Asia-Pacific Economic Cooperation

APEC Energy Working Group

Increasing the Knowledge and Awareness of Carbon Capture and Storage: Capacity-Building in the APEC Region (Phase IV)

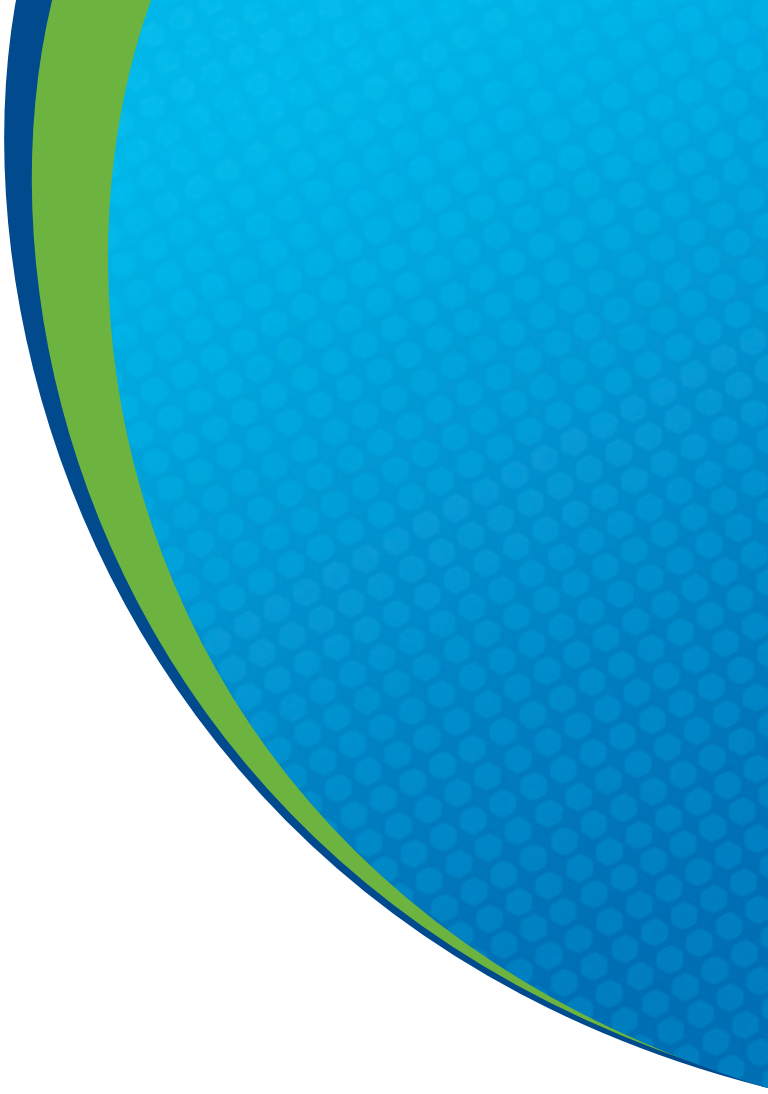
APEC Energy Working Group
Project EWG 09/2008A

CO2CRC Technologies Pty Ltd
Final report

June 2010

CO2TECH Confidential Consultancy Report No: RPT10-2282

CO2CRC Technologies



APEC Energy Working Group Project EWG 09/2008A

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Ministry of Environment, Indonesia – Ir Sulistyowati
Indonesian National Committee of the World Energy Council – Dr Hardiv H Situmeang
British Embassy, Jakarta, Indonesia – Rahimah

Australian School of Petroleum, University of Adelaide – Prof. John Kaldi
Global CCS Institute – Suzete Ribero and Alice Gibson
Indonesian Coal Society - Taufik Sastrawinata and Indra Dwitama
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Executive summary

Developing APEC economies are anticipated to sharply increase their consumption of fossil fuel energy and as a consequence their carbon dioxide (CO_2) emissions. Technologies to capture the CO_2 and store it in geological formations (commonly called carbon capture and storage or CCS) have the potential to provide a viable, medium-term option for developing APEC economies to increase their energy use from fossil fuel with reduced CO_2 emissions to the atmosphere.

The need to deploy CCS on a global scale is regarded as urgent to avoid damaging climate change. The G8 Leaders declared in July 2008 that they support a target of 20 large-scale CCS demonstration projects launched globally by 2010 with a view to beginning broad deployment of CCS by 2020.

Steps towards deployment of CCS have been taken in many industrialized economies, including some APEC counties such as Australia, Canada, Japan, and the United States. To begin to develop CCS within an economy, a good understanding of CCS technologies and their potential is required. This project has built on previously completed APEC projects in the area of CCS by providing CCS training workshops in Indonesia and China, delivered through CO2CRC. In addition, these workshops have developed strong partnerships between APEC and major bodies such as the IEA and the Global CCS Institute.

The workshop in Indonesia was combined the launch of a technical study 'Understanding Carbon Capture and Storage (CCS) Technology in Indonesia' undertaken by a CCS Study Working Group which comprised Ministry of Energy and Mineral Resources (MEMR), the Ministry of Environment, the Indonesian State Electricity Corporation (PT PLN), Shell and the Indonesian National Committee of the World Energy Council with support from the United Kingdom Embassy in Jakarta.

The lead agencies in the workshop were APEC, MEMR and the IEA with funding support from the Global CCS Institute. This joint workshop was very successful, with excellent attendance and high-level representation of government and industry. Follow-up meetings with the IEA, the Global CCS Institute and the Clinton Foundation have already taken place. There was a desire expressed for more capacity-building workshops in the future.

The workshop in China took place much later than anticipated after lengthy processes to obtain the necessary permissions and find a suitable date to all parties. The workshop was well attended with a large number of power generation companies. Much of the interest was in the capture technology and the potential for Enhanced Oil Recovery (EOR). The Chinese experts who presented on current research and CCS projects in China were greatly appreciated and there was considerable interest in technology exchange. Given the depth of technological expertise available within China, future workshops should be targeted at bringing together experts from China and overseas for more detailed, specialised technical coverage.

Contents

Appendices

Project description

1.1 Project background

In order to meet their future energy needs, developing APEC economies are anticipated to sharply increase their consumption of predominantly fossil fuel energy. As a result, carbon dioxide (CO_2) emissions from energy production and use in the APEC region are forecast to rise by 60 per cent between 1999 and 2020. Technologies to capture the CO_2 and store (or sequester) it in geological formations (commonly called carbon capture and storage or CCS) have the potential to provide a viable, medium-term option for developing APEC economies to retain the benefits of deriving energy from low-cost fossil fuels, such as coal, while at the same time reducing CO_2 emissions to the atmosphere and, thus, promoting environmentally sustainable growth.

There is a sense of urgency, which was highlighted by the International Energy Agency (IEA) in their 2004 statement that "governments need to take action now to ensure that CCS technologies are developed and deployed on a large scale over the next few decades". This urgency was again emphasized by G8 Leaders in July 2008, who, at their summit meeting in Hokkaido, Japan, declared that they "strongly support the launching of 20 large-scale CCS demonstration projects globally by 2010, taking into account various national circumstances, with a view to beginning broad deployment of CCS by 2020".

There are presently significant efforts in progress in the area of CCS in Australia, Canada, the European Union, Japan, Norway, the United States and other industrialized economies across the world. The deployment of CCS is at varying stages of implementation and a number of demonstration or commercial projects are operating, under way or being planned. In addition, assessment and feasibility studies of CCS are being carried out by the IEA Greenhouse Gas R&D Programme, the Carbon Sequestration Leadership Forum (CSLF), the Global CCS Institute and other international organizations.

A good understanding of CCS technologies and their potential is needed before candidate economies can consider these technologies and include them in their medium-to-long term energy planning strategies. This project has built on previously-completed APEC projects in the area of CCS, including the assessment of the geological storage potential of CO_2 in APEC economies (Phase I – EWG 06/2003); the development of training materials to promote and transfer CCS technologies to developing APEC economies (Phase II – EWG 02/2004); and the organization and hosting of two capacity-building training workshops in China and Mexico (Phase III – EWG 07/2005). These EWG reports are available at www.ewg.apec.org.

To address this ongoing need for more CCS training, two additional capacity-building workshops were undertaken in Phase IV. CO2CRC responded to the request for proposals by the Asia Pacific Economic Cooperation and was contracted to implement Phase IV.

The increased awareness of CCS in recent years has raised the profile of APEC CCS capacity building projects not only within APEC economies but also with other bodies involved in CCS capacity building. This phase of the project has developed strong partnerships with major bodies such as the IEA and the Global CCS Institute.

1.2 Objectives

The primary objective of this project was to help increase the capacity of developing APEC economies to assess the potential of CCS technologies within their own economies and evaluate options for the implementation and potential uptake of such technologies. The project objectives were:

- to disseminate in-depth information covering all aspects of CCS and presentation of actual CCS technology case studies;

- to develop a greater understanding of the options and uptake potential for CCS
- to provide CCS technology transfer opportunities for governments and energy companies in developing technologies;
- A report on the potential for CCS technologies in the host economies and recommendations to advance CCS technologies in these economies.

1.3 Main deliverables

- Identification of host economies
- A literature review for each of the host economies
- Updated training materials
- A workshop in Indonesia
- A workshop in China
- Final workshop report

Training workshops

Training workshops were held in Indonesia and in China under Phase IV. Due to the dramatic increase in activity in CCS capacity building, these two workshops were fundamentally different and reflected the varying stages of awareness of CCS and the array of organizations involved in CCS capacity building in the two economies.

The first workshop was held in Jakarta, Indonesia as part of a joint workshop entitled “Carbon Capture and Storage in Indonesia” from 10 – 12 November 2009.

The second workshop was held in Hangzhou, China from 7 – 8 June 2010.

2.1 Indonesia

During preparation for the Indonesian workshop, a desktop review of CCS potential in Indonesia was conducted, including a search for current CCS activity. It emerged that a CCS National Workshop took place in Jakarta in October 2008, organized by the United Kingdom Embassy. A CCS Study working Group had been formed comprising the Ministry of Energy and Mineral Resources (MEMR), the Ministry of Environment, the Indonesian State Electricity Corporation (PT PLN), Shell and the Indonesian National Committee of the World Energy Council with support from the United Kingdom Embassy in Jakarta. The CCS study group was led by the MEMR Agency for Oil and Gas Research (LEMIGAS). The CCS study group had just completed a technical study 'Understanding Carbon Capture and Storage (CCS) Technology in Indonesia'. In addition, the Indonesian government signed a letter of co-operation with the International Energy Agency (IEA) in Paris, which covers a bilateral program of six projects, including one on CCS. Dr Bambang Dwiyanto, the Head of MEMR Research & Development is overseeing this program. The IEA is working closely on this CCS project with Dr Hadi Purnomo and Dr Ego Syahrial, both of LEMIGAS, and Dr Hadiyanto, Director of Geo Resources, MEMR.

The study 'Understanding Carbon Capture and Storage (CCS) Technology in Indonesia' was scheduled to be released by the Indonesian government in November at the same time as CO2CRC was planning to hold the APEC workshop. A CCS workshop was planned to coincide with the release of the study and at the same time the IEA was planning to hold a one-day CCS Roadmap Roundtable workshop.

So that there was not any duplication of effort, negotiations took place to combine all of the events into a joint launch of the study and a workshop on CCS in Indonesia. The lead agencies in the workshop were APEC, MEMR and the IEA. Funding for the local costs of the APEC workshop materials and the Global CCS Institute of Australia provided part costs for the venue.

This joint workshop was very successful, with excellent attendance on all three days. There was a high level of representation of government and industry at the workshop. The first day featured the launch of the aforementioned study 'Understanding Carbon Capture and Storage (CCS) Technology in Indonesia' and presentations of the CCS potential in Indonesia, including some case studies of potential CCS project locations. The remaining days involved delivery of the APEC training materials. The panel discussions were animated and covered a wide range of issues. Immediately following the joint workshop, APEC and CO2CRC representatives were invited to attend the IEA roundtable discussion with government officials and officials from state-owned electricity and oil and gas companies. The major purpose of this meeting was to map the future collaboration between the IEA and MEMR and to discuss the key steps and barriers to the development of CCS in Indonesia.

2.2 China

The preparation for the workshop in China was complex and lengthy. The desktop study on Carbon Capture and Storage (CCS) in China (see Appendices) revealed that there was considerable activity relating to CCS, including conferences, workshops, a few projects and significant international collaborations, much of which had developed since the previous workshop in 2006.

Discussion with the Project Overseer and others about the need for a second APEC Capacity–Building workshop in China was centered on the issue that China is a very large country with considerable activity in the CCS area. While China has experts in specific fields, this expertise appears to be compartmentalised into areas of technical speciality. The idea of this workshop was to bring together researchers from the various parts of the CCS chain, including researchers, electricity generators, and oil and gas company representatives to understand the implications of implementing CCS across each sector. The workshop was designed to feature a wide range of areas of expertise and target a broad group of Chinese participants.

Further, as CCS Capacity-Building is about not only providing information on CCS, but also about building confidence in the technology and building links between experts, Chinese experts in the various fields were invited to present reports on their research and active projects at the workshop.

Despite significant organizational and financial challenges, the workshop was successfully held. Zhejiang University had invited researchers, power generation companies and engineers from the oil and gas sectors, although attendance was dominated by the power generation sector. Attendance on Day 1 was high and there was slightly lower attendance on Day 2. The level of engagement in discussion, the depth of technical questions and the interest in the experience in both overseas and Chinese projects were all indicators of success.

2.3 Summary

Both workshops achieved the objectives originally identified

- to disseminate in-depth information covering all aspects of CCS and presentation of actual CCS technology case studies;

- to develop a greater understanding of the options and uptake potential for CCS
- to provide CCS technology transfer opportunities for governments and energy companies in developing technologies;
- to report on the potential for CCS technologies in the host economies and recommendations to advance CCS technologies in these economies.

There was a high level of engagement amongst the Indonesian workshop participants and an increase in awareness of all aspects of implementing CCS technologies, apparent by busy question and answer sessions and the animated panel sessions. Immediate follow-up was provided through the IEA roundtable meeting, and future actions were planned during that session. The IEA is developing a roadmap for next steps towards implementing CCS in Indonesia.

The APEC training material was presented as a valuable resource for the workshop participants to use in advancing CCS in China. Importantly, great value came from the involvement of the Chinese experts in disseminating information about their research and demonstration projects. The presence of both the power utilities and the oil and gas companies enabled the exchange of ideas between the two sectors.

Training materials

3.1 Training module updates

In line with the recommendations from Phase III, the modules from Phase III were reviewed and updated so that they reflected recent developments in CCS: references to current projects and research were inserted in the capture modules, a new section on integrated economics of capture and storage was created and a new module on public awareness and community consultation was added.

The modifications to the modules were:

- Introduction to CO_2 capture and geological storage in energy and climate policy - new diagrams, a section on where CO_2 can be captured and updated climate change statistics.
- Module 1 CO_2 capture and storage overview - New diagrams, updated climate change predictions; Major section on trapping moved to Module 5; New sections and diagrams on capture and transport; Revised section on storage options and overview of trapping; New section on monitoring and new section on challenges for CCS.
- Module 2: Post combustion flue gas separation - New diagrams, updates on all major PCC capture technologies.
- Module 3: CO_2 capture – Pre-combustion (decarbonisation) and oxyfuel technologies. New section on pre-combustion capture technologies.
- Module 4: CO_2 compression and transport to storage site - new information on impurities.
- Module 5: CO_2 storage options and trapping mechanisms - Some new diagrams, trapping from Module 1 moved here.
- Module 6: Identification and selection of suitable CO_2 storage sites - Main part of this module was replaced, and the technical details on geological characteristics of basins, hydrodynamic regimes, etc., from the previous version retained as technical appendices.

- Module 7: Key steps in developing and implementing a CO_2 capture and storage project - removed details that were covered in module 6 (basin scale assessment, etc.) and included updates on expertise in CCS projects.

- Module 8: Health, safety and environmental risks of CCS projects - Risk assessment methodologies moved to Module 9.

- Module 9: Risk management, measurement, monitoring and verification in CO_2 storage projects - Expanded section on monitoring and verification to include technologies; Methodologies for planning a monitoring program retained as a technical appendix.

- Module 10: Regulatory and legal aspect of CO_2 storage - Updated with recent legislative changes.

- Module 11: The Clean Development Mechanism - Section on recent work, including CCS in CDM.

- Module 12: Economics of CO_2 capture and storage - New module on integrated source-sink economics with worked examples.

- Module 13: Public awareness and community consultation - New module on principles of consultation and awareness programs, includes steps in community engagement from APEC community outreach strategy and a case study from the CO2CRC Otway project.

- Module 14: Potential for CO_2 capture and storage in the APEC region – Includes recent figures on storage capacity and work being undertaken.

All modules now contain a section with links to current relevant websites.

3.2 Agenda and presentations

New presentations were made for the workshops in Phase IV to reflect the updated training modules, host economy requirements and new presenters.

The workshop presentations for Indonesia covered all the major areas of CCS technology and issues relating to CCS implementation. These included

- The need for CCS – CO_2 emissions and climate change

- CO_2 capture opportunities, technologies and challenges

- CO_2 transport

- CO_2 storage opportunities, technologies and challenges (screening, site selection, injection, trapping)

- Health, safety, risk and monitoring

- Legal and regulatory requirements and enabling mechanisms (CDM, carbon trading)

- Economics

- Public awareness and community consultation

- International experience and CCS bodies

Following the recommendations from Phase III, presentations were included that covered

- Regulatory issues
- Public acceptance
- Economics of capture, transport and storage including case studies
- Examples of challenges and developments in capture technology
- Examples of challenges and developments in storage technology

The workshop presentations for China were prepared to follow all of the training modules in order, updating the presentations from Indonesia and the presentations from the previous workshop in China. These presentations covered all of the topics above.

Indonesia

The agenda for the Indonesian workshop was originally designed to allow for longer breaks. With the advent of a joint workshop, the agenda was modified considerably, and included many experts from Indonesia. There was, in general, ample opportunity for discussion during and after the workshop, as lunch was provided.

As the workshop for Indonesia was a joint workshop, the Indonesian experts delivered the introductions to the various CCS technologies during Day 1. Consequently, the presentations delivered by the APEC workshop experts did not directly follow the flow of the training modules. In order to help participants locate the relevant information, presentations on Day 2 and Day 3 concluded with a slide outlining where further information on the presentation could be found in the training package on the training CD, which was included in the workshop binder.

