR;

- Topic 5: Research on non-linear flow mechanisms and principles of multiphase and multicomponent flow during the CO<sub>2</sub> injection process
- Topic 6: Principles of O<sub>2</sub>/CO<sub>2</sub> circulating combustion for coal and the mechanism of synergetic removal of pollutants
- Topic 7: Theory and technology of CO<sub>2</sub> separation and concentration from coal combustion;
- Topic 8: Theory and method of preventing CO<sub>2</sub> corrosion.

### **Project 2: Fundamental research on syngas production through coal gasification and pyrolysis**

Research into syngas production based on coal gasification and pyrolysis has been proposed in connection to the problem of gas emission and pollution in China's coal industry. The objective of the project is to develop a multi-generation system based on partial coal gasification and pyrolysis that will help realize low-cost, high efficiency and lower pollution power generation.

Based on the results of seven complementary research streams, the following key technology problems will be addressed:

- (1) Fundamentals of the large-scale gasification and syngas production based on coal gasification and pyrolysis;
- (2) The fundamentals of catalyst synthesis for the fuel slurry reactor; the fundamentals of engineering of the reactor; and the fundamentals of combustion of relief gas and crude gas;
- (3) The special conditions of dual gas multi-generation systems and design and optimization theory for complex systems.

The participants in the project include: Taiyuan University of Technology, Tsinghua University, China University of Petroleum (Beijing), Institute of coal chemistry (Chinese Academy of Science), East China University of Science and Technology, Xi'an Jiaotong University, Institute of Engineering Thermophysics of Chinese Academy and the Research Institute of Petroleum Exploration & Development.

### **Project 3: Fundamental research on the high efficiency transfer of natural gas and syngas**

Catalysis is core to innovation in high-efficiency natural gas and syngas transfer technology. This project aims to develop dynamic research on catalyst theory and concepts, and research into optimum catalyst reaction conditions, starting with the development of a new catalytic reaction and new catalytic materials followed by in-depth study of the optimum micro-structure and macro-structure for natural gas and syngas.. The objective of the project is the high-efficiency conversion of natural gas and syngas to high quality liquid fuels and high added-value chemicals that can be

easily transported. The project aims to extend the results to relevant coal conversion processes by catalyst-centred science and technology innovation.

The project will be undertaken by Dalian Institute of Chemical Physics (Chinese Academy of Sciences), Institute of coal chemistry (Chinese Academy of Science), Nanjing University, Xiamen University and other corporations. The project comprises eight research topics:

- 1) Key problems of syngas production from natural gas, large scale hydrogen production and CO<sub>2</sub> handling
- 2) Obtaining high quality liquid fuels from syngas
- 3) Oxygen containing compound production from syngas
- 4) High temperature fuel cells based on syngas and natural gas
- 5) Direct conversion of methane into methanol
- 6) Novel processes for direct conversion of methane into methanol
- 7) The relationship between structure and activity and dynamic properties of catalysts and catalyst systems
- 8) Micro-mechanisms and the identification of intermediates during the catalytic process

#### **Project 4: A study of high efficiency heat transfer in gas turbines**

This project will research the energy transmission, conversion and utilization and CO<sub>2</sub> removal process of the system. Research will start from the point of fuel chemical release and will include heat transfer processes through to the high-efficiency process of hydrogen production by gasification. The research will aim to define the energy system's process structure and composition and to develop and establish the technological fundamentals of system characteristics and optimization of the advanced humid-air gas turbine cycle.

Eight subjects are incorporated in the project: research on the macromolecular structure of biomass and response mechanisms under thermo-chemical circumstances (Subject 01); fundamental research on the biomass gasification (Subject 02); fundamental research on biomass selective pyrolysis (Subject 03); research on the selective control law of the complex bio-oil catalytic process (Subject 04); research on the characteristic molecular properties and separation of bio-oils (Subject 05); study of reaction mechanisms and fundamental laws of hydrogen production by reformation of bio-oil (Subject 06); research on the mechanisms involved in the catalytic synthesis of liquid fuel by rich-CO<sub>2</sub> biomass (Subject 07); optimization theory and modelling of biomass liquefaction processes (Subject 08).

These subjects will be jointly completed by South China University of Technology, Huazhong University of Science and Technology, Tianjin University, Sichuan University, Zhejiang University, Lanzhou Institute of Chemical Physics (Chinese Academy of Sciences), University of Science and Technology of China,

China University of Mining and technology, East China University of Science and Technology, Southeast University, Guangzhou Institute of Energy Conversion (Chinese Academy of Sciences).

### **3 The National High-Tech Research and Development Programme (863 Program)**

#### **Project 1: Development of Carbon Capture and Storage**

Driven by increasing demand for CO<sub>2</sub> emissions reduction, this project aims to develop advanced international CO<sub>2</sub> capture technologies such as adsorption and absorption and to explore CO<sub>2</sub> storage technology. Three research topics are incorporated in the project, to be accomplished between May 2008 and December 2010.

- **CO<sub>2</sub> capture technologies based on absorption.** This topic looks at the applicability of high efficiency CO<sub>2</sub> absorption solvents, the fillers for the absorber, new high efficiency absorption/separation equipment and technologies, CO<sub>2</sub> absorption process simulation technology and new technologies on integration and optimization.
- **CO<sub>2</sub> capture technologies based on adsorption.** This topic looks at high efficiency CO<sub>2</sub> adsorption materials, CO<sub>2</sub> adsorption process simulation technology and new technologies on integration and optimization.
- **CO<sub>2</sub> geological storage.** This topic looks at off-shore and saline aquifer CO<sub>2</sub> storage technologies. It will explore techniques for establishing storage capacity and the monitoring of gas integrity.

#### **4. Other Domestic Projects**

##### **(1) CO<sub>2</sub> Injection/Sequestration in Deep Coal Seams for Coal Bed Methane (CBM) exploitation**

China United Coalbed Methane Corp. Ltd (CUCBM) received a total of 9.9 million RMB through MOST, in collaboration with Petromin Resources Ltd. of Canada, Enviro Energy International Holdings Limited of Hong Kong, Alberta Research Council of Canada (ARC) to carry out this research project. [note: this collaborative work with Canada is also described below under international collaborative projects]

This was the first project engaging in research on CBM exploitation by CO<sub>2</sub> injection/sequestration in deep coal seams in China. The project was classified as Class A (i.e. most important) in the aspect of international technical cooperation and lasted five years. In the first two years, testing injection of CO<sub>2</sub> in one CBM well was carried out to prove that CO<sub>2</sub> injection in deep and unminable coal seams can increase output of CBM as well as sequester CO<sub>2</sub>. CUCBM and ARC had jointly carried out successful test of CO<sub>2</sub> injection in a CBM well (Well number 'TL-003', in the south part of Qinshui Basin) in shallow seams and important data were collected. The result proved that the technology has good prospect of application in terms of increasing CBM output and CO<sub>2</sub> sequestration. Early phase testing results had shown

that recovery from CBM wells can be increased to 80% through the injection of pure CO<sub>2</sub> into the wells. Additionally, the output of CBM wells can be increased by four times of the original and 1Mt CO<sub>2</sub> can be sequestered per square kilometre of seams. The project was completed in 2006.

## **(2) Integrated Research on CO<sub>2</sub> Emission Reduction, and its Resource Recycling, Low NO<sub>x</sub> Combustion, SO<sub>x</sub> Control and multi-pollutants removal**

The project is an application study on integrated control of multiple pollutants in coal-fired power plants. The project comprises three parts: research on coal combustion, control and analysis of CO<sub>2</sub> emissions reduction and multiple pollutants. An integrated system for eliminating flue gas, CO<sub>2</sub> and multiple pollutants had been designed, manufactured and installed. The system has been up to the design requirements after successful adjustment and tests. The project is funded by MOST and involves National Power Station Combustion Engineering Research Centre and Shenyang Normal University.

## **5. International Collaboration Projects**

China also participates in a number of important international collaborative projects on CCS, as follows.

### **(1) China-UK Near Zero Emissions Coal (NZEC)**

The joint China-UK Near Zero Emissions Coal (NZEC) initiative addresses the challenge of rising CO<sub>2</sub> emissions through the joint research, development and demonstration of near zero emissions coal technology. The UK envisages an ambitious three-phase approach to achieve the NZEC demonstration objective. Phase I will explore options for demonstration and build capacity for CCS in China. Phase 2 will carry out further development work on storage and capture options leading to Phase 3, which will see construction of a demonstration plant by 2014. It is likely that Phases 2 and 3 will be carried out under a wider EU-China collaboration. See [www.nzec.info/en/decc](http://www.nzec.info/en/decc) and [www.acca21.org.cn](http://www.acca21.org.cn) for further information on the UK NZEC project.