The APEC workshop presenters were given the relevant updated module(s) and a template to prepare their presentations. The presentations were prepared in advance, and copied on to the training CD. They were also printed into a workshop binder.

Any updated presentations and presentations by Indonesian experts which were not available prior to the workshop were made available on a website hosted by CO2CRC.

China

The agenda for the Chinese workshop was developed to allow for significant discussion periods at the end of each of the two days.

The agenda followed the order of the modules, with Chinese experts presenting research overviews and case studies from projects in China throughout the two days. The APEC training presentations were based closely on the updated modules, and all were prepared with the same template. The presentations were translated into Chinese and printed through Zhejiang University into a booklet. A training CD was prepared and the participants were given a CD and the presentations. The booklet and the CD contained the presentations in both English and Chinese.

Any updated presentations and presentations by Chinese experts which were not available prior to the workshop were made available on a website hosted by CO2CRC.

3.3 Other materials included in the training CD

In addition to the training modules and the presentations, the CD contained the Case Studies from Phase III (Weyburn and Sleipner) and the Community Outreach materials.

Permission was sought from various organizations to include several publications. These were:

- Technology Roadmap. Carbon capture and storage. International Energy Agency © OECD/IEA 2009
- Best practices for Monitoring, Verification and Accounting of CO_2 stored in Deep Geologic Formations, National Energy Technology Laboratory, US Department of Energy
- Carbon Sequestration Atlas of the United States and Canada, US Department of Energy
- CO_2 EOR Technology, US Department of Energy
- Atmospheric monitoring and verification technologies for CO_2 storage at geosequestration sites in Australia, Etheridge et al, CO2CRC
- Storage Capacity Estimation, Site Selection and Characterisation for CO_2 Storage Projects, CO2CRC
- Demonstrating Carbon Capture and Storage in Canada, Natural Resources Canada

Other references were added to the material available on the website for the Indonesian workshop and made available on the CD for the Chinese workshop

- Geological Storage of Carbon Dioxide - Staying safely underground, IEA GHG R&D Programme
- Carbon Capture and Storage - Meeting the challenge of climate change, IEA GHG R&D Programme

3.4 Availability of materials

The presentations were printed and presented in a workshop binder. The participants received a CD containing the presentations, training modules, case studies, community outreach material and references.

The Indonesian workshop CD is APEC publication APEC#209-RE-04.5

The Chinese workshop CD is APEC publication APEC#210-RE-04.1

CO2CRC hosted pages for each of the workshops on its workshop website: http://www.co2crc.com.au/ccsw/ . The website facilitated printing of the presentations in the host economy and allowed updated presentations to be made available to participants.

3.5 Recommendations for future training materials

Modules

- Add a section on demonstration projects and commercial projects that includes various types of capture and storage projects.

- Update all links.

- Module 14: Potential for CO_2 capture and storage in the APEC region. Updating the maps (based largely on the APEC study completed in 2004) was outside the scope of this project. Given the increase activity in assessing CO_2 storage capacity and the rapid development of APEC economies and subsequently their emissions, a study in the next few years would improve the currency of this module

Presentations

Include video and animations in the presentations where practicable.

Other materials

Provide new best practice manuals as they become available.

Workshop reports

4.1 Indonesia

Workshop overview – Venue, sessions and speakers

The workshop in Indonesia was hosted by MEMR at the MEMR building in Jakarta.

Day 1. Morning. CCS study and workshop launch – This was attended by the Minister of Energy and Mineral Resources of Indonesia, Dr Darwin Zahedy Saleh and the State Minister of Environment of Indonesia, Professor Dr Ir Gusti Muhammad Hatta. The launch of the CCS study was also attended by the Deputy Head of Mission of the British Embassy, the Ambassador of the Royal Norwegian embassy, the Ambassador of the Kingdom of The Netherlands and embassy officials from Australia and the United States.

After the launch of the CCS study, a panel session was held involving senior government officials and members of the state-owned oil and gas and electricity companies.

Chair: Ton Ten Have, Shell

Panellists: Bambang Praptono, Director of Planning and Technology, PT PLN; Dr.-Ing. Evita Legowo, Director General, Oil and Gas; Dr Massnelliyarti Hillman, Deputy Minister, Ministry of Envionment; Faturrahman, BPMIGAS; Dr R Sukhyar, Head of Geology Agency, MEMR; Syarizal, Senior Geologist PT Pertamina

Day 1. Afternoon. Joint workshop commenced.

Introduction to CCS technologies and applications to Indonesia – organized by MEMR/LEMIGAS.

Presenters:

- Dr Ego Syahrial, LEMIGAS

- Dr Hardiv H. Situmeang, Chairman of Indonesian National Committee of the World Energy Council

- Dr Simon James, Royal Dutch Shell
- Utomo P. Iskandar, LEMIGAS
- Michael C. Putra, Royal Dutch Shell

Day 2 and Day 3 (morning). Joint workshop

CCS technologies – implementation – organized by APEC in consultation with MEMR/LEMIGAS and the IEA.

Chairs: Professor John Kaldi, Dr Frank Mourits, Brendan Beck

Presenters:

- Dr Frank Mourits, Natural Resources Canada and APEC Expert Group on Clean Fossil Energy (EGCFE)
- Professor John Kaldi, CO2CRC
- Ir Sulistyowati, MM, Assistant Deputy for Climate Change Impact Control, State Ministry of Environment
- Dr Hardiv H. Situmeang, Chairman of Indonesian National Committee of the World Energy Council
- Suzete Ribeiro, Global CCS Institute
- Brendan Beck, IEA
- Dr Simon James, Shell
- Dr Peter Neal, CO2CRC
- Anni Bartlett, CO2CRC

Panel Session - Implementing CCS: Globally and in Indonesia.

Chair: John Kaldi

Panellists: Brendan Beck**,** Ego Syahrial, Michael Putra, Hardiv Situmeang, Nicci Jordaan (Sasol), Ananda Idris (Statoil Indonesia)

The workshop was closed by Dr Bambang Dwiyanto, Head of Research and Development Agency, MEMR

A full agenda is given in the Appendices.

Workshop organization

As mentioned in §2.1, the original plans for the APEC workshop were adjusted to avoid duplication and maximize attendance, resulting in a joint APEC/MEMR/IEA workshop. CO2CRC would like to acknowledge the efforts of Mr Brett Jacobs from the IEA, Dr Ego Syahrial and Ms Farida Zed of MEMR and Imah Rahimah of the UK Embassy in coordinating the joint workshop with CO2CRC and APEC.

MEMR took responsibility for inviting participants, organizing the venue and catering. CO2CRC's invitation list was incorporated into the MEMR list.

The Indonesian Coal Society organized the printing of workshop binders and CDs at very short notice.

The venue was provided by MEMR without charge. The UK Embassy in Jakarta and the Global CCS Institute provided financial support for the other venue costs such as audio/visual and catering. The Global CCS Institute also provided financial support for other costs (such as printing) for the APEC training materials and workshops.

The tight timeline around moving from an APEC workshop to a joint workshop provided some challenges for the project team, but the significant profile that the joint workshop had as a result of high level ministerial involvement would have been difficult to achieve as a stand-alone event. In addition, the ability to participate with the IEA in the roundtable meeting with government officials at the end of the workshop provided the project team with an opportunity to clarify the options for Indonesia to contribute to deployment of CCS.

The workshop timings were approximately right, although the early morning start on Day 2 was delayed due to traffic problems. To accommodate the late start, the panel sessions planned for Day 2 and Day 3 were rolled into one panel session on Day 3.

Workshop attendance

The workshop was well attended. The first day, being the launch of the CCS study and the joint workshop by two Indonesian government ministers attracted a large group. By the afternoon session, this had thinned to 150 participants. Day 2 had 70 participants on average and Day 3 (morning) had 56 participants on average. Participants signed in at a registration desk each day and the summary numbers are given in the tables below. A full list of participating organizations is given in the Appendices.

Day 1

Group	Participants
Government agencies	94
Research bodies	37
Oil and gas industry	37
Coal and mining industries	4
Electricity	22
CCS bodies	6
Government representatives	19
Other (Banking/Consulting)	11
Total registered	230

Day 2

Group	Participants
Government agencies	35
Research bodies	24
Oil and gas industry	22
Coal and mining industries	7
Electricity	17
CCS bodies	6
Government representatives	4
Other (Banking/Consulting)	2
Total registered	117

Day 3 (morning)

Group	Participants
Government agencies	19
Research bodies	22
Oil and gas industry	17
Coal and mining industries	6
Electricity	10
CCS bodies	5
Government representatives	0
Other (Banking/Consulting)	6
Total registered	85

The invitations were issued by MEMR; the timeline was short with invitations issued no more than ten days prior to the workshop as a new Minister had recently been appointed for MEMR. Consequently, CO2CRC was unable to obtain the contact details of participants. However, there were many breaks in the workshop for informal contact (as recommended by Phase III) and exchange of contact details was evident amongst participants and presenters.

In addition, due to the short timeline, the ability to advertise the workshop in neighboring APEC economies was limited. However, CO2CRC and APEC have had requests from other APEC economies to hold CCS capacity building workshops in their economies. There is clearly a high level of interest in this type of project.

Workshop participation

The workshop was conducted in sessions, with presenters at each session available for questions through the session chair at the end of the session. The questions and answer sessions were busy, with many questions spilling over into the break time in informal discussion. Participants were very engaged with the topic and questions ranged from big picture questions (e.g. “How will we pay for CCS?”, “Is CCS safe?”, “How can we tell the public about CCS?”) to technical questions (e.g. “What cements are use to secured wells following injection?”).

The panel sessions were also very lively. Each of the panelists was given an opportunity to speak for five minutes before questions were taken. Areas explored were:

- Indonesia’s need for energy security alongside environmental considerations
- Indonesia’s exposure to climate change
- The need for CCS in a climate change mitigation portfolio
- Policy frameworks for CCS
- Financial frameworks for CCS (CDM? Carbon Market?)
- The need for public understanding and acceptance of CCS
- Possibilities for early CCS projects
- Next steps for Indonesia.

Workshop feedback

Formal feedback was difficult to obtain, with only a few participants returning the feedback forms. While not a big sample, the feedback on how the workshop sessions had contributed to the knowledge of how to implement CCS in Indonesia was overall positive, with most participants rating the workshop sessions in the medium to high range.

Informal feedback was very positive. Senior MEMR officials were very impressed with the training material on the CDs and requested that the CDs be made available to its staff.

The suggestions on the feedback forms were for more contact between those with experience in CCS and Indonesia, to involve Universities in the next round of workshops and to have more specialised working groups.

A summary of the feedback can be found in the Appendices.

Workshop suggestions for advancing CCS in Indonesia

The following opportunities and challenges were identified from the presentations, discussions and feedback forms. The challenges identified are common to most developing APEC economies:

Challenges

- Cost of CCS
- How can the cost be minimized?
- How can research and development of CCS in Indonesia be funded?
- What financial mechanisms can be employed
- The lack of legal and regulatory framework for CCS in Indonesia
- Little technical CCS capacity in Indonesia
- No public awareness of CCS in Indonesia
- Need coordination between various international CCS bodies

Opportunities

- Develop a demonstration project (funded by international sources or oil, gas, coal industries) – this will help demonstrate safety and inform public and government
- Develop CCS awareness programs in the context of climate change
- Develop a national regulatory framework
- Build on the large oil and gas industry experience in Indonesia – exploration, injection and monitoring techniques from the oil and gas industry have been adapted to CCS
- The natural gas industry has the potential for low-cost carbon dioxide capture. Some fields (eg Natuna) have very high carbon dioxide content.
- Potential for Enhanced Oil Recovery (EOR) using carbon dioxide injection and storage in Indonesia – this option was regarded as appealing as it provides increased energy security and an income stream.
- Possibility for storage in saline aquifers or depleted oil and gas fields in association natural gas production from fields with high carbon dioxide content – this possibility was not as appealing but interest was expressed in this as an option for a demonstration project
- Building on the CCS research and development already undertaken in Indonesia
- Further knowledge sharing and capacity building
- Joint studies on source-sink matching, CCS with EOR and other storage opportunities with international R&D organizations

Follow-up activities and recommendations for advancing CCS in Indonesia

As mentioned previously, immediately following the joint workshop, IEA and MEMR held a roundtable discussion with government officials and officials from state-owned electricity and oil and gas companies to map the future collaboration between the IEA and MEMR and to discuss the key steps and barriers to the development of CCS in Indonesia.

In addition, the Global CCS Institute traveled to Indonesia on 15-17 December with the Clinton Foundation to follow up the potential for a large-scale demonstration project. Meetings were held with a variety of organizations including government, industry and financing groups

These recommendations come from the workshop and from the follow-up work with the IEA-MEMR roundtable discussion (for full report see http://www.iea.org/subjectqueries/ccs/ccs_roundtables.asp) and meetings with the Global CCS Institute.

Recommendations from these meetings include:

- Develop a pilot project in Indonesia. Candidates for such a project include EOR using carbon dioxide from natural gas separation. Funding from international bodies, including oil and gas companies, would be needed. A pilot project would provide a mechanism for developing and refining legislation and technical expertise. In addition it would provide a vehicle for developing public awareness and confidence in CCS technology.

- Investigate funding mechanisms for future CCS projects such as levies on fossil fuel production, a carbon dioxide tax and including CCS in the CDM.

- Further capacity-building - bodies such as APEC, the IEA and the Global CCS Institute could facilitate this through holding more technical workshops such as EOR specific workshops and capture workshops. However, it will be vital to co-ordinate activity with other capacity-building organizations.

Activities initiated include

- Developing a regulatory framework for CCS in Indonesia. This work will be collaborative between Indonesia, the IEA and the Global CCS Institute.

- A scoping study to look at possible CCS projects – the Global CCS Institute and the Clinton Foundation are facilitating this scoping study

4.2 China

Workshop overview – Venue, sessions and speakers

The workshop in China was hosted by Zhejiang University and held at the Jinxi Hotel, Hangzhou, Zhejiang. As the venue was in the same building as the accommodation there were opportunities for informal discussion.

Professor Luo, Dean of the Department of Energy Engineering, Zhejiang University welcomed the delegates and gave a speech. Dr Frank Mourits, Deputy Chair of the APEC Expert Group on Clean Fossil Energy, gave an opening speech on behalf of Scott Smouse, Chair of the APEC Expert Group on Clean Fossil Energy. Dr Mourits thanked Zhejiang University for their contribution to and strong support for the workshop and congratulated them on their excellent organization. A transcript of Dr Mourits' speech is in the Appendices. The Deputy President of Zhejiang University congratulated all participants in the

workshop for their commitment to reducing carbon dioxide emissions and emphasized that the kind of exchange taking place in the workshop was very important. He talked about the need for a multi-disciplinary platform to deliver a diverse energy portfolio including biomass and solar energy.

Presenters were

- Dr Frank Mourits, Natural Resources Canada and APEC Expert Group on Clean Fossil Energy (EGCFE)
- Prof Mengxiang Fang, Zhejiang University
- Dr Tony Zhang, Monash University, CO2CRC
- Prof Paul Webley, Monash University, CO2CRC
- Rick Causebrook, Geoscience Australia, CO2CRC
- Prof Mingyuan Li, EOR Research Centre, China University of Petroleum
- Dr Peter Neal, University of New South Wales, CO2CRC
- Prof Zhang Jian, Shengli Oilfield Branch Company, Sinopec
- Prof Rongshu Zeng, Chinese Academy of Science
- Dr Xufeng Li, China Geological Survey
- Brendan Beck, IEA
- Dr Gao Shiwang for Dr Shishen Xu, Thermal Power Research Institute
- Prof Li Zheng, Tsinghua University
- Anni Bartlett, CO2CRC

The panel discussion for Day 1 was chaired by Dr Rongshu Zeng and comprised Dr Frank Mourits, Prof Paul Webley, Prof Mengxiang Fang. This panel explored the technology challenges of capture and the technology challenges of storage and what work was being done to address those challenges.

The panel discussion for Day 2 was chaired by Brendan Beck and comprised Guo Shiwang, Peter Neal, Rick Causebrook and Zhensheng Jiang. This panel explored the readiness of APEC economies and of China for deployment of CCS.

Workshop organisation

Zhejiang University was the host for this workshop, as they had strong ties with US DOE through the APEC EGCFE Chair, Scott Smouse. They had previously successfully organised similar CCS workshops in which the Chair had been involved. The organization of the APEC workshop was complicated by the need for Zhejiang University to obtain a letter of approval. Due to lengthy delays in securing this letter two extensions to the project were granted by APEC.

More substantial issues arose with funding the workshop. The Global CCS Institute had indicated that it was willing to cover the local costs of the workshop, as they had with the Indonesian workshop but ultimately this funding was unavailable. The workshop went ahead through a last-minute reallocation of the project funds by APEC together with contributions by various organizations associated with the workshop.

There were some last minute changes to the speakers but all presentations were delivered.

The workshop had simultaneous translation. This was invaluable as the discussions were quite lively, and would have been severely hampered by sequential translation.

Workshop attendance

The workshop was well attended with the number of participants on the first day being about 80 and on the second day about 45. A full list of participants is given in the Appendices. While there were some representatives from the oil and gas industry and the environmental sector, the attendance was largely from the power generation sector. There were no government officials.

Workshop participation

The workshop was conducted in sessions. During the delivery of the workshop, the amount of time available for discussion and questions at the end of each session varied. Several participants would have appreciated greater time for questions, although the experts were available at the breaks and during the long lunch to follow up on questions.

There was a panel discussion in the afternoon of each day. These were lively discussions, with several key themes emerging.

The topics covered on Day 1 were the technology challenges for CCS:

- Reduce the cost of separating the CO_2 from the flue gases including energy penalty
- Scale up existing technology to large power plants
- Develop application to biomass, cement kilns, iron and steel manufacturing
- Minimise environmental impact
- Capacity estimation – how to get a realistic estimate?
- Beyond EOR: targeting saline aquifers
- Tracking the injected CO_2 – how can we do this?

The topics for Day 2 related to the wider implementation challenges for CCS:

- Are APEC economies ready for CCS?
- Are enterprises ready for CCS (or CCUS) if the government introduces a carbon tax?
- What is the largest barrier in China and in other APEC economies to implementing CCS?

Some of the key themes that emerged during the discussion sessions were:

- The capture technology still is a considerable way from being implemented on a large scale
- Enhanced oil recovery (EOR) has potential to store CO_2 with some economic benefit. Questions centered on the actual amount of CO_2 stored and the overall emissions given the oil recovery, how to source and pay for the CO_2, the potential for well damage.
- The potential for coal bed methane recovery using CO_2.

- Government policy drivers are needed to implement CCS due to the current high cost and energy penalty
- Access to land and permission to store CO_2
- Need for a nationwide assessment for potential storage sites
- The ability of China to develop new technology and then export it to the rest of the world

Feedback

There was excellent feedback about this workshop, with 47 feedback forms being returned.

The feedback rated the usefulness of most sessions as being medium to high, with an average of more than 60% in the medium-high to high categories. By far the most useful sessions were considered to be the sessions delivered by the Chinese experts on current projects in China. Making connections between areas of expertise in China was one of the major aims of this workshop, so this objective achieved.

Due to the large number of power companies who attended, there was strong interest in more detail on capture technologies. Some attendees were interested in non-CCS low-emission technology, but this was outside the scope of the workshop.

There was some overlap in the presentations. This was partly due to the Chinese expert presenters covering the technology as part of their presentations, while the workshop modules also covered the technology. This overlap may be somewhat avoidable with presentations being shared in advance of the workshop, although this was difficult to organise in this instance.

The feedback, both formal and informal, was that there is a need for more focused, specialty workshops in the future. There is intense interest in the technology and how it is being applied. The material in the current APEC training modules can be used within the organisations represented at the workshop to inform their employees about CCS.

A summary of the feedback can be found in the Appendices

Workshop suggestions for advancing CCS in China

There was great interest in CCS as a technology to reduce emissions. There was some opinion that ways should be first found to increase energy efficiency and renewable energy. Also the re-use of CO_2 as a way of reducing emissions such as in enhanced oil recovery (EOR) was seen as important. There was a strong sentiment that China has the technological expertise and depth of talent to adapt, improve and export CCS technology to the rest of the world. Overall, the major issues that need to be addressed to advance CCS in China are:

- Policy drivers need to be implemented by government to enable industry to take up the technology
- The cost of capture technology needs to come down to be adopted widely
- Technology needs to be shared across countries and across organizations
- The China Geological Survey's studies into suitable basins is important to understanding the potential for future projects
- Greater confidence is needed in the safety of capture, transport and storage

- While CCS is currently expensive, there are opportunities for CCS in enhanced oil recovery (EOR) and enhanced coal bed methane production (ECBM)

Follow-up activities and recommendations for advancing CCS in China

1. Hold future technical workshops to address in detail capture, transport and storage technologies in collaboration with current Chinese CCS project experts and international project experts.

2. Work with bodies such as the CSLF, IEA GHG or the Global CCS Institute to establish networks within China for technology sharing.

3. Develop a central website for information on all bilateral activities in China (see "Carbon Capture and Storage in China" literature review). This would include reports from those activities and announcements of new workshops, conferences and projects.

Appendices

Appendix 1: Workshop agenda, Indonesia

Asia-Pacific Economic Cooperation

British Embassy Jakarta

Launching Indonesia Carbon Capture and Storage (CCS) Study

By CCS Working Group

&

Joint Workshop

"Carbon Capture and Storage in Indonesia"

By APEC/MEMR/IEA

10-12 November 2009, Jakarta

Agenda

Conference Room
10th Floor
Ministry of Energy and Mineral Resources of Indonesia
Jalan Medan Merdeka Selatan No. 18
Jakarta 10110
Indonesia

PT PLN (PERSERO)

WORLD ENERGY COUNCIL
Komite Nasional
Indonesia

GLOBAL CCS INSTITUTE

CO2CRC

ICS
Indonesian Coal Society

British Embassy Jakarta

Launching Indonesia Carbon Capture and Storage (CCS) Study

By CCS Working Group

Day 1: Tuesday 10 November 2009

09.00 – 09.15	**Welcoming address** • Introduction of Launching the Indonesia CCS Study and Joint Workshop CCS in Indonesia (*Head of Agency of Research & Development for Energy & Mineral Resources - Ministry of Energy and Mineral Resources*)
09.15 – 10.15	**Opening Remarks** • United Kingdom Ambassador for Indonesia • Minister of Environment of Indonesia • Minister of Energy and Mineral Resources of Indonesia
10.15 – 10.30	**Coffee break**
10.30 – 12.30	**Panel discussion:** **Theme:** "Challenges And Proposed Solutions of CCS Implementation In Indonesia" **Chair:** Ton Ten Have, Shell **Panel Members:** KLH, MIGAS, BPMIGAS, PERTAMINA, PLN, Geological Agency
12.30 – 13.30	**Lunch**
13.30 – 14.00	**Overview of CCS study: understanding carbon capture & storage potential in Indonesia** *Dr. Ego Syahrial, PPPTMGB LEMIGAS*
14.00 – 14.30	**CO_2 emission sources in Indonesia** *Hardiv Situmeang, KNI-WEC, Djoko Prasetidjo, PT PLN (Persero) and Royal Dutch* Shell
14.30 – 15.15	**CO_2 capture & transport technology** *Hardiv Situmeang, KNI-WEC*
15.15 – 15.30	**Coffee break**
15.30 – 16.00	**Methodology for site selection** *Elisabeth Mackie, Royal Dutch Shell*
16.00 – 16.30	**CO_2 geological storage potential** *Dr. Ego Syahrial / Utomo P. Iskandar, PPPTMGB LEMIGAS*
16.30 – 17.00	**CO_2 policy and regulatory framework** *Michael C. Putra, Royal Dutch Shell*

PT PLN (PERSERO)

WORLD ENERGY COUNCIL
CONSEIL MONDIAL DE L'ÉNERGIE
Komite Nasional Indonesia

Joint Workshop: "Carbon Capture and Storage in Indonesia"
By APEC/MEMR/IEA

Day 2: Wednesday 11 November 2009

08:30 - 9:15	**Introduction to APEC's CCS programme** *Dr Frank Mourits, Natural Resources Canada* **Introduction to the Global CCS Institute - Facilitating commercial scale CCS deployment** *Suzete Ribeiro, Global CCS Institute* **The APEC training modules** *Prof. John Kaldi / Anni Bartlett, CO2CRC*
9:15 - 10:15	**Government, community and the environment 1** • CCS as a Mitigation Action in Reducing Emissions in the Context of UNFCCC Negotiation *Masnellyarti Hilman / Sulistyowati, Ministry of Environment* • CCS legal and regulatory issues: a global update *Brendan Beck, IEA*
10:15 - 10:30	**Coffee Break**
10:30– 12:30	**Government, community and the environment 2** • Potential Implementation CCS in Indonesia as Mitigation Technology *Hardiv Situmeang, KNI-WEC* • Evaluating the risks *Simon James, Shell* • Monitoring programs – overview and example *Prof J Kaldi, CO2CRC* • Public awareness and community consultation *A Bartlett, CO2CRC*
12:30– 13:30	**Lunch**
13:30 – 14:30	**How much will it cost?** • The economics of CCS/current costs of CCS *P Neal, CO2CRC*
14:30 – 15:15	**Challenges in capture technology and recent advances** *A Bartlett, CO2CRC* **Challenges in storage technology and recent advances** *Prof. J Kaldi, CO2CRC*

Joint Workshop: "Carbon Capture and Storage in Indonesia"
By APEC/MEMR/IEA

Day 2: Wednesday 11 November 2009

15:15 – 15:30	**Coffee Break**
15:30 – 16:00	**Pilot to Demonstration to Commercial - projects around the world** *Suzete Ribeiro, Global CCS Institute*
16:00 – 17:00	**Panel discussion – From concept to implementation** *Chair: Prof J Kaldi, CO2CRC*

Day 3: Thursday 12 November 2009

09:00 – 09:30	**International CCS bodies** *Hardiv Situmeang, KNI-WEC / GCCSI*
09:30 – 10:30	**The IEA CCS Roadmap - Actions to CCS deployment** • Technical, Financial, Regulatory, Public Engagement, and International Collaboration *Brendan Beck, IEA*
10:30 – 10:45	**Coffee Break**
10:45 – 11:45	**Panel discussion: The next steps** *Chair from IEA/APEC* *Panel Members: Ministry of Environment*
11:45 – 12:00	**Close of workshop** *MEMR representative-CCS Working Group*

Appendix 2: Workshop participants, Indonesia

Participating Organisations

ADB

Adimitra Baratama Nusantara

Airlangga University

Alstom Power

Arutmin

Aryacitra

Australian Embassy

B2TE

Bappenas

Biro Perencanaan

BNP Paribas

Bogor Agricultural University

BP

BPMigas

BPPT

British Embassy

BUMN

Center for Research on Energy

Chevron

CO2CRC

CPE

CSI

Department of Energy and Minerals

DH Energy

Directorate General - O&G

Ditjen Migas

DJLPE

Dutch Embassy

EADS Astrium

Electricty and Energy Utilization

EMP

ExxonMobil

French Trade Commision

Geology Agency

Global CCS Institute

Greenworks Asia

IEA

IIEE

Indonesian Coal Society

Indonesian Power

ITB

KLH (Ministry of Environment)

KNI-WEC

LEMIGAS

Medco Power

Ministry of Environment

Mott MacDonald

Natural Resources Canada

Netherlands Embassy

Norwegian Embassy

P3TEK

Pelangi Indonesia

Pertamina

PetroChina

PLN

PME

PPPTKEBT

PT.BA

PT.Elnusa.TK

PT.Kideco

Pusdatin

R&D For Mineral and Coal Tech

Royal Danish Embassy

Sasol Synfuels

Sekolah Tinggi Teknik

Shell

SJR

Sojitz

State Energy Council

Statoil

TNO B&O

Total E&P

US Embassy

WWF

YBUI

Appendix 3: Workshop feedback, Indonesia

APEC/MEMR/IEA Joint Workshop

Carbon Capture and Storage in Indonesia
Workshop feedback: Day 2 and Day 3
We would be grateful for your feedback on this workshop

Name_____ Organisation_____
I attended Day 2 (11) Day3 (11)
Please rate each workshop session; how useful was it for increasing your knowledge of how to develop CCS in your economy?

	Low		Medium	High	
Day 2					
Introduction to APEC's CCS programme		1	5	4	
Introduction to the Global CCS Institute		2	3	5	
The APEC training modules		1	5	4	1
CCS as a Mitigation Action in Reducing Emissions in the Context of UNFCC Negotiation		1	3	4	
CCS legal and regulatory issues			4	4	2
Potential Implementation of CCS in Indonesia as a Mitigation Technology			4	4	2
Evaluating the risks		1	3	3	3
Monitoring programs – overview and example			2	5	4
Public awareness and community consultation			4	4	3
The economics of CCS			2	8	1
Challenges in capture technology			4	4	1
Challenges in storage technology			2	6	2
Pilot to demonstration to commercial – projects around the world			1	5	3
Panel discussion Day 2 - From concept to implementation *Postponed to Day 3*					
Day 3					

International CCS bodies		1	2	5	
The IEA CCS Roadmap			1	6	2
Panel discussion Day 3 – The next steps			2	6	1

Comments

How could the sessions be improved?

More detail; Questions during presentations, Animations in presentations; Shorter workshop; Translation of sessions; Larger invitation list

Please list any areas that should be covered in future workshops

Public health issues in transportation and storage; Public and industry involvement in CCS; In depth case study on CCS deployment/demonstration project; Have greater University involvement; More on regulation; Incorporate industry, forestry and transport in the workshops

What topics would you like more detail about?

Wells – cementing and drilling; Site selection; Geological formations and CCS behavior; Capacity building opportunities; Examples relating to climate and paleoclimate; Power generation and CCS; Disadvantages of CCS and how to reduce them; CCS and coal mining; Challenges in capture and storage; Best practice; risk; Indonesia's capacity for CCS.

Which sessions contained too much detail for you?

Regulatory framework.

What do you think needs to be addressed to implement CCS in your economy?

Increase public awareness about CO_2 emissions; capacity building (fellowships in CCS projects?); technology transfer; Balance of economics between developed and developing economies. Government departments more aware of CCS as a climate change mitigation option.

Please provide any other comments

Have a session to provide knowledge sharing between expert and user; Need more detail relating to legislation; More public involvement needed; Wider sectors need to be involved; Visit power plants; Split into working groups; Involve universities; Information about CCS to other meetings (power generators)

Thank you for your time.

Appendix 4: Workshop agenda, China

Asia-Pacific Economic Cooperation

APEC CCS Capacity-Building Workshop

Agenda

Day 1, June 7

Session 1 **8:30 - 10:30** **Opening and introduction**	**Opening** *Scott Smouse, US Department of Energy, National Energy Technology Laboratory* *Representative ,National Energy Bureau ,P.R. China* *Representative, Energy Bureau, Zhejiang province* *Representative, Zhejiang University*
	Introduction • Overview of carbon capture and storage activities in APEC *Dr Frank Mourits, Natural Resources Canada* • CCS as emerging technology for China *Prof. Mengxiang Fang, Zhejiang University* • The APEC training materials *Anni Bartlett, Cooperative Research Centre for Greenhouse Gas Technolgies, (CO2CRC)* • CO_2 capture and geological storage (CCS) overview (Module 1) *Anni Bartlett, CO2CRC* Questions/Discussion
10:30 – 10:50	Morning tea
Session 2 **10:50 – 12:00** **Technology for CCS (1)**	• CO_2 Capture (Module 2 and Module 3) *Dr Tony Zhang, Monash University/CO2CRC* Questions/Discussion • CO_2 Compression and transport (Module 4) *Prof. Paul Webley, Monash University/CO2CRC* Questions
12:00 – 14:00	Lunch
Session 3 **14:00 – 15:35** **Technology for CCS (2)**	• Trapping CO_2 underground (Module 5) *Rick Causebrook, Geoscience Australia/CO2CRC* • CO_2 storage –how we find suitable storage sites (Module 6 and Module 7) *Rick Causebrook, Geoscience Australia/CO2CRC* • EOR and storage of CO_2 *Prof. Mingyuan Li, China Petroleum University* Questions/Discussion
Session 4 **15:35 – 17:05** **Local case studies**	• Capture 1 *Dr Gao Shiwang and Dr Shisen Xu, TPRI* • Capture 2 *Prof. Zhang Jian, Shengli Power plant* • Preliminary study of CO_2 storage in Liubei Oilfield, Jizhong Depression, Hebai Province, China *Prof. Zeng Rongshu, Chinese Academy of Science* • Capacity assessment and demonstration projects of CO_2 Geological storage in China *Dr Eryong Zhang and Xufeng Li , China Geological Survey*
Session 5 **17:05 – 18:00**	**Panel discussion** – From concept to implementation

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CO2CRC

Asia-Pacific Economic Cooperation

DAY 2, June 8

Session 6 **8:30 - 10:30** **Government, community and the environment**	• Evaluating the risks (Module 8 and Module 9) *Rick Causebrook, Geoscience Australia/CO2CRC* • Monitoring programs (Module 9) *Rick Causebrook, Geoscience Australia/CO2CRC* • Regulatory frameworks (Module 10) *Brendan Beck, IEA* • Public awareness and community consultation (Module 13) *Anni Bartlett, CO2CRC* Questions/Discussion
10:30 – 11:50	Morning tea
Session 7 **10:50 – 12:00** **How much will it cost?**	• The economics of CCS (Module 12) *Dr Peter Neal, UNSW / CO2CRC* • Emissions trading schemes and other enabling mechanisms (Module 11) *Brendan Beck, IEA* Questions/Discussion
12:00 – 14:00	Lunch
Session 8 **14:00 – 15:00** **Current & future CCS in China**	• Current and future CCS in China *Prof.Li Zheng, Tsinghua University* Questions/Discussion
15:00 – 16:00 **Making CCS commercial**	• On the road to CCS commercialization *Brendan Beck, IEA*
Session 10 **16:00 – 17:00**	**Panel discussion** – The next steps

浙江大学

CO2CRC

Appendix 5: Workshop participants, China

APEC CCS Capacity-Building Workshop

(NO.)	(Name)	(Organization)
1	Frank Mourits	Natural Resources Canada
2	Anni Bartlett	CO2CRC
3	Tony Zhang	Monash University/CO2CRC
4	Brendan Beck	International Energy Agency
5	Paul Webley	Monash University/CO2CRC
6	Peter Neal	The University of New South Wales/CO2CRC
7	Rick Causebrook	Geoscience Australia/CO2CRC
8	Dennis Best	International Energy Agency
9	Jim Zhou	
19	Mingjiang Ni	Zhejiang university
11	Zhongyang Luo	Zhejiang university
12	Zhesheng Jiang	Electrical Power Technology Market Association of China
13	Mengxiang Fang	Zhejiang university
14	Shisen Xu	Thermal Power Research Institute
15	Mingyuan Li	China Petroleum University（Beijing）
16	Zheng Li	Tsinghua University
17	Rongshu Zeng	Chinese Academy of Science
18	Xufeng Li	China Geological Survey
19	Jian Zhang	Shengli Engineering&Consulting Co.,Ltd
20	Dongjie Zhang	Tsinghua University
21	Xiaocun Li	Institute of Rock Soil Mechanics,Chinese Academy of Science
22	Hongfei Shi	Shanghai power equipment research institute
23	Shiwang Hao	Xi’an Thermal Power Research Institute Co.,Ltd
24	Xinrong Yan	China HuaDian Corporation
25	Yuhui Shen	China Huadian Engineering Co., Ltd.
26	Yang Wang	China Huadian Engineering Co., Ltd.
27	Tongyu Peng	Wangting Power Plant , China HuaDian Corporation
28	Zhiming Ma	Hangzhou Banshan Power Plant, China HuaDian Corporation
29	Zhu Da	Hangzhou Huadian Power Co., Mid-Levels
30	Jiang Huannong	Qishuyan Jiangsu Huadian Power Co., Ltd.
31	Liu Cuiwei	Xinjiang Huadian Power Co., Ltd. Liang Wei Wu
32	Hu Long	Xinjiang Huadian Power Co., Ltd. Liang Wei Wu
33	Mi Wenzhen	China Power Investment Corporation Ministry of Environmental Protection Science and Technology Agency
34	Su Fengming	China Power Complete Equipment Co., Ltd.
35	Wu Ling	China Power Investment Corporation Yuanda Environmental
36	Ding Junwei	China Datang Corporation
37	Gao Jian	China Datang Corporation
38	Wang Wenxuan	China Datang Group Technology Engineering