### **(2) China-Australia CAGS Project**

The China Australia Geological Storage (CAGS) project is set to start this year. Several discussions between Chinese and Australian officials and potential collaborative partners have been held, and several associated CCS meetings have taken place in China and Australia. These meetings included a China and EU/UK workshop, in which a technology road map exercise was started, an Asia Pacific Partnership Clean Fossil Energy Meeting, and several other high level official meetings. The latest meeting was held in Beijing in July, 2009 in which technical and official delegates from China and Australia participated. A stable foundation for the project was approved through agreement on project stages, scoping and the core aims. If agreed to, the project will also be co-badged under the Carbon Sequestration Leadership Forum (CSLF).

At a high level, the CAGS project will aim to deliver the technology transfer necessary to facilitate China's own assessment of sites for geological storage of CO<sub>2</sub> across different regions in China. In order to identify potential storage, the project will conduct training and knowledge sharing aimed at CO<sub>2</sub> geological storage through several phases, such as staff selection, data collection, training module development, training and implementation and site specific assessment.

### **(3) EC Framework projects**

#### **■ MOVECBM**

The objective of the EC MOVECBM project is to improve understanding of CO<sub>2</sub> injection into coal seams and the migration of methane, thus ensuring long-term reliable and safe storage. In the MOVECBM project, modelling and laboratory work will be based on the parameters of the test site in Kaniów, Poland previously investigated by the EC RECOPOL project. The former CO<sub>2</sub> injection well from the RECOPOL project will be used to improve the understanding of CO<sub>2</sub> storage and ECBM through continuous monitoring of the composition of the gas to define the actual adsorption of CO<sub>2</sub> that was injected in the period August 2004 till June 2005.

In parallel to the field production test in Kaniów, a small scale combined injection and production experiment will be carried out in the Velenje coal mine in Slovenia. Here, in the coal mine, horizontal injection and production wells are used to investigate adsorption, desorption and migration processes for local coal conditions. The results from Velenje are expected to provide the missing information between the larger scale field experiment in Kaniów and the much smaller scale laboratory work.

From the Chinese side, Research Institute of Petroleum Exploration and Development, PetroChina (RIPED) and China United Coalbed Methane Company (CUCBM) joined the project.

#### **■ COACH**

The EU-China COACH project officially launched in November 2006 in Beijing as a project under the Sustainable Energy Systems theme of the Sixth Framework Programme (FP6) of the EU. Major activities include application of carbon capture technology in coal-fired power plants, evaluation of China's CO<sub>2</sub> storage potential and the study of relevant regulations and financing mechanisms. Activities will also be carried out to improve public awareness and to build CCS capacity. The project is expected to be completed by the end of 2009. Eight Chinese organizations are involved in this project.

#### **■ STRACO2**

This project was launched in January 2008 with a planned duration of 18 months. The overall objective of the project is to support the ongoing development of the

comprehensive regulatory framework in the EU for CCS technologies for zero emissions applications. Its specific objectives are to i) identify S&T development priorities in multiple aspects of technical applications and regulations for specific themes; ii) facilitate and increase S&T cooperation at the EU level; iii) identify through research, pivotal issues for regulatory development; iv) establish the EU regulatory framework as the basis for dialogue and priority setting with regulatory authorities in China with a view to further joint activities; and vi) facilitate and increase S&T cooperation at the international level with China.

The STRACO2 consortium came together for the consolidation meeting in Beijing on 2nd - 3rd December 2008. A STRACO2 International Conference on CCS Regulation in the EU and China was held in Brussels on 18th -19th February 2009. Another two workshops were held in Beijing and Brussels in March and April of this year. Opportunities and challenges China and EU face in terms of cooperation in CCS monitoring and control were discussed, as well as collaborative opportunities in the future. The project will be completed by the end of 2009.

#### ■ Others

Some Chinese organizations have also joined in with the consortium of the EC funded FP projects, such as CACHET, CAPRICE and GeoCapacity. These projects mainly focus on research areas of interest in Europe, and only one or two Chinese organizations have joined each project.