		Co., Ltd.
39	Xun Jun	Beijing guodian Longyuan Environmental Protection Co., Ltd.
40	Xu Yantao	Guodian Penglai power CO.,LTD.
41	Wu guoxin	Guodian Taizhou Power CO.,LTD..
42	Tu Xiaobao	Guodian Zhejiang Beilun First Power CO.,LTD.
43	Chen Hangjun	Guohua Power CO.,LTD.
44	Lin Ronghua	Shenhua Guohua（Beijing） Power Research Institute CO.,LTD.
45	Liao Haiyan	Shenhua Guohua（Beijing） Power Research Institute CO.,LTD.
46	Sang Rubo	Zhejiang Zheneng Beilun Power CO.,LTD.
47	Yao Minfang	Senneng Group CO.,LTD.
48	Fen Deming	China Power Engineering consulting Group Corporation
49	Long Hui	China Power Engineering consulting Group Corporation
50	Deng Wenxiang	East China Electric Power Design Institute
51	Ma Xinqiang	Northwest Electric Power Design Insitute Heat Engine Desulfrization Department
52	Li Luwei	Southwest Electric Power Design Institute
53	Sun Hansen	China United Coalbed methane CO.,LTD.
54	Yan Jisheng	China United Coalbed methane CO.,LTD.
55	Yang Xueyan	Sinopec Exploration & Production Research Institute
56	Zhang Xinjun	Sinopec Shengli Oil Field shengli Survey & Design Institute CO.,LTD.
57	Chen Nan	Shanghai Electric Power Plant Technology Research &Development Center, Combustion Technology Institute
58	Zhang Jianwen	Shanghai boiler Co.,Ltd.
59	Xiao-Jiang Wu	Shanghai Boiler Co.,Ltd.
60	Tai-sheng Liu	Dong Fang Boiler Group Co.,Ltd.
61	Deng-ke Sun	Dong Fang Boiler Group Co.,Ltd.
62	Qi Zhang	Babcock & Wilcox Beijing Company Ltd.
63	Jie-Zhong Sun	Wu Xi Huaguang Boiler Joint Stock Co., Ltd.
64	Song LI	Zhejiang Zheda Insigma Mechanical & Electrical Engineering Co.,Ltd.
65	Xiang-kai XU	Zhejiang Zheda Insigma Mechanical & Electrical Engineering Co.,Ltd.
66	Wen-Ming Fang	Zhejiang Zheda Insigma Mechanical & Electrical Engineering Co.,Ltd.
67	Zhi-bang Yao	Zhejiang United Electronic Industry Co., Ltd.
68	Xiao-Feng Yao	Zhejiang United Electronic Industry Co., Ltd.
69	Jun chen	Zhejiang United Electronic Industry Co., Ltd.
70	Dong Zhimin	Zhejiang United Electronic Industry Co., Ltd.
71	Xu Changchun	Jiang Su Xinshiji Jiangnan Environmental Protection Co., Ltd
72	Pang Keliang	Jiang Su Xinshiji Jiangnan Environmental Protection Co., Ltd
73	Haobo Dai	Zhejiang Tiandi Environmental Protection Co., Ltd
74	Jingling Zhao	Zhejiang Tiandi Environmental Protection Co.,

		Ltd
75	Feng Hao	Zhejiang Tiandi Environmental Protection Co., Ltd
76	Haijiao Liu	Zhejiang Tiandi Environmental Protection Co., Ltd
77	Deyong Liu	Zhejiang Tiandi Environmental Protection Co., Ltd
78	Jingming Zhong	Zhejiang Tianda Environmental Protection Co., Ltd
79	Cheng Yang	Zhejiang Tianda Environmental Protection Co., Ltd
80	Dongming Zhang	Zhejiang Tianda Environmental Protection Co., Ltd
81	Hao Zhou	Babcock and Wilcox Beijing Company
82	Xiqiang Li	GE
83	Jing Zhang	Electrical Power Technology Market Association of China
84	Kunlin Wu	CHC Wangting power plant
85	Xinchun Li	North China Electric Power Design Institute Engineering Co., Ltd
86	Lei Xia	Asiachem Consulting Co., Ltd
87	Hong Yi	Zhejiang University

Appendix 6: Workshop feedback, China

Asia-Pacific Economic Cooperation

CCS Capacity-Building Workshop

Workshop feedback:
反馈表

We would be grateful for your feedback on this workshop
非常感谢您给予我们的反馈意见

Name_____ Organisation_____
姓名_____ 单位 _____
I attended Day 1 (47) Day 2 (47)
我参加了第一天 □ 第二天 □
Please rate each workshop session; how useful was it for increasing your knowledge of how to develop CCS in your economy?
请您对每一个环节打分：您觉得它们对增加您对CCS的认识起到的作用。

	Low（低）		Medium（中）	High（高）	
Day 1					
Session 1: Opening and introduction 开幕式以及大会报告		4	16	11	13
Session 2: Technology for CCS (1) CCS技术（1）	1		18	17	11
Session 3: Technology for CCS (2) CCS技术（1）	1		16	18	12
Session 4: Local case studies 中国的一些示范项目		2	9	16	20
Session 5: Panel discussion 小组讨论		1	4	18	16
Day 2					
Session 6: Government, community, environment 政府，社区和环境	1	2	16	11	14
Session 7: Cost 费用问题	1	2	16	13	13
Session 8: CCS in China 中国的CCS进展情况		1	7	19	20
Session 9: Making CCS commercial 让CCS技术更加具有经济价值		2	12	17	13
Session 10: Panel discussion 小组讨论			4	13	14

浙江大学

CO2CRC

Comments评论

How could the sessions be improved? 如何提高每个环节？

More detailed technology sharing
More detailed policies and guidelines
More practical examples
Materials distributed in advance
More time for questions/discussion
Less overlap in presentations (3)
More technical experts from projects
Have separate technical sessions
More detailed case studies
Have group discussions
More detail about technical problems

Please list any areas that should be covered in future workshops

请列举可以在今后研讨会中增加的研究领域

More detailed technology sharing (2)
More detail on post combustion capture (technology, energy consumption and costs) (4)
More detail on storage in saline aquifers
Details of a large scale coal-fired power plant with CCS
Detail of chilled ammonia capture (2)
Comparison of capture technologies(2)
Different combustion technologies
Emission sources such as coal processing and oil refineries
Technology transfer issues
Financing
Framework for CCS development
Integrated utilisation of CO_2 /CO_2 in algae farms
Energy efficiency and emission reduction in power plants
More detail on laws, environmental impact, risk, liability (2)
Chinese government's position and policies on CCS (2)
Current world projects
Detailed cost breakdown of each section of the CCS chain

What topics would you like more detail about?

你对哪个方面想了解得更多 ？

Chinese government's position and policies on CCS (2)
Chinese CCS roadmap (2)
Capture (5), compression and transport technologies (2)
How to develop CCS in areas without suitable geological storage
Capture in coal-fired power plants, engineering and feasibility (4)
Geological storage options
Storage sites in China
Re-use of CO_2 (3)
Case studies of CCS projects and the economics of these projects
More detail on laws, environmental impact/assessment (2), monitoring
China's carbon cycle
Industrial emission sources and their % contribution
Investment in capture technologies and reduction in operating costs
Current state of CCS in developed countries, policies, regulation and taxes
Storage sessions did not adequately canvas the risk, liability, gaps and shortages
Current world projects, especially capture

Which sessions contained too much detail for you?

你认为哪个环节包含的内容太多了 ？

All sessions were good (2) CCS roadmap Regulations, economics (2) and geology

What do you think needs to be addressed to implement CCS in your economy?

你认为在你所在的经济体制中必须实施的 CCS技术是什么？

Capture technology development (3) Capture from the chemical industry (with high CO_2 concentration) Mature and reliable technology Reduce cost and energy consumption (2) Application to large scale power plants (2) Sequestration technologies other than geological Understanding the technology, then demonstration Demonstration capture projects EOR projects Storage sites Emissions from oil refineries and coal processing

Please provide any other comments

请提供其他的

Please contact us is there are similar workshops/conferences It would be good to build a platform for sharing information To what extent does CO_2 affect climate change – CCS is still too costly for companies to accept and may be a waste of energy Simultaneous translation was excellent More details about the transport to the venue could have been provided

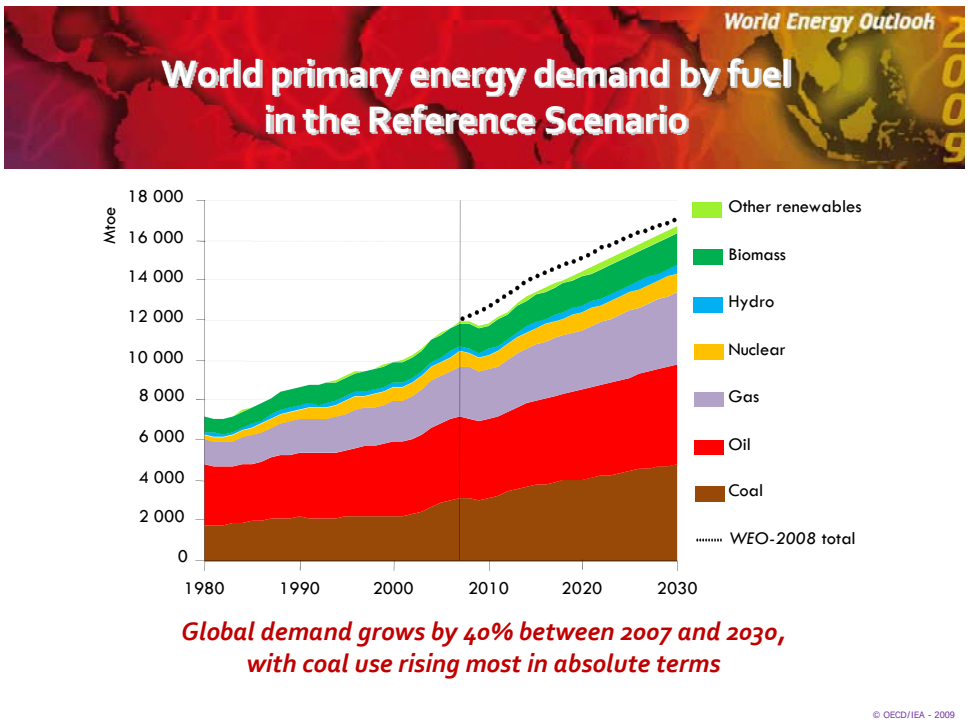
Thank you for your time.

谢谢您抽出时间填写本次调查问卷

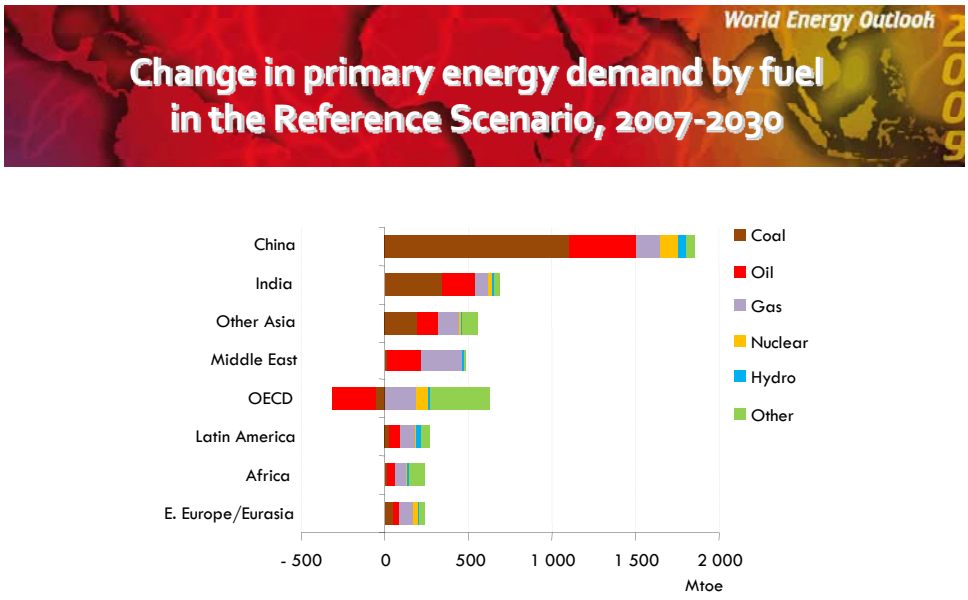
Appendix 7 Opening speech, China workshop

Opening speech by Dr. Frank Mourits to APEC CCS Capacity-Building Workshop in Hangzhou, China, 7 June 2010

We are all aware that global demand for energy will continue to rely on fossil fuels at least until the middle of this century. But we also know that fossil energy, under its present patterns of production and use, is and will continue to be a major source of greenhouse gas emissions, in addition to having other less desirable impacts on our local and global environment.



In the 2009 World Energy Outlook prepared by the International Energy Agency (or the IEA), fossil fuels are projected to remain the dominant contributor to the growth of energy demand in the IEA's Reference Scenario, providing some 77% of incremental demand during the period. Coal has the highest growth rate among fossil fuels, its share is rising from 27% to 29%. China, whose coal demand almost doubles over the period, accounts for 65% of the global coal demand increase.



The increase in China's demand for energy – for coal in particular – dwarfs that of all other countries and regions

What does this mean for our own field of fossil energy in APEC? Given these trends, there is a clear need to transition to a more sustainable energy economy if we are to have an insurance policy against the still uncertain but potentially catastrophic consequences of greenhouse gas induced global climate change. What does this mean to us as producers and consumers of fossil energy, and how can we make fossil energy sources environmentally sustainable?

Improving the efficiency with which we produce, transport and use fossil fuels has considerable potential that we must first exploit. Beyond this, the most promising means of reducing CO_2 emissions, particularly from the growth in coal-based electricity generation, will be through carbon capture and geological storage or CCS. The IEA has estimated that CCS can create the second largest CO_2 emissions reduction of all available options,, exceeded only by energy efficiency improvements.

Only 15 years ago, CCS was just an idea of a few scientists, and its development and deployment was thought to require decades to accomplish, if at all. Today, the critical role of CCS in tackling global climate change is increasingly being recognized. Its widespread deployment can make fossil fuels part of the solution, not part of the problem. CCS can contribute to human welfare by enabling the clean and climate-friendly use of the world's vast fossil fuel resources.

The potential of CCS was recognized by the G8, which with the assistance of the IEA, the Carbon Sequestration Leadership Forum (or CSLF) and experts in the field, has focused on what needs to be done in the near term in order that CCS technologies can be adequately demonstrated, their costs reduced, and the necessary regulatory frameworks developed.

The G8 Summit in 2008 in Japan called for the launch of 20 large-scale CCS demonstration projects in 2010 and the start of broad deployment of CCS by 2020. The 2009 G8 Summit in Italy added to that by calling for its members to:

1. accelerate the development of policies, legal and regulatory frameworks and financial incentives for the development and deployment of CCS technology;

2. encourage greater involvement of developing countries by promoting collaboration and knowledge diffusion (which is what this workshop is all about);

3. invite the IEA, together with the Carbon Sequestration Leadership Forum, to further develop technology roadmaps (Brendan Beck from the IEA will present on this tomorrow).

Beyond the G8, APEC has also recognized the need for action on CCS. APEC Leaders, meeting in Sydney, Australia, in September 2007, produced a Declaration on Climate Change, Energy Security and Clean Development. In this declaration they committed to meet the energy needs of APEC economies, while addressing the issue of environmental quality and contributing to the reduction of greenhouse gas emissions.

Specifically, they agreed to promote policies that advance the deployment of low and zero emission energy uses, including clean coal and carbon capture and storage, through co-operative work under the APEC Energy Working Group (or EWG).

This commitment at the APEC top follows longstanding directives from APEC Energy Ministers to its Energy Working Group. Beginning in 2004, they have asked the EWG to accelerate the development and deployment of innovative energy technologies that can address energy security and reduce greenhouse gases and other atmospheric pollutants. Carbon capture and storage technologies have been consistently included in these directives.

Therefore, we have a clear mandate to contribute to the realization of the policy objectives of APEC Leaders and Energy Ministers, as far as CCS is concerned. The Expert Group on Clean Fossil Energy (or EGCFE), which works under the EWG, has made this as one of its priority themes, together with the goal of helping APEC economies to improve the efficiency of coal-fired power generation.

Today's workshop responds to these calls by APEC Leaders and Energy Ministers. The workshop is an important step, since capacity-building in the technical, economic, legal and regulatory aspects of CCS has been identified as an essential part of the CCS roadmap. In the next session, I will be telling you more about the work by the EGCFE in the area of CCS and the projects that have been completed to date and are being proposed for the coming year.

Finally, this workshop would not have been possible without the hard work and perseverance of two project teams. We are very grateful for the enthusiasm and strong support from the Zhejiang University team, which is being led by Professor Luo. This team has been responsible for the excellent local organisation of the workshop.

The second team I like to thank is the team from the Cooperate Research Centre for Greenhouse Gas Technologies (or CO2CRC) in Australia, which is being led by Mrs Anni Bartlett. The CO2CRC has a contract with APEC to provide the overall development of the workshop, prepare the workshop materials and coordinate with the local organiser. Anni will tell you more about the workshop materials in the next session.

Thank you for your attention. I wish you all a very successful and informative workshop.

Appendix 8: Literature Review, Indonesia

Carbon Capture and Storage in Indonesia

Literature review

Regan, M, Bartlett, A and Van Puyvelde, D. R.

June 2010

CO2CRC Technologies

Contents

Introduction

This desktop study was undertaken through research into publically available information to provide a background for an APEC CCS Capacity Building Workshop. This workshop was held in November 2009 in conjunction with the release of a major technical study on Understanding Carbon Capture and Storage Potential in Indonesia, led by the Agency for Oil and Gas Research Development (LEMIGAS) of the Ministry of Energy and Mineral Resources of Indonesia.

CO_2 emissions

Indonesia's CO_2 emissions related to the consumption of fossil fuels in 2006 were 280 million metric tons, ranking Indonesia 22nd in the world (Energy Information Administration 2009). While Indonesia has considerable greenhouse gas emissions from forestry and land use change, its emissions due to the use of fossil fuel are rising. This study examines emission sources that are candidates for carbon capture and storage (CCS).

According to the Energy Information Administration (EIA), in 2004 the use of oil accounted for the majority of energy-related CO_2 emissions (56%). Emissions from the use of natural gas followed (24%), with the use of coal resulting in 16% of energy related CO_2 emissions (Energy Information Administration, 2007).

Figure 1 illustrates the geographical distribution of stationary CO_2 sources in Indonesia. Emissions on the island of Java are reasonably concentrated with centres to the east and west of the island. On the island of Sumatra, CO_2 emission sources are quite widely spread. The other main CO_2 emission centre is in eastern Kalimantan.

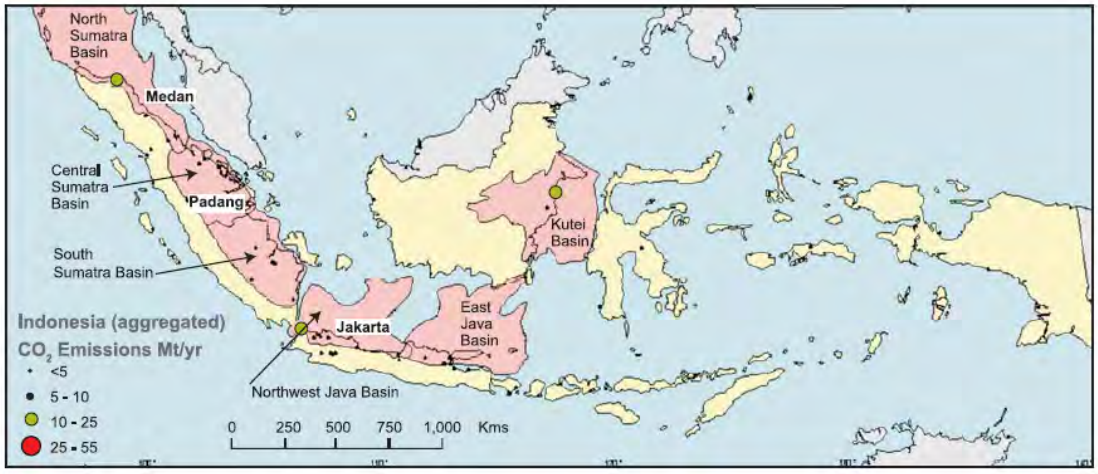


Figure 1: Locations of large stationary CO_2 sources in Indonesia (APEC/ICTPL, 2005).

Energy use

Indonesia's primary energy consumption in 2008 was 124 million tonnes of oil equivalent (Mtoe), (approximately 900 million barrels of oil equivalent, (Mboe)) which accounts for 1.1% of the worlds total primary energy consumption. In the 10-year period from 1998 – 2008, primary energy consumption in Indonesia has increased at an average annual rate of 3.5% (Figure 2) (BP, 2009).

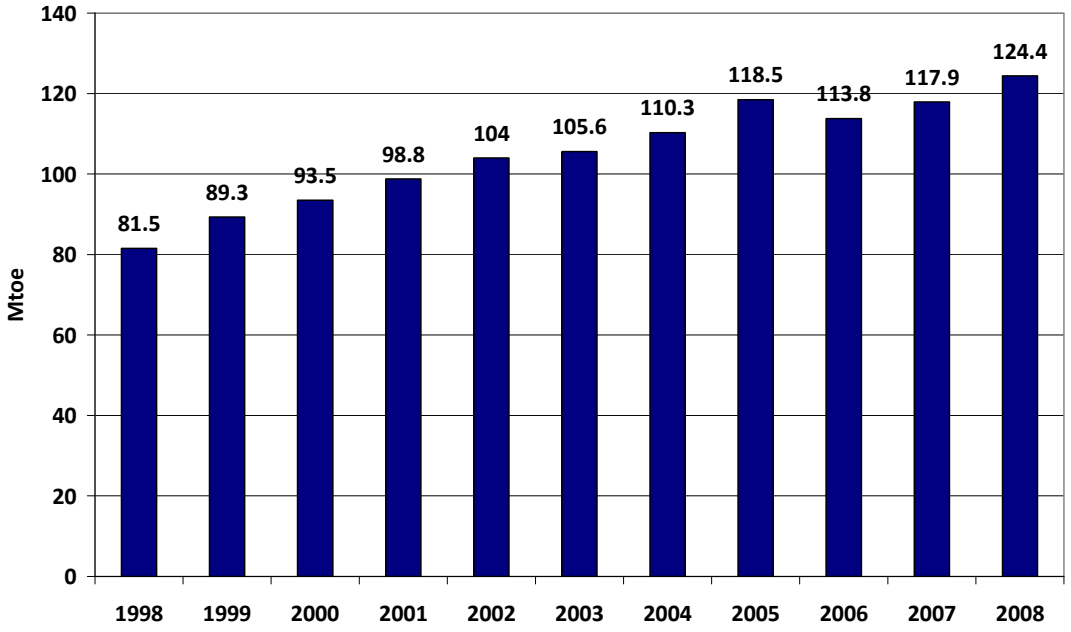


Figure 2: Indonesia's Primary Energy Consumption 1998 – 2008 (BP, 2009).

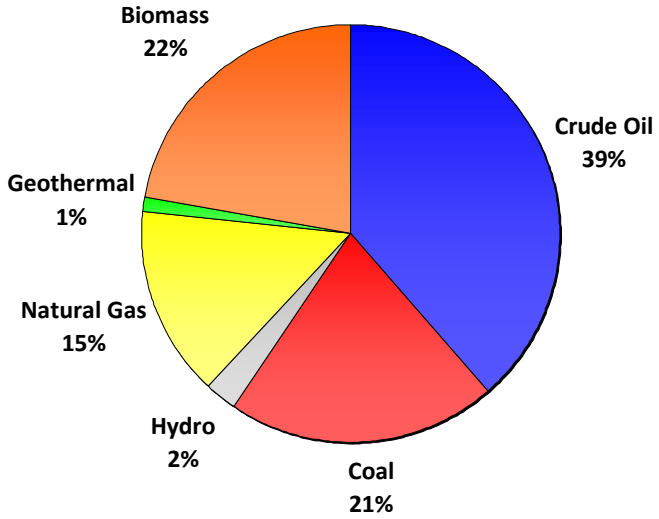


Figure 3: Primary energy supply by fuel including biomass (CDI-EMR, 2008).

Data from the Centre for Data and Information on Energy and Mineral Resources (Indonesian Government) include energy supplied from biomass, indicating that it is a major component in the supply of primary energy in Indonesia (Figure 3) (CDI-EMR, 2008). Most of this biomass is used directly within households and only a small amount is used for electricity generation.

In terms of consumption of final energy by sector (biomass included), the household sector is the largest consumer as shown in Figure 4. The industrial and transportation sectors are the other main consumers of final energy in Indonesia.

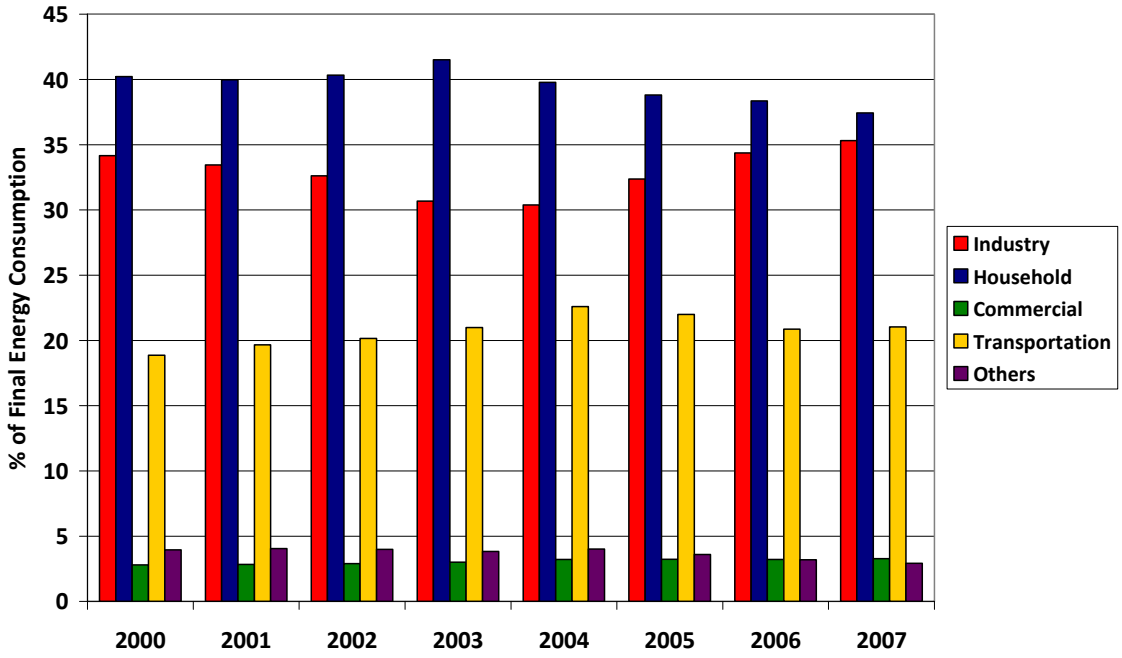


Figure 4: Consumption of final energy by sector (CDI-EMR, 2008).

Electricity generation in Indonesia totaled 133,108 GWh in 2006. Almost half of the electricity generated in 2006 was attributed to the combustion of coal (44%), followed by oil (29%) and natural gas (15%). Electricity from non fossil fuel energy sources in the form of hydro and geothermal accounted for a significant proportion of Indonesia's total electricity generation (Figure 5). Electricity generation has risen steadily since 1998 to 151,200 GWh in 2008 (IEA, 2009).

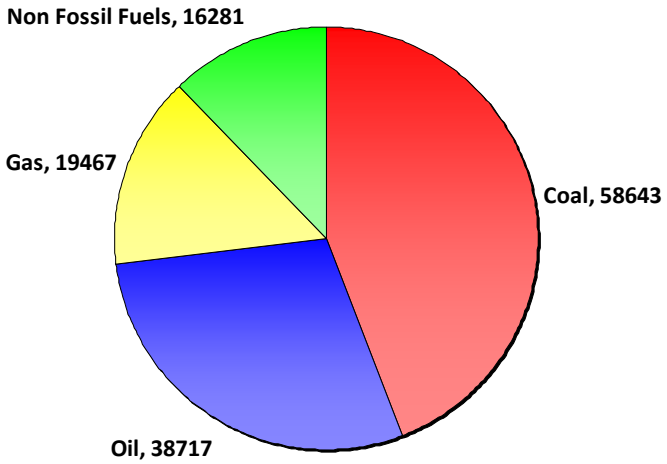


Figure 5: Electricity generation (GWh) by fuel type, Indonesia, 2006 (IEA, 2009).

A Presidential Decree (Presidential Regulation No. 5/2006) has set out a target for an optimal energy mix for 2025. (Ministry of Energy and Mineral Resources, Indonesia, 2008). Figure 6 displays the energy mix in 2006, projected 2025 primary energy mix under "business as usual" conditions, and an optimized energy mix for 2025. While a substantial increase in the use of non-fossil fuel energy is targeted in the optimized energy mix scenario, there is an increase in use of fossil fuel over 2006 figures in this scenario. Another regulation, (Presidential Regulation No. 71/2006) sets a target of 10, 000 MW of electricity generation from coal.

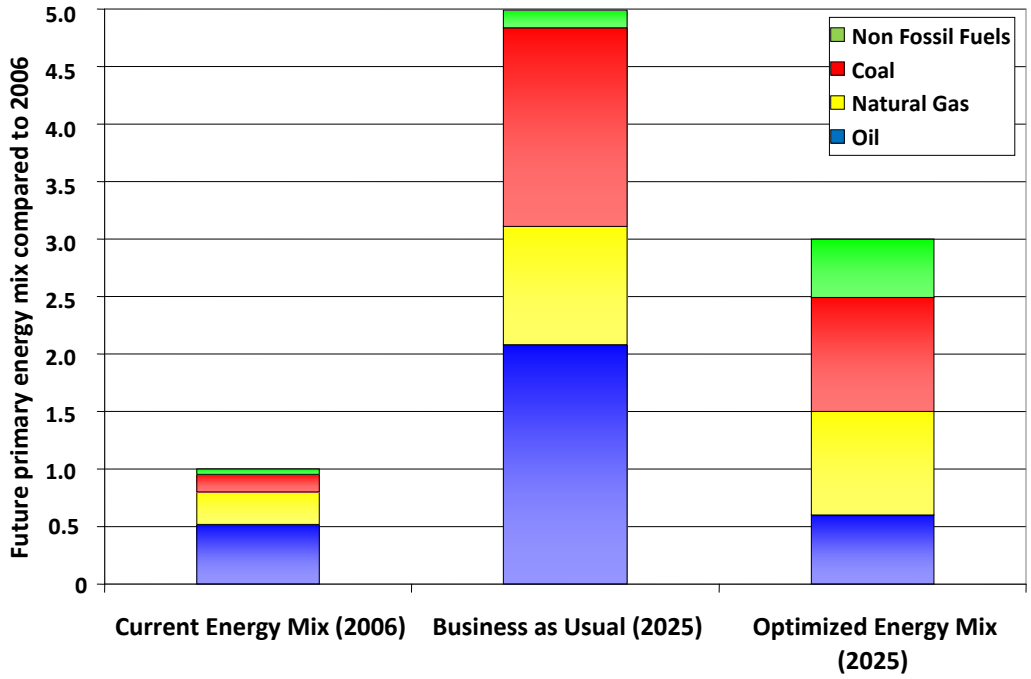


Figure 6: Current (2006) and projected primary energy mix scenarios (Ministry of Energy and Mineral Resources, Indonesia, 2008).

Energy resources

Oil

Indonesia has proven oil reserves at the end of 2008 of 3.7 billion barrels of oil. Globally, this equates to 0.3% of the world's proven oil reserves (BP 2009). With oil fields reaching maturity and exploration unable to replace produced volumes, Indonesia's proven oil reserves have been steadily declining - reserves at the turn of the century (2000) were 5.12 billion barrels of oil (CDI-EMR, 2008).

Oil production has steadily decreased since 2000. Daily oil production in 2008 averaged just over 1 million barrels (MMbbl) per day. This equates to around 1.2% of total world daily oil production for that year. Although this was a slight increase from 2007 (0.97 MMbbl/day) production has decreased by around 500,000 bbl/day since 1998 (BP, 2009).

Conversely, consumption has steadily increased, with daily consumption in 2008 averaging 1.2 MMbbl/day., making Indonesia's oil consumption 1.5% of world daily oil consumption (BP, 2009). As a result of these two trends in oil production and consumption, in 2004 Indonesia became a net importer of oil (Figure 7).

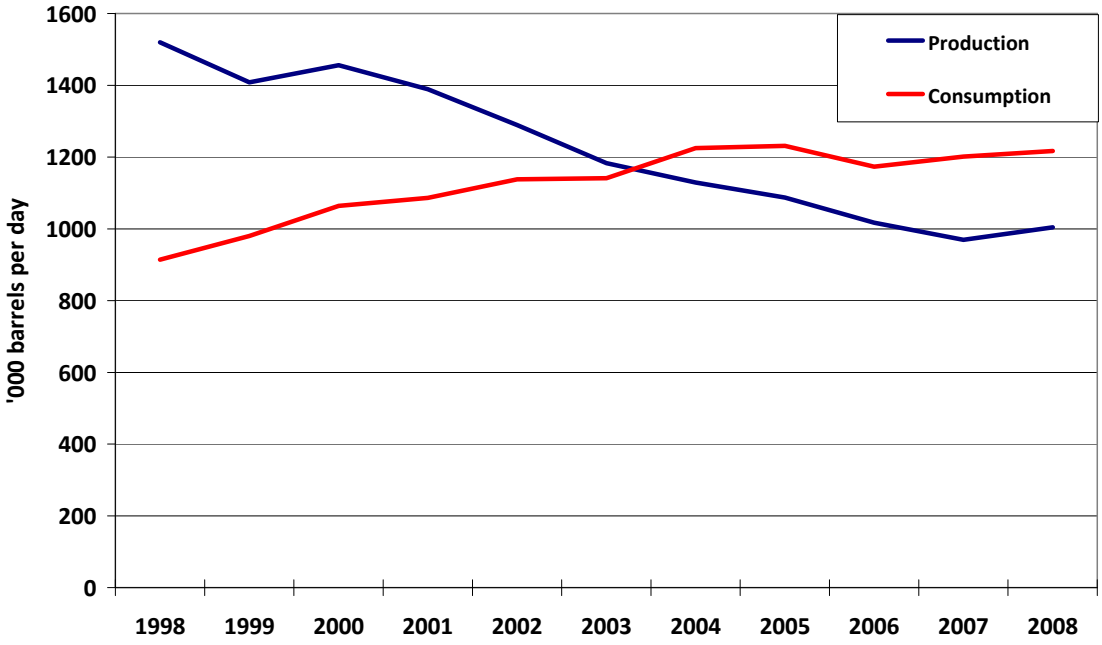


Figure 7: Indonesia's Production and consumption of oil, 1998 – 2008 (BP, 2009).

Coal

Indonesia's proven coal reserves at the end of 2008 were 4.33 billion tonnes, or 0.5% of the world's coal reserves. 60% of the coal reserves are sub-bituminous and lignite (BP, 2009). The majority of Indonesia's coal reserves (approximately two thirds) lie in the island of Sumatra, with the remainder located in Kalimantan, West Java and Sulawesi (Energy Information Administration, 2007).

Indonesia has seen a dramatic increase in coal production, with a 73% increase since 1998. In 2008, Indonesia produced 141.1 Mtoe of coal, 4.2% of world coal production. Although coal

consumption in Indonesia has increased by around 69% since 1998, coal consumption relative to production is minor with consumption in 2008 totaling 30 Mtoe (Figure 8) (BP, 2009). Indonesia is a major exporter of coal, with EIA estimates indicating that Indonesia was the second largest exporter of coal in the world in 2004 (Energy Information Administration, 2007).