#### (4) China-Canada ECBM Projects

A project agreement on coal bed methane technology development and CO<sub>2</sub> storage was signed between China and Canada on 15 March 2002. It is one of the largest cooperation programmes between the two countries. Each participant contributed an equivalent of 5 million Canadian dollars and joint implementation is handled by China United Coal bed Methane (CUCBM) and Canada. The Ministry of Foreign Trade and Economic Cooperation, the Canadian Embassy in China, CUCBM, and the Commonwealth of Canada jointly signed the project's implementation plan. The project lasted from March 15, 2002 to March 31, 2006. CUCBM and Canada Alberta Research Council successfully finished a micro-pilot field test of a shallow coal seam with single well injection at south Qinshui Basin, Shanxi province, and generated information on important technical parameters.

In January 2008, China's first ever 'deep coal seams injection/CO<sub>2</sub> Enhanced Coal bed Methane (ECBM) and geological storage research programme' was kicked off, as a continuation of the micro-pilot test in Qinshui Basin. The project focuses on the development of EOR technology through a multi-well pilot CO<sub>2</sub> injection in deep unmineable coal seams and geological storage. CUCBM, Petromin and EnviroEnergy are responsible for the project. 9.9 million yuan RMB has been invested in the project. The project will last 5 years, comprising two phases: a single well injection pilot test in deep coal seams well in the first 2 years and multi-well pilot testing during the

following 3 years. The north block of Shizhuang at Qinshui Basin, Jincheng City, Shanxi Province have been chosen as pilot sites.

#### **(5) Tianjin Dagang CCS Project**

In September 2008, EESTech and Tianjin Dagang Huashi Power Generation signed a memorandum of understanding. Its aim is to establish a CCS project in China using EESTech's carbon management and storage technology. Dagang plans to use one of its two 330MW power units to demonstrate the capture of CO<sub>2</sub> from its flue gas stream and then transport the CO<sub>2</sub> for geo-sequestration and EOR. The project is expected to showcase the development of a CO<sub>2</sub> capture project that can be profiled internationally as a sustainable climate change project. The parties also plan to seek support and endorsement from all levels of the government of China to ensure the project becomes a reference site that will set new benchmarks for the validation and effectiveness of CCS technologies.

#### **(6) Sino-Japan CCS cooperation**

In May 2008, Japan and China announced their intention to jointly develop a CCS and EOR project that aims to recover 3-4 million tonnes of CO<sub>2</sub> per annum from two coal-fired power plants in China. The Japanese partners, under the Ministry of Economy, Trade and Industry (METI), include: JGC Corporation (a supplier to the Algerian In Salah CCS project), Japan Coal Energy Center, Toyota Motors, Mitsubishi and the Research Institute of Innovative Technology for the Earth (RITE – a sustainable energy research establishment under METI). For China, the NDRC is the lead government department with input from: CNPC-PetroChina, Daqing Oil Field Ltd. (local oil field partner), Harbin district government, Harbin Utilities Company and China Huadian Corporation.

The USD 300 million project will be located in Heilongjiang province in north-east China, 100 km from the Daqing oil field. Daqing Oil Field Ltd. and RITE are jointly engineering the project and schedule to commission it in 2011. The intention is to use two 600 MW coal-fired power plants, retrofitted for post-combustion CCS and linked by pipeline to a near-by mature oil field, to enhance oil production by 3040,000 barrels per day. The reason for using two power plants is to spread the 10-15% energy penalty associated with CCS and so limit local electricity supply disruptions. Based on initial tests in China, the partners believe that it will be possible to achieve a CO<sub>2</sub>-to-oil recovery ratio of 2:1.

#### **(7) Chinese Advanced Power Plant Carbon Capture Options (CAPPCCO)**

The CAPPCCO project aims to produce a carbon capture characteristics database for existing and planned plants; to develop and assess capture options for planned new pulverized coal (PC) plants and existing PC plants; to address the special issues for adding carbon capture to Chinese power plants; and to finance capture ready and capture retrofit. The overall objectives of CAPPCCO consist of developing and defining options for integrating carbon dioxide capture plant with advanced Chinese

pulverized coal power plants to allow a rapid transition to a high level of CO<sub>2</sub> emission reductions; assessing the performance of advanced (non-CO<sub>2</sub>) pollutant control technologies on Chinese coals; and identifying and engaging with key stakeholders to ensure that relevant information transfer takes place.

CAPPCCO is sponsored by the UK Department of Energy & Climate Change (DECC) and China's Ministry of Science and Technology (MOST). Its participants include Imperial College London (UK), University of Cambridge (UK), Doosan Babcock (UK), Alstom (UK), Harbin Institute of Technology (CHN), National Power Plant Combustion Engineering Technology Center (CHN), Harbin Boiler Company Limited, Yuanbaoshan Power Plant (CHN), Datang International Power Generation Co. Ltd (CHN) and Xi'an Jiaotong University (CHN).