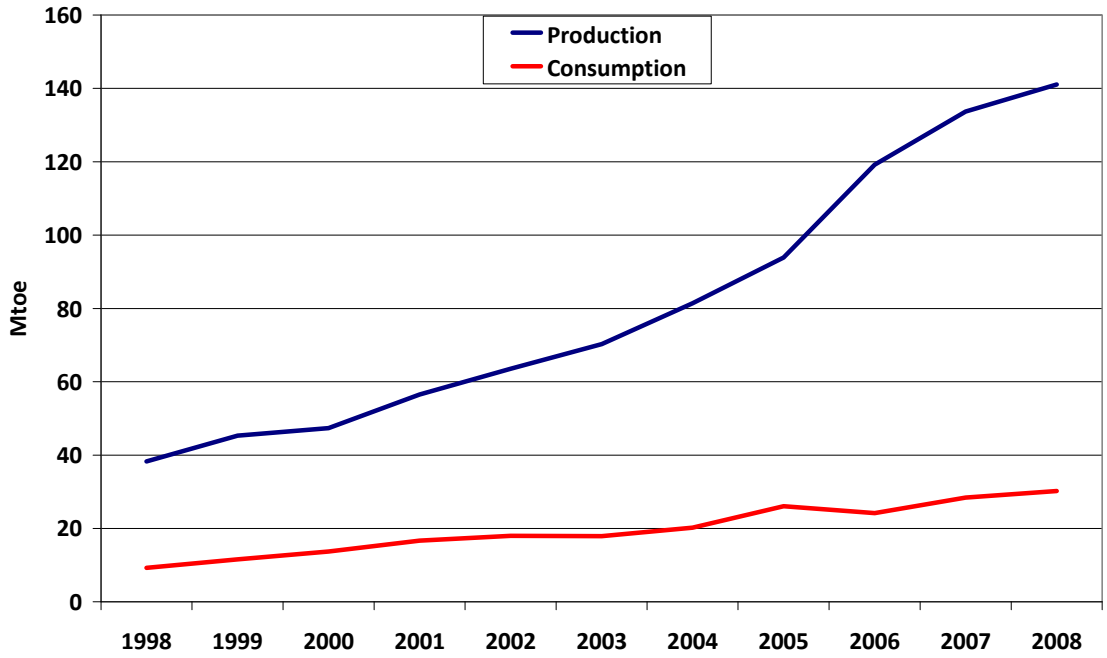


Figure 8: Indonesia's coal consumption and production, 1998 – 2008 (million tonnes of oil equivalent) (BP, 2009).

Natural Gas

According to BP (2009), Indonesia had proven natural gas reserves of 112.5 trillion cubic feet (Tcf), or 1.7% of world natural gas proven reserves. Indonesia has the largest natural gas reserves of the Asia Pacific region, ahead of Australia (1.4% of world natural gas proven reserves). Over 70% of these natural gas reserves are located in offshore basins, with the largest reserves located in waters found off Natuna Island, East Kalimantan, South Sumatra and West Papua (Energy Information Administration, 2007).

In 2008, Indonesia was amongst the top producers of natural gas in the world, with total production reaching 2.4 Tcf, 2.3% of world natural gas production. Production over the last 10 years has however been quite consistent, ranging between 2.2 – 2.6 Tcf (BP, 2009).

Domestic consumption of natural gas has followed a similar trend to that of production for the last 10 years (Figure 9), however consumption has been around half that of production. In 2008, consumption of natural gas was 1.34 Tcf (BP, 2009).

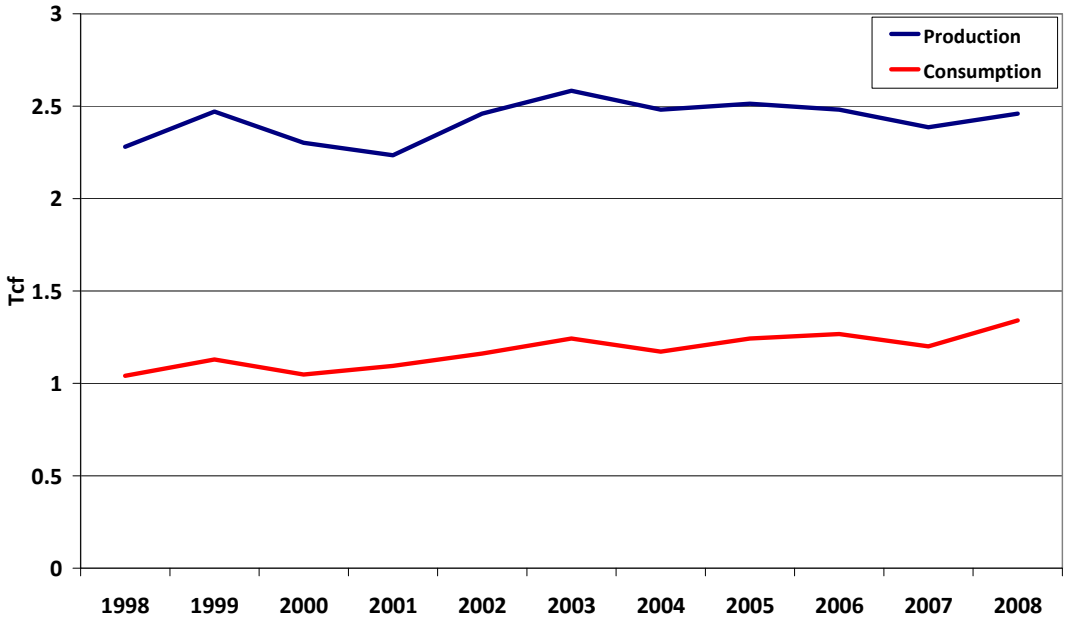


Figure 9: Indonesia's Consumption and Production of Natural Gas 1998 – 2008 (BP, 2009).

The Indonesian government has made an effort to increase domestic natural gas consumption due to declining oil reserves, however the limited transmission and distribution network has proved an obstacle in increasing domestic consumption (Energy Information Administration, 2007).

As such, Indonesia exports the remaining balance of natural gas, and is in fact the third largest exporter of liquefied natural gas (LNG) in the world behind Qatar and Malaysia (BP, 2009).

Coalbed methane

Indonesia is estimated to have in the order of 450-453 Tcf of coalbed methane (CBM) (Chakhmakhchev, 2007; Stevens and Hadiyanto, 2004). LEMIGAS and MEDCO have conducted a CBM pilot project in the Rambutan Field, South Sumatra. The pilot project is the first step in a plan to have CBM contribute to 1-2% of energy by the year 2025 (Research and Development Agency MEMR).

CCS potential in Indonesia

CO_2 storage potential

A study into the potential for Indonesia to implement CCS has been undertaken by a study group led by the Agency for Oil and Gas Research Development (LEMIGAS) of the Ministry of Energy and Mineral Resources of Indonesia. The results were released in conjunction with an APEC CCS Capacity Building Workshop in November 2009.

Prior to this study, an estimate was made in 2005 of the geological storage capacity of Indonesia's sedimentary basins. Based on USGS estimates of known hydrocarbon accumulations (past production and remaining reserves), an estimate of roughly 10 300 Mt of CO_2 could be stored in depleted oil and gas reservoirs (APEC/ICTPL, 2005). If energy-related CO_2 emissions are taken into consideration, this storage estimate equates to around 37 years of storage capacity.

In addition to displaying the major stationary CO_2 point sources in Indonesia, Figure 1 also displays a number of sedimentary basins that were studied in that particular document. The LEMIGAS study notes that the most likely basins for storage are located in South Sumatra (South Sumatra basin), East Kalimantan (Kutei Basin) and the Natuna basin. They are geologically stable, sparsely populated and the presence of the oil and gas industry means that the area has existing infrastructure and geological characterization. Another potential location is the Northwest Java Basin. The LEMIGAS study looked into some potential source-sink matches.

The study identified that oil and gas related CO_2 emissions from gas processing plants, LNG plant and refineries represent low cost sources of CO_2 that could be made available as early CCS projects. The declining production of the oilfields may make enhanced oil recovery (EOR) operations an attractive possible option for early CCS projects. In addition, the interest in coalbed methane (CBM) as a resource raises the possibility of ECBM projects, although the study notes the early stage of technical development of ECBM using CO_2 and the current lack of development of CBM in Indonesia.

CCS regulation in Indonesia

There is currently no specific regulatory framework in place in Indonesia related to the application of CCS. Existing legislation in both Indonesia and internationally needs to be analysed so that a policy framework can be formulated to support the implementation of CCS.

Some of the relevant existing laws and policies within Indonesia are

Oil and Gas - Law Number 22 (2001), Government Regulation 35 (2004) and 36 (2004) and Green Oil and Gas Industry Initiative

Energy - Law Number 30 (2007), Presidential Regulation Number 5, (2006) and 6 (2006)

Environment - Law Number 32 (2009) and 17 (2004, Kyoto Protocol) Presidential Regulation 33 (2005, Montreal Protocol Amendment, Ozone layer)

Long term energy policy scenarios for Indonesia were developed in 2007 included examining the possibility of introducing CCS after 2023. Early modeling has suggested the portfolio of emission reduction strategies, including CCS, could reduce CO_2 emissions by 13.4% from the business as usual scenario (LEMIGAS, 2009).

CCS activity in Indonesia

There are currently no CCS projects underway in Indonesia. According to a statement from the Indonesian Minister of Environment at the High-Level Conference on Fighting Climate Change with CCS, the Indonesian government is working with contractors on gas projects in Papua Province to introduce CCS technologies (IISD, 2009).

In 2007 the Indonesian government signed a Memorandum of Understanding (MoU) with the French oil and gas company Total on CCS. Under the agreement, the Indonesian government will have access to data from Total's CCS pilot project. This project involves the geological storage of 150 000 metric tons of CO_2 in a depleted gas field in Rousse. The source of the CO_2 is from oxy-fuel combustion at Lacq's steam production unit at the gas processing plant (Innovation Norway, 2008).

A workshop on CCS was held in October, 2008. The Government of the United Kingdom. MEMR, the Ministry of the Environment, World Energy Council (WEC) (Indonesian Committee), Shell, CCSA and IEA GHG all contributed to the workshop.

The LEMIGAS study into the potential for Indonesia to implement CCS had funding support from the Government of the United Kingdom. The study was carried out by a CCS Study Working Group involving LEMIGAS, KNI-WEC, PT PLN (Persero), KLH, Royal Dutch Shell and the UK Embassy.

The IEA is working with Indonesia on a range of energy initiatives, including a CCS project with MEMR. Part of this work will be developing a CCS roadmap for Indonesia.

Indonesia is a member of the Global CCS Institute which was formally launched in April of 2009.

Specific opportunities and challenges for Indonesia

Opportunities

- MEMR/LEMIGAS study identifies the potential for CCS in Indonesia
- Many sedimentary basins
- Experience in the oil and gas industry
- Good potential for source-sink matching
- New power generation and industrial facilities are being constructed – may avoid retrofit costs

Challenges

- Application of CCS would increase the cost of electricity
- Potential conflict of interest if storage to occur in hydrocarbon provinces
- More detailed studies into plant development for capture and geological storage sites needed
- No regulatory framework in place
- Financial capacity of Indonesian government to provide incentives for the establishment of CCS activities

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Appendix 9: Literature Review, China

Carbon Capture and Storage in China

Literature review

Regan, M, Bartlett, A and Soroka, M

June 2010

CO2CRC Technologies

Contents

Introduction

China's recent industrial growth has lead to a dramatic increase in emissions of carbon dioxide. With many large, stationary sources and identified basins with potential for CO_2 storage, in recent years there has been considerable interest in China's capacity for carbon capture and storage (CCS). This paper provides a background to China's CCS potential.

CO_2 emissions

As of 2007, China has become the world's largest emitter of carbon dioxide, overtaking the United States (IEA 2007). Energy-related CO_2 emissions in 2007 were 6 071 million tonnes (IEA 2009). Table 1 summarises energy-related CO_2 emissions by sector with a comparison to 1990 CO_2 emissions. There is a strong increase in emissions from both the power generation and industrial sectors, with a 5-fold increase in emissions from the power generation sector. From 1990 to 2005, CO_2 emissions grew at an annual average rate of 5.6% (IEA 2007).

Table 1: China's energy-related CO_2 emissions by sector (IEA 2007, IEA 2009).

Sector	1990 emissions (million tonnes CO_2)	2005 emissions (million tonnes CO_2)	2007 emissions (million tonnes CO_2)
Power Generation	652	2500	3060
Industry	800	1430	1700
Transport	121	337	399
Other	670	833	912
Total	**2244**	**5101**	**6071**

From Table 1 it can be seen that emissions from stationary point sources dominate China's CO_2 emissions. Li et al. (2009) state that there are over 1,620 large stationary CO_2 point sources in China, where each source emits at least 100,000 tonnes of CO_2 per annum. The combined annual CO_2 emissions from these 1,620 stationary point sources amount to 3,890 million tonnes of CO_2.

Figure 1 summarises the sector distribution of CO_2 emissions from stationary point sources. By far the largest emitter of CO_2 is the power sector, contributing 73% of the total emissions coming from 629 of the 1620 stationary CO_2 point sources. This, therefore, makes the power sector a prime target for application of carbon capture and storage (CCS). CO_2 emissions from cement plants contribute around 14% of the total CO_2 emissions. Iron and steel plants and other industrial plants contribute the remainder of CO_2 emissions from stationary point sources (Dahowski et al. 2009; Li et al. 2009).

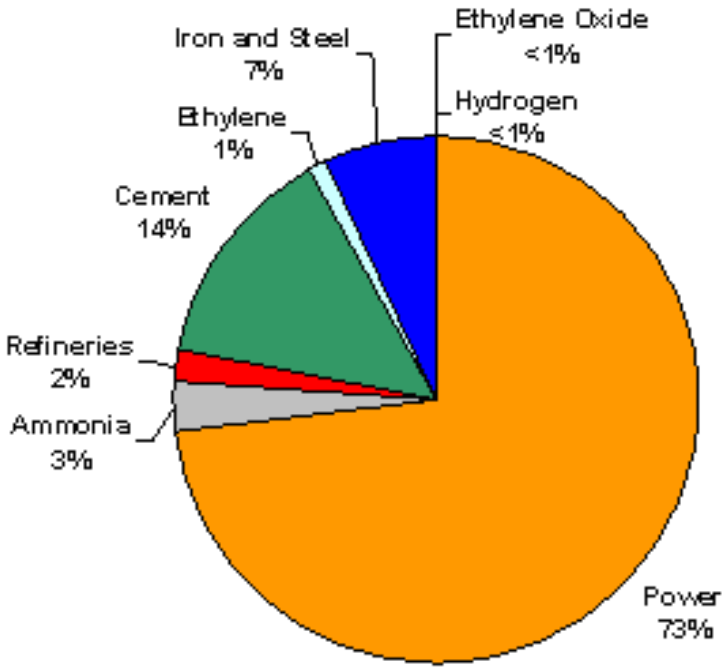

Figure 1: CO_2 emissions by sector from large stationary point sources (Sourced: Dahowski et al. 2009).

However, it is from industrial plants making ammonia, hydrogen and ethlyene oxide through gasification processes, that provide early CCS opportunities due to the high purity CO_2 and a relative closeness of suitable storage sites (Qian et al. 2009).

The geographical distribution of the 1,620 large stationary point sources is shown in Figure 2. It can be seen that the vast majority of these CO_2 point sources are located in the east of the country, where there is the greatest population density in China. In fact, 58% of the CO_2 point sources are located in the East and South Central Administrative Regions (Dahowski et al. 2009).

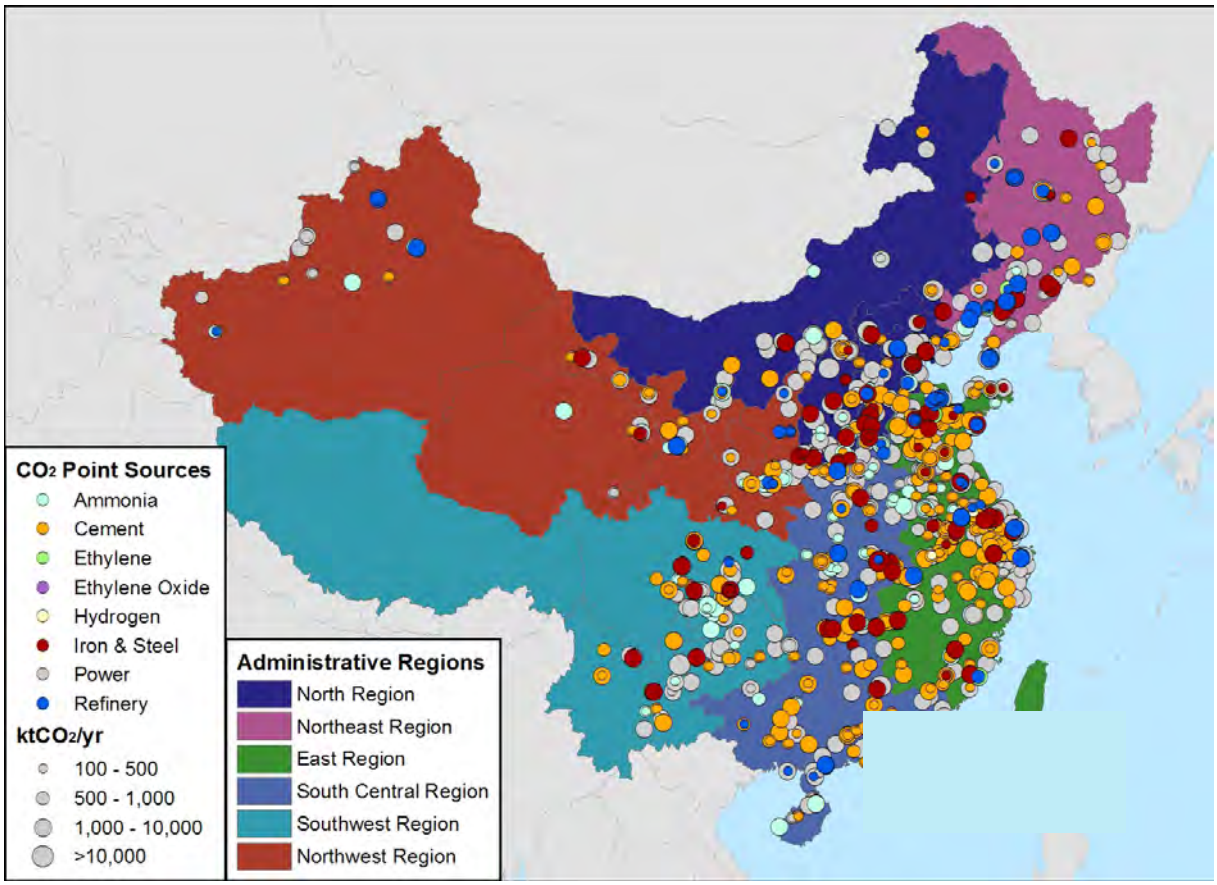

Figure 2: Geographical distribution of large, stationary point sources of CO_2 emissions (Dahowski et al. 2009). ***Reproduced with permission of R Dahowski.***

In terms of future CO_2 emissions, China is predicted to dominate the world's annual CO_2 emissions up to 2030 (end of prediction periods). In the Reference Scenario, based on unchanged underlying trends in energy demand and supply, China's CO_2 emissions are predicted to increase to 9.6 Gt by 2020 and 11.6 Gt by 2030 (Figure 3).

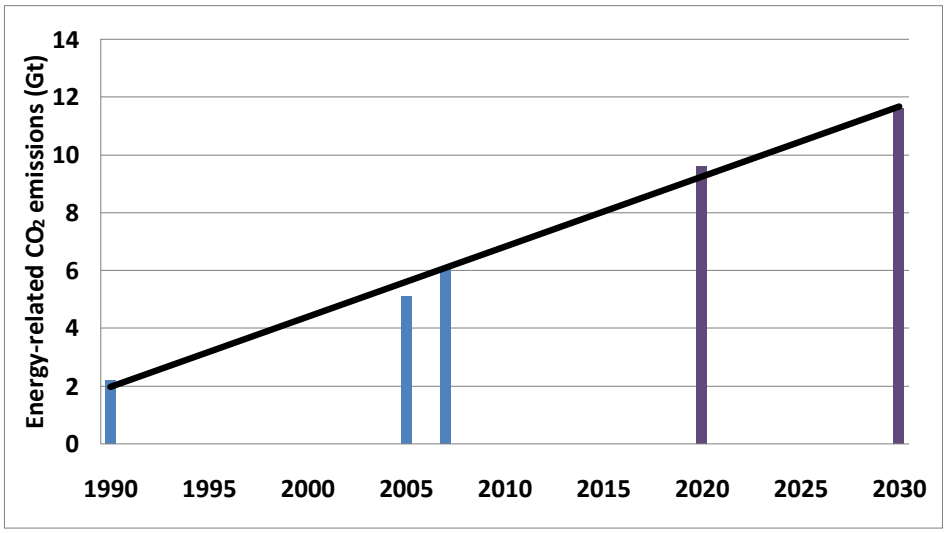

Figure 3: China's energy-related CO_2 emissions under the Reference Scenario (Sourced IEA 2007; IEA 2009).

Energy resources

China's primary energy requirements in 2007 were 1,970 million tonnes of oil equivalent (Mtoe), up from 874 Mtoe in 1990. Primary energy requirements in China are predicted, in the IEA's Reference Scenario, to reach 3,827 Mtoe by 2030 (IEA 2007; IEA 2009).

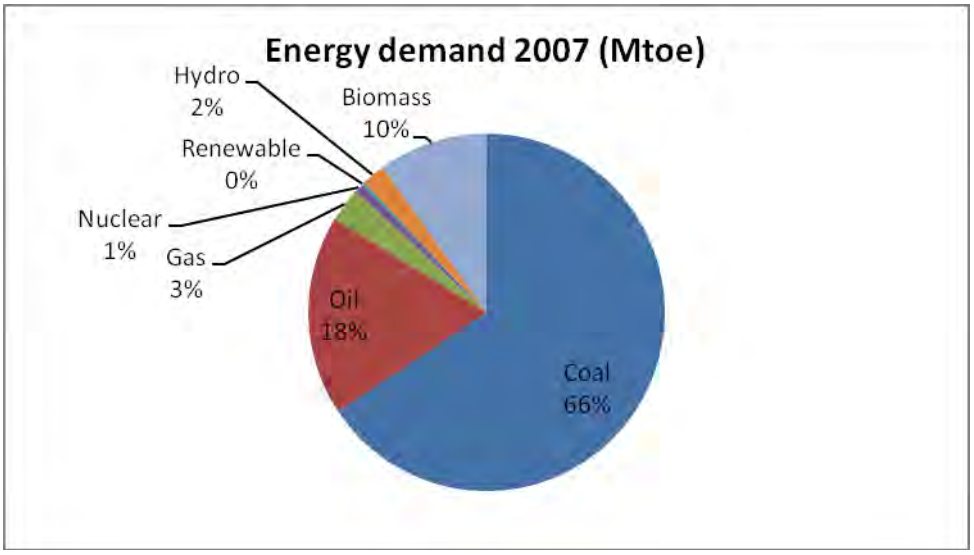

Figure 4: China's primary energy demand in 2007 (IEA 2009).

Figure 4 displays the distribution of China's primary energy sources in 2007. Coal is by far the prominent source of primary energy for China, accounting for 66% of primary energy needs. Coal's share of the energy demand is predicted to fall to 63% by 2030 (IEA 2009).

Biomass is a large percentage of the primary energy mix due to use in the rural areas of China. Fuelwood and crop wastes continue to be used in rural households as a source of energy for cooking and heating.

Natural gas, hydroelectricity, nuclear power and renewables provide only a small percentage of China's primary energy requirements.

The power sector is the main user of primary energy, accounting for about half of primary energy requirements. Industrial energy requirements account for about a quarter of the primary energy generated in China (IEA 2007).

Table 2 summarises the IEA's predictions of primary energy requirements for China until the year 2030. Coal is predicted to continue to be the main source of primary energy for China, making it vital that techniques such as CCS be applied in order to minimise/reduce CO_2 emissions.

Table 2: Predicted growth in China's primary energy requirements (Mtoe) (IEA 2007).

	1990	2005	2015	2030	2005 – 2030*
Coal	534	1,094	1869	2,399	3.2%
Oil	116	327	543	808	3.7%
Natural Gas	13	42	109	199	6.4%
Nuclear	0	14	32	67	6.5%
Hydro	11	34	62	86	3.8%
Biomass	200	227	225	227	0.0%
Other Renewables	-	3	12	33	9.9%
Total	874	1,742	2,851	3,819	3.2%

* Average annual rate of growth

Coal

In terms of total resources, China is second only to Russia, with a potential total coal resource of 1,003 billion tonnes (IEA 2007). However, in terms of proven coal reserves, this figure drops to 115 billion tonnes, accounting for 13.9% of the world's proven coal reserves at the end of 2008 (BP 2009).

Around 80% of the coal resources lie in China's north-west region in the provinces of Shanxi, Inner Mongolia, Shaanxi, Xinjiang, Ningxia, Hebei, Gansu and Qinghai (IEA 2007).

China's coal production has increased dramatically since the turn of the century (2000) in response to the strong increase in demand (Figure 5). Production was quite stable in the late 1990s; however production volumes have increased over twofold between 2000 and 2008.

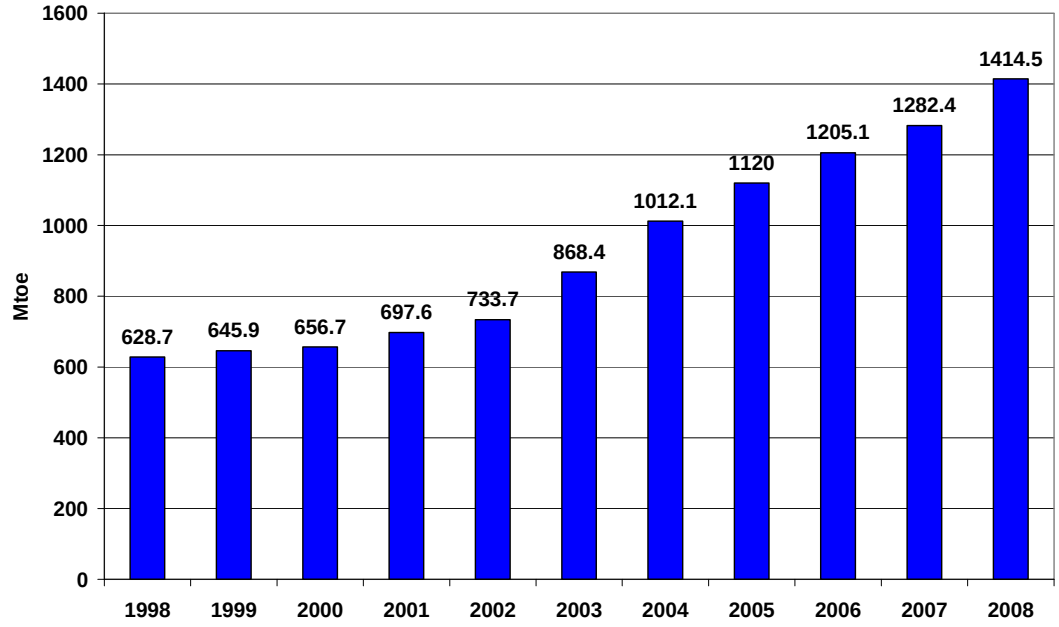

Figure 5: China's Coal Production from 1998 – 2008 (Sourced: (BP 2009).

At current production rates, China's reserves to production ratio (R/P) is 41 (BP 2009). In other words, at current production rates, China's current coal reserves will last for 41 years. Coal production is forecasted to increase strongly over the next 25 years in the IEA's Reference Scenario, dominated by the production of steam coal (Table 3).

Table 3 China's coal production by coal type (million tonnes of coal equivalent) in the Reference Scenario (IEA 2007).

	2005 (million tonnes of coal equivalent (Mtce)	2015 (million tonnes of coal equivalent (Mtce)	2030 (million tonnes of coal equivalent (Mtce)
Steam Coal	1,380	2,238	2,939
Coking Coal	256	366	395
Total	1,636	2,604	3,334

In 2008, China's coal consumption was 1,406 million tonnes of oil equivalent, equating to 42.6% of world coal consumption for that year (BP 2009).

The electricity sector and industrial sector (direct use of coal) account for almost half of the coal consumption in China, at 48% and 46% respectively. China's predicted strong increase in coal consumption is expected to be dominated by increased use in the electricity sector. Coal consumption in the electricity sector is predicted to increase at an annual rate of 3.5% per year from 2006 – 2030. In comparison, the US electric power sector's coal consumption is expected to increase by 0.7% per annum over the equivalent period (EIA 2009).

Oil

At the end of 2008, China had proved oil reserves amounting to 15.5 billion barrels, equating to 1.2% of the world's total proved oil reserves. At 2008 production rates, the R/P ratio for China's proved oil reserves was 11.1 years (BP 2009).

The majority of these reserves are located in five sedimentary basins: Bohai Gulf, Songliao, Tarim, Junggar and Ordos, and with the exception of the Bohai Gulf (partly onshore and offshore) these reserves are located onshore. The Daqing field located in the Songliao basin is the largest oil field in China, with proven and probable oil reserves equating to 14% of China's total proven and probable reserves. The Daqing field has been producing since the 1960's (IEA 2007).

China's oil production from 1998 – 2008 is presented in Figure 6. In 2006, around 90% of the 3.7 million barrels of oil produced daily (MMb/d) originated from onshore fields. Out of a total of 492 oil fields in production, the biggest 11 fields contribute almost half of China's oil production. Only one of these 11 fields, Tahe field, is yet to peak in terms of production. Subsequently, oil production is predicted to increase marginally, with the IEA predicting production to peak at around 3.9 MMb/d in 2012, with a subsequent gradual decline to 2.7 MMb/d in 2030 (IEA 2007).

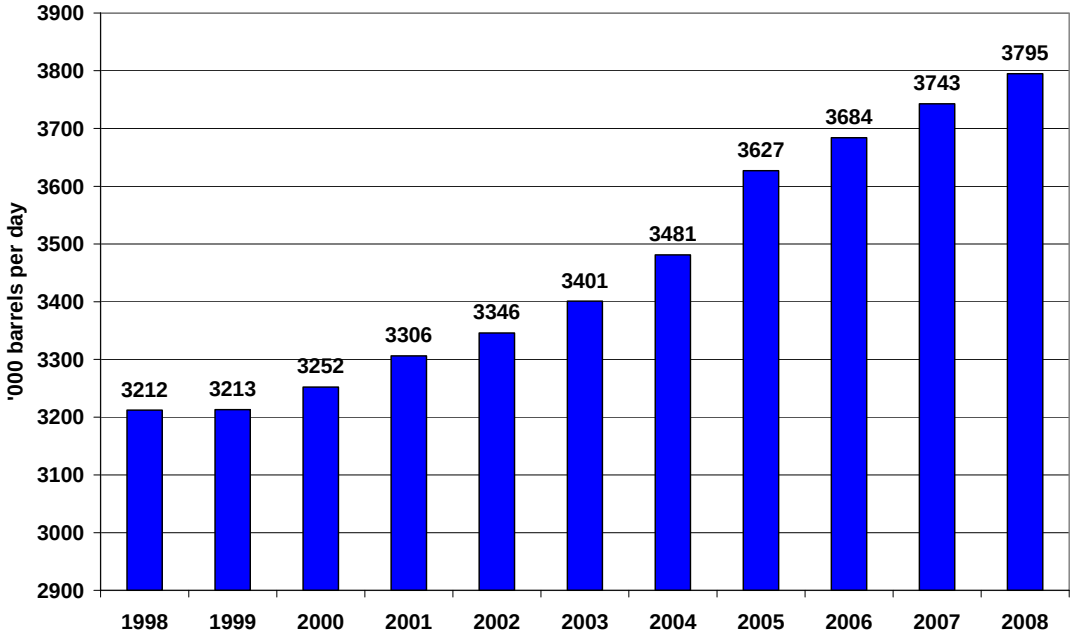

Figure 6: China's oil production from 1998 – 2008 (Sourced BP 2009).

China's imports of oil amounted to 3.7MMb/d in 2006, equal to around 50% of total daily oil consumption. The Middle East and Africa supply almost 80% of this imported oil (IEA 2007). China's daily consumption of oil is second only to that of the US, with 2008 figures indicating that China's consumption equalled 10% of total world oil consumption (the US consumed 22.5%) (BP 2009). By 2030, China's daily oil consumption is also predicted to increase dramatically to around 16 MMb/d. With domestic oil production expected to be relatively steady over the corresponding period, reliance on imported oil is going to increase drastically, with the IEA predicting (Reference Scenario) that net oil imports will be 13.1 MMb/d by 2030 (IEA 2007).

Natural Gas

China's proven natural gas reserves at the end of 2008 amounted to 86.7 trillion cubic feet, Tcf, (2.46 trillion cubic metres), equating to 1.3% of total world proved reserves (BP 2009). The IEA estimates that 80% of the proven and probable reserves are found in non-associated natural gas (natural gas in a reservoir with no/minimal crude oil), with close to 90% of these reserves being located onshore. However, to date production has occurred mostly from associated reserves (natural gas found in association with crude oil). China's natural gas reserves are mainly located in five sedimentary basins: Ordos (27%), Sichuan (23%), Tarim (19%), Bohai Gulf (8%) and Songliao (7%) (IEA 2007).

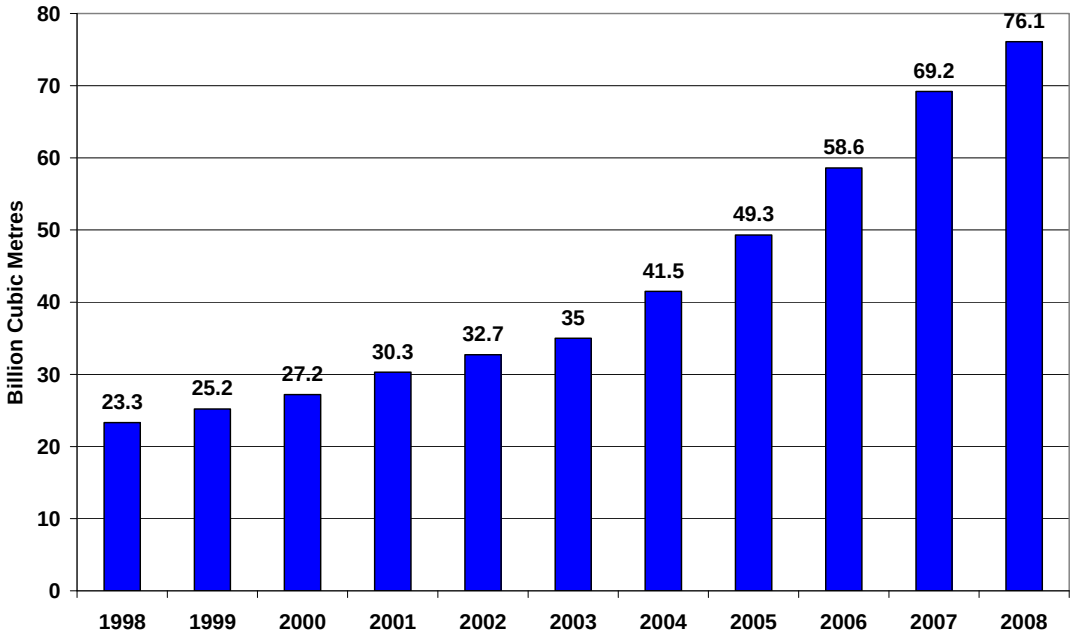

Figure 7: China's natural gas production from 1998 – 2008 (Sourced: (BP 2009).

Figure 7 summarises China's natural gas production from 1998 – 2008. Production in 2008, amounting to 76.1 billion cubic metres (bcm) equated to 2.5% of total world production (BP 2009).

Under the IEA Reference Scenario, This natural gas production is predicted to increase to a maximum of 118 bcm by 2020, before declining slightly to 111 bcm by 2030. It also shows that in 2006, China began to import natural gas in the form of LNG and imports are predicted to increase significantly over the period to 2030. However, the IEA warns that the predictions on natural gas imports are highly uncertain (IEA 2007).

Consumption of natural gas in China amounted to 80.7 bcm, equating to 2.7% of total world gas consumption. As can be seen from Figure 5, natural gas is predicted to be only a relatively minor contributor to China's primary energy needs into the future.

CCS in China

Geological Storage Potential

China theoretically has significant storage capacity for CCS. The China Geological Survey has surveyed over 417 basins, identifying 50 basins as prospective CO_2 storage basins. The estimated total capacity from is of the order of 1.455 x 10^6 $MtCO_2$ (Zhang et al, 2005). Storage in saline aquifers is estimated as having essentially all of the storage potential, 99% or 1.435 x 10^6 $MtCO_2$ in twenty-four basins.

Other recent studies have suggested an estimate of total theoretical CO_2 geological storage capacity at 3 x 10^6 $MtCO_2$ in China's onshore and offshore sedimentary basins (Li et al. 2009; Dahowski et al. 2009).

The saline aquifer storage potential capacity is estimated to be located in 16 onshore basins, with the remaining located in 9 offshore basins (Dahowski et al. 2009). A map of the candidate storage formations investigated in the above studies is presented in Figure 10.