### **(8) Developing CCS Guidelines for China**

This is a collaborative project by Tsinghua University and the World Resources Institute (WRI), funded by the US Department of State and the Asia Pacific Partnership on Clean Development and Climate. The main outcomes will be: 1) a publication of a set of guidelines for safe and effective CCS (including capture, transport, sequestration) and 2) a framework for the post-closure stewardship. It began with an informal translation of the WRI's US guidelines.

### **(9) US/China Study on Regional Opportunities for CCS**

The US Department of Energy and MOST are funding a joint study examining Regional Opportunities for Carbon Dioxide Capture and Storage in China. Partners include the U.S./China Energy and Environmental Technology Center, Tsinghua University, Institute of Rock and Soil Mechanics: Chinese Academy of Sciences, Leonardo Technologies, Inc., Battelle Pacific Northwest National Laboratory and Montana State University.

## **C. Enterprise Actions**

### **1. Pilot program in Jilin oilfield established by PetroChina**

PetroChina started China's first project on CO<sub>2</sub> storage and utilization (EOR) at Jilin Oilfield, and this has been in operation since 2006. The company has invested 200 million RMB, and CO<sub>2</sub> was injected into 10 wells to enhance oil recovery and to store. The development program of Changchun gas field with CO<sub>2</sub> was established.

The CO<sub>2</sub> mainly comes from natural gas. A pilot test program of miscible flooding in the Hei79 and Hei59 fields has been planned; immiscible flooding pilot test program in Hong 87-2 field and a test program in Qian'an have been planned as well. The programme works well at present.

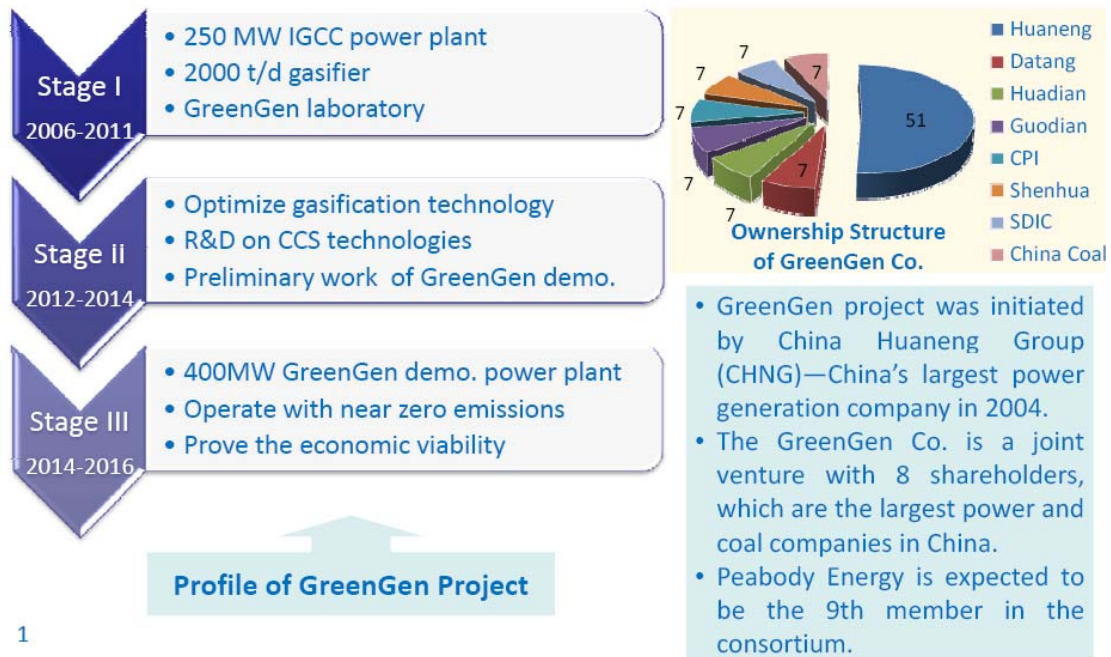
### **2. Huaneng's Greengen and CO<sub>2</sub> Capture Demonstration Projects**

## 2.1 Huaneng's Greengen Project

China Huaneng Group firstly proposed the Greengen Project in 2004, aiming at the development, demonstration and popularization of hydrogen production by coal gasification, hydrogen gas turbine combined power generation, fuel cell power generation and coal based energy system with CCS. Greengen was to elevate coal generation efficiency and realize near zero emissions of pollutant and CO<sub>2</sub>, and to prepare technology for addressing climate change to realize the sustainable development of coal-based power generation. Based on the support of National Development and Reform Commission, eight of China's large enterprises, including Huaneng Group, Datang Group, Huadian Group, Guodian Group, China Power Investment Corporation, Shenhua Group, State Development and Investment Corporation and China National Coal Group established the Greengen Corporation, and Peabody Energy is expected to be the 9<sup>th</sup> member of the consortium.

The Greengen Project aims at developing coal-gasification-based hydrogen power generation and CO<sub>2</sub> storage technology with the construction of a coal-based power plant featuring near-zero emissions and high efficiency). The GreenGen Project will prove that the near-zero emissions power plant is economically feasible and therefore that the sustainable development of the power industry could be achieved.

The implementation of the project can be divided into three stages. The first stage is the construction of an Integrated Gasification Combined Cycle (IGCC) power plant. In this stage, a 250 MW IGCC power plant is planned to be built between 2006 to 2011. Until now, the IGCC's preliminary engineering design has been completed with the detailed engineering design underway, and the construction was officially started in July 2009 after the approval was given by the NDRC. The second stage would cover optimization of a Thermal Power Research Institute (TPRI) gasifier with its own IPR and development of the main technologies, including hydrogen production based on coal, hydrogen power generation, CCS, fuel cell power generation and other key technologies to prepare for construction of near-zero emission power plant. The third stage, from 2014 to 2016, is the implementation of the Greengen near-zero emissions demonstration project. The project will develop a large-scale hydrogen production based on coal, in which hydrogen gas turbine power generation and other CCS technologies will be verified.



## 2.2 Huaneng’s CO<sub>2</sub> capture demonstration project

This post-combustion CO<sub>2</sub> capture research, as the first project in the China-Australia cooperation framework of climate change and energy problems, is being deployed in Huaneng’s Beijing thermal power plant jointly by Huaneng Group and its Xi’an Thermal Power Research Institute and Australia’s Commonwealth Scientific and Industrial Research Organization. This project is planned to capture 3000-5000 tCO<sub>2</sub> per year, which is currently China’s first and the world’s largest research platform for CO<sub>2</sub> capture technology based on coal power plant.

Due to the characteristics of the flue gas from the coal fired power plant, a chemical absorption method is used for CO<sub>2</sub> capture in this demonstration project. In the lower temperature conditions (40~50 °C), the chemical solvent is used to absorb CO<sub>2</sub> contained in the flue gas. When the solution is heated (to 100~120 °C), high concentration CO<sub>2</sub> will be liberated from the solution and the rest solution is recycled.

This project is a China Huaneng Group Corp. initiative and technology is supplied by Xi’an Thermal Power Research Institute and designed by North China Power Engineering Co., Ltd.

## 3. ENN Resource Recycling of CO<sub>2</sub>

Founded in 1989, the ENN Group is committed to the development and utilization of clean energy. Clean energy innovation is its mission. Its portfolio focuses on gas distribution and the exploitation of coal-based clean energy, it explores zero emission hydrogen energy and bio-energy by recycling of treatment of CO<sub>2</sub>. ENN has been forming a clean energy industry chain covering energy supply and

service, logistics and trading, development and production. On this basis, it develops high technology and finance business to drive the ENN enterprise to enable rapid and sustainable expansion.

The project has been centred on cultivating microbes with high oil content, which can quickly and efficiently absorb CO<sub>2</sub> due to their super rapid photosynthesis. As a result, new and green energy will be produced. At present, breakthroughs have been made in some core technologies with a demonstration project established.

#### **4. Shenhua Group**

Shenhua, China's largest coal miner, is working on research and development in CCS at its coal-to-liquids plant. This CCS project will be applied to Shenhua's 1-million-ton direct coal-to-liquids plant in Ordos, Inner Mongolia autonomous region, which launched trial operation at the end of 2008.

Storage measures, including geological storage, are being considered for Shenhua's CCS project, which will be put into full operation in one or two years. Shenhua Group is now collaborating with US DOE on the research of aquifer storage in Ordos basin. At current stage, Shenhua did not announce the detail of this project, but it may be in the stage of site selection now.