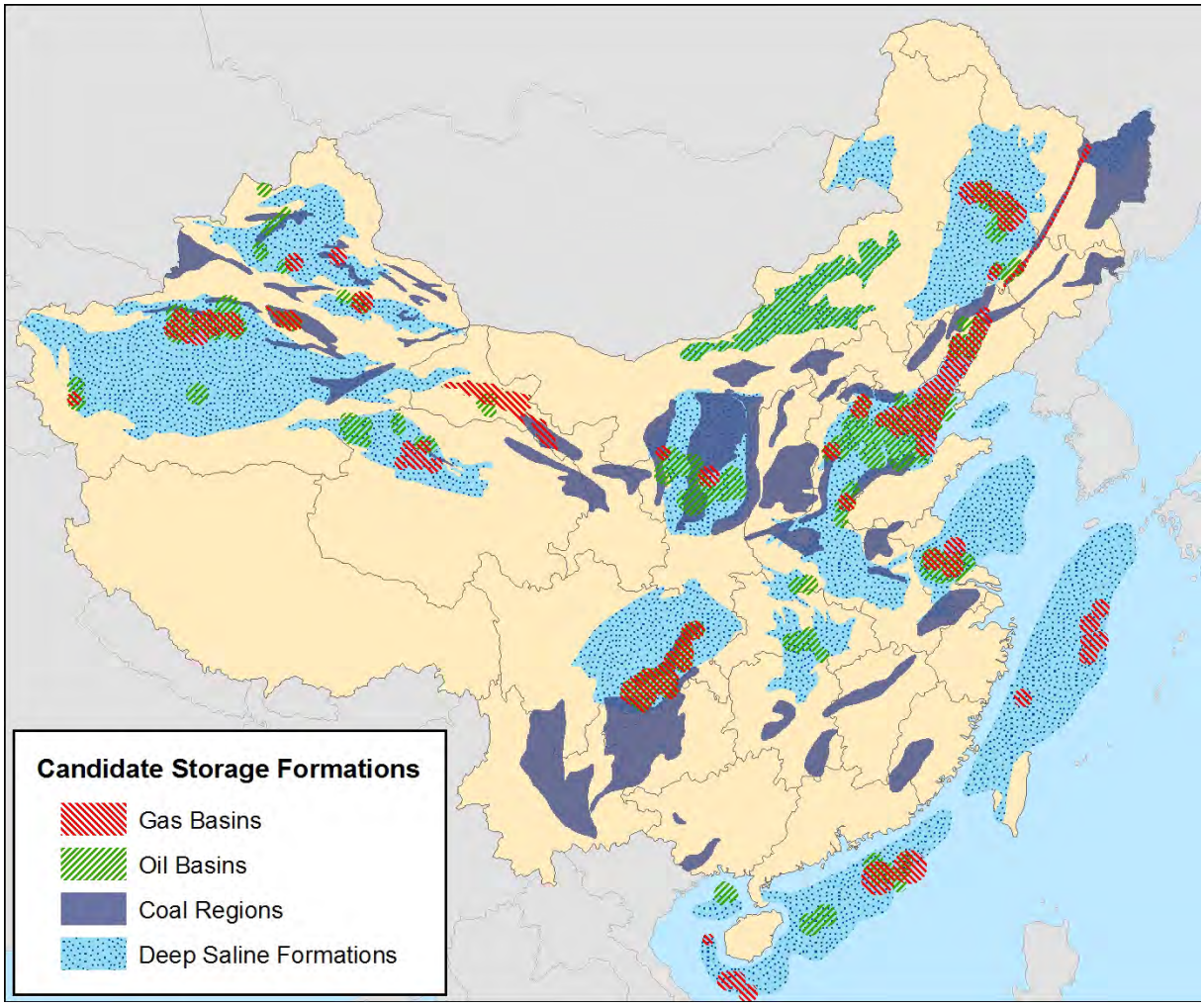

Figure 7: Potential CO_2 Storage Formations (Dahowski et al. 2009). ***With kind permission R. Dahowski.***

The remaining capacity according to the China Geological Survey is in 46 oil and gas basins (7.8 x 10^3 $MtCO_2$) and 68 coal beds (12 x 10^3 $MtCO_2$). Studies conducted by Li et al (2009) and Dahowski et al (2009) suggest that around 5,100 $MtCO_2$ could potentially be stored in depleted gas fields, 4,800 $MtCO_2$ in

depleted oil fields in association with EOR, and 12,000 $MtCO_2$ in coal seams in association with enhanced coalbed methane.

The potential storage capacity of some basins covered in the study by Dahowski et al is presented in Table 4. The Tarim basin in the north-west of China by far holds the greatest theoretical storage capacity. The only issue with this basin is the distance from the majority of the point sources of CO_2 located in the east. However, the two next largest onshore basins and the largest offshore basin are located in the vicinity of the majority of the point sources. The majority of the point sources are within close proximity to a potential storage reservoir. 91% of point sources are located within 100 miles (161 km) of a candidate storage formation, and 83% of point sources are located within 50 miles (80 km) of a candidate formation (Dahowski et al. 2009).

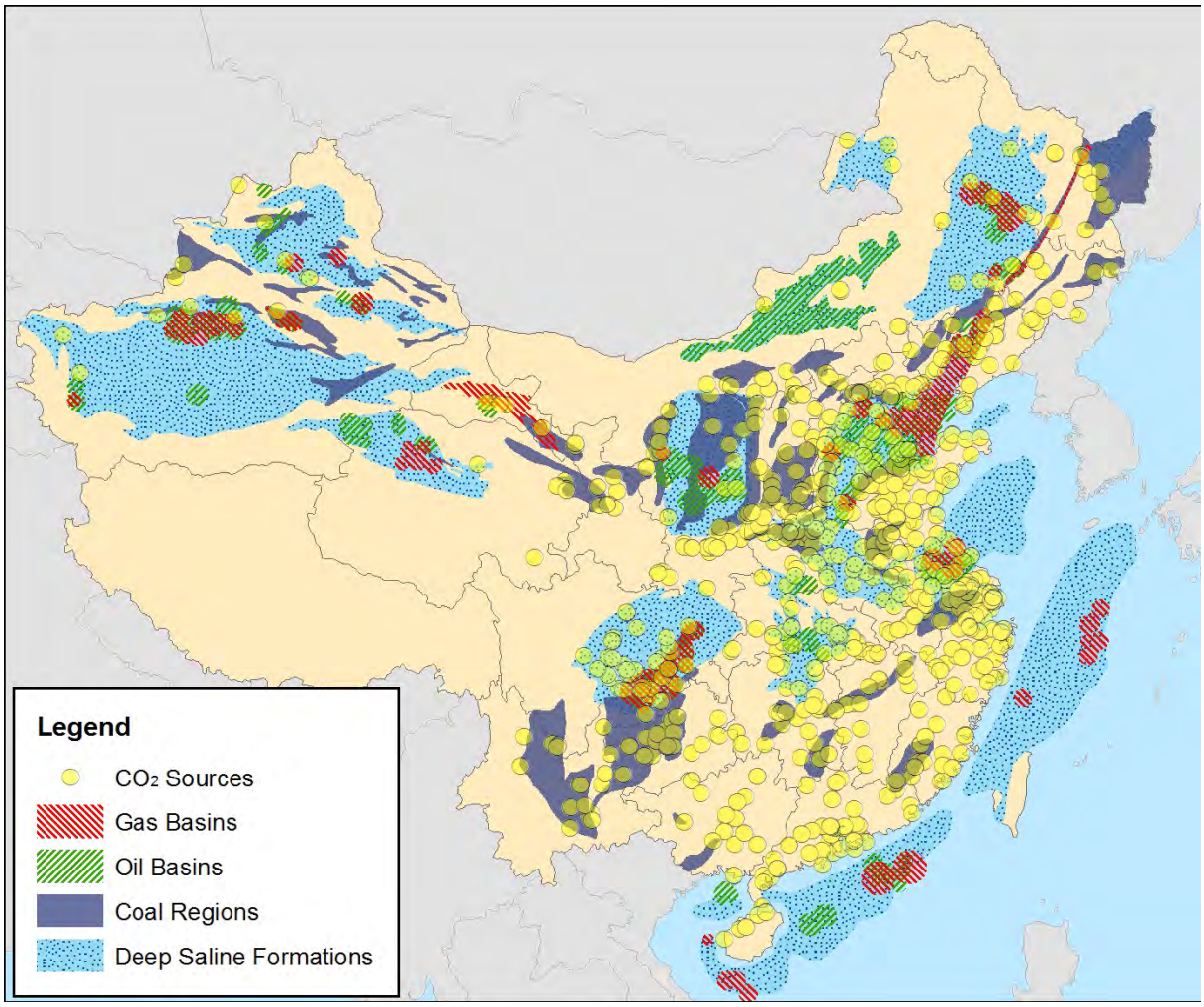

Figure 8: Proximity of CO_2 sources to potential storage formations (Dahowski et al. 2009). ***With kind permission R. Dahowski.***

Table 4: Estimates of theoretical CO_2 storage potential in China by basin (Li et al. 2009).

	Estimated Capacity in Saline Aquifers ($MtCO_2$)	Estimated Capacity in Oil Fields ($MtCO_2$)	Estimated Capacity in Gas Fields ($MtCO_2$)
Onshore			
Tarim Basin	745,800	69	620
Ordos Basin	256,500	360	1,110
Bohai Bay Basin	233,300	1,930	280
Songliao	227,800	1,570	590
Zhunggar Basin	197,100	200	100
Hehuai Basin	178,000		
Subei Basin	89,900	100	8
Erlian Basin	85,000	31	
Sichuan Basin	77,600	20	1,050
Turpan-Hami Basin	54,300	120	36
Jianghan-Dongting Basin	52,800	24	
Sanjiang Basin	44,900		
Qinshui Basin	29,000		
Qaidam Basin	21,500	81	350
Offshore			
East China Sea Basin	341,800		160
Southern Yellow Sea Basin	133,800		
Bohai Wan Basin	109,200	130	46
Zhujiangkou Basin	68,700	41	12
Yinggehai Basin	56,000		680
Northern Yellow Sea Basin	31,500		
Beibu Gulf Basin	23,800	18	

The UK-China NZEC Initiative studied two basins as part of the project, the Songliao and Subei basins. Within the Songliao basin, several oil provinces were examined. In the Daquing oil province and the Jilin oil province, there appears to be considerable capacity for storage in oil reservoirs once depleted and good potential for CO_2 – EOR. A major saline formation in the Songliao area was also assessed, showing good storage potential.

Another recent study, as part of the COACH and GeoCapacity projects, covered oilfields and saline aquifers in North China together with a coalfield in Hebei Province.

Regulation

There is currently no regulation in place for CCS in China. CCS has however been listed in a number of key research and development plans, these being:

- National Medium and Long-term Science and Technology Development Plan towards 2020
- National Key Technology Program supporting strategic CCS studies at Chinese research institutions
- National High Technology Program (863 Program) - plans to include support for CCS research and development in the 12th 5-year plan
- National Basic Research Program (973 Program)
- China's Scientific and Technological Actions on Climate Change
- China's National Climate Change Program includes CCS as a key task for GHG technology development (H. Liu & Gallagher 2009).

The measures in the climate change program include a target of 20% reduction of energy consumption per unit GDP by 2010 and raise the proportion of non-hydropower renewable energy in the primary energy supply by up to 10% by 2010 (NDRC, 2007).

China, through the Administrative Centre for China's Agenda 21 (ACCA21), is involved in the European Union's Support to the Regulatory Activities for Carbon Capture and Storage (STRACO2) program, which seeks to support the development of regulatory framework for CCS in the European Union. China's involvement is aimed at ensuring that the regulatory framework is able to be applied to rapidly developing nations.

Tsinghua University in association with the World Resources Institute, with funding from the U.S Department of State and the Asia-Pacific Partnership on Clean Development and Climate are developing a set of guidelines for safe and effective CCS in China, in addition to a framework for the post-closure stewardship of the CCS site.

Planned and current CCS projects in China

There are a few current and planned CCS projects in China, the details of which are given below.

The Greengen Project, Bohai Basin, Tianjin

- Greengen project aims to develop near-zero emissions coal-fuelled generation with hydrogen production and CCS.
- The project involves 3 main stages. The first stage is to build a 250MW IGCC power plant with 2000t/d gasification.
- The second stage involves research and development of key technologies such as developing improved IGCC technologies.
- The third stage involves the construction of a near-zero emissions coal-fueled power generation plant (400MW) with hydrogen production and CCS.
- The timeline of the project is from 2006 – 2016, with the first stage completed by 2011, and the third stage completed by 2016.
- There are nine partners involved, eight Chinese partners headed by the China Huaneng Group, and one foreign equity partner, Peabody Energy.
- CO_2 capture of 2,000 tpd to 3,500 tpd.
- Reference: http://www.greengen.com.cn/en/index.asp

Shenhua Coal to Liquids (CTL) Project (Ordos, Inner Mongolia)

- Project plans to produce one million tonnes of liquid transport fuel annually using a direct liquefaction process.
- CCS of 2.9 Mt CO_2/year, expected to start in 2010/2011.
- Captured CO_2 is to be used for enhanced oil recovery (EOR) projects in nearby hydrocarbon fields.
- Project partners are Shenhua Group, Sasol, and West Virginia University (Morse et al. 2009).

NZEC Project

- The NZEC project is a collaboration between the Chinese Ministry of Science and Technology (MOST) and experts from the United Kingdom to demonstrate near-zero emissions coal technology through CCS.
- The first phase is designed to explore options for demonstration and build capacity for CCS in China. The first phase began in November 2007 and is planned to run for two years.
- The second phase will carry out further development on storage and capture options, which then leads to Phase 3.
- Phase 3 aims to construct a demonstration plant involving CCS by 2014.
- The project has a considerable number of partners from the UK and China.
- Reference: http://www.nzec.info/en/

Huaneng/TPRI/CSIRO Post Combustion Pilot Plant

- A project with collaboration between the China Huaneng Group, the Thermal Power Research Institute (TPRI and Australia's CSIRO).
- A post combustion research pilot plant was installed in 2008 at the Huaneng Beijing Co-Generation Power Plant.
- The project is designed to capture 3,000 t/year of CO_2.
- Reference: http://www.csiro.au/news/CarbonCaptureMilestone.html

Shanghai Shidongkou Power Plant Project (Chen & Xu 2009)

- A project between the Huaneng Group and the Shanghai Electric Company.
- Project plants to build 2 x 660 MW ultra super critical power units with CO_2 capture.

Current CO_2 injection in geological formations is occurring in China in the form of enhanced oil recovery projects. This list highlights three major CO_2 EOR projects currently under operation.

Jilin oil field (PetroChina)

- CO_2 sourced from natural gas with a CO_2 content of 10 – 14%

Daqing oil field

- CO_2 sourced from natural gas with a CO_2 content of 20%.

Shengli oil field (Sinopec)

- CO_2 sourced from a power plant with a CO_2 content in the flue gas of 13.5% (China University of Petroleum Beijing, 2009).

There is at least one enhanced coalbed methane (ECBM) project through CO_2 injection located in China. This project is a collaboration between China and Canada and is located in the Qinshui Basin. The project commenced with a micro-pilot test to evaluate the potential for ECBM by CO_2 injection with the aim to conduct a large-scale pilot and upscale to commercial production. Reference:http://www.arc.ab.ca/areas-of-focus/carbon-conversion-capture-and-storage/carbon-storage/co2-enhanced-coal-bed-methane/cida-ecbm-project/

Some other proposed IGCC plants are in Langfang, Beijing; Dongguan, Guangdong Province and Lianyungan, Jiangsu Province. There is a possibility of CCS for EOR with these plants.

Calculating Geological Storage Capacity

There are several projects that have previously been mentioned that have looked at storage capacity. Others included:

- Chinese Academy of Science –estimation of CO_2 storage in coal beds, 2005
- Advanced Resources International, August 2009 – EOR opportunities in China

Collaborations

China is involved in a significant number of international collaborations regarding the development of CCS. Some of these are listed below.

China – US collaborations

- MOU to enhance Cooperation on Climate Change, Energy and the Environment – CCS is part of this MOU.
- US – China Clean Energy Research Center – established November 2009, $150M over five years. CCS amongst the initiatives.
- DOE - China Fossil Energy Cooperation Protocol (Annex II: Clean Fuels, and Annex IV: Energy and Environmental Control)
- US-China Bilateral Agreements for R&D Collaboration: NETL/PNNL and Chinese Academy of Sciences (CAS) Institute of Energy and Power; NETL and CAS Institute of Process Engineering; NETL and CNPC; NETL and Shenhua Group
- PNNL CO_2 emissions study (with CAS) and geologic storage potential. (Smouse, 2009)

A November 2009 roadmap for US – China CCS collaboration suggests the following activities:

- Target high-purity CO_2 from coal gasifiers outside the power sector in low cost CCS projects. US will contribute $20-40 million per project (Projects cost $50 – 100 million)
- R&D on retrofitting older power plants
- Market developments

NZEC – Near-Zero Emission Coal

- China – UK.
- NZEC project developed from the EU-China Partnership on Climate Change.
- Details given above.

COACH – Cooperation Action within CCS China – EU.

- China – European Union.
- Aims at establishing broad cooperation between China and the EU in the field of CCS.
- Reference: http://www.co2-coach.com/

GeoCapacity

- Source-sink matching and estimating storage potential.
- Tsinghua University a participant.
- Reference: http://www.geology.cz/geocapacity

CSLF – Carbon Sequestration Leadership Forum

- Twenty-two member nations including China.

- Aims to facilitate the development of cost-effective techniques for CCS.
- Reference: http://www.cslforum.org/

STRACO2 – Support to Regulatory Activities for Carbon Capture and Storage

- Nine partners: six European, three Chinese organisations.
- Reference: http://www.euchina-ccs.org/

CAPRICE

- Consortium consists of twelve partners, Tsinghua University from China.
- Objective is international collaboration and exchange in the area of CO_2 capture using amine processes.
- Reference: http://www.caprice-project.eu/index.php

FutureGen

- Eleven members, one from China (China Huaneng Group)
- Aims to build the world's first coal-fueled, near-zero emissions power plant.
- Reference: http://www.futuregenalliance.org/

Asia-Pacific Partnership on Clean Development and Climate

- Seven member nations including China.
- Aims at accelerating the development and deployment of clean energy technologies.
- Eight task forces, including the Clean Fossil Energy Task Force
- Reference: http://www.asiapacificpartnership.org/english/default.aspx

Global CCS Institute

- Capacity building activities with China and assistance with GreenGen. NDRC and Huaneng group are associated with the Global CCS Institute.

APEC Energy Working Group

- 2005 Study into storage capacity in sedimentary basins in China and South-East Asia.

MOVECBM – Monitoring and Verification of Enhanced Coalbed Methane

- 20 participants, 2 from China (Research Institute of Petroleum Exploration and Development and China United Coalbed Methane Company)
- Focus is on the monitoring and verification of the CO_2 storage capacity of deep subsurface coal and possible emissions to the surface.
- Reference: http://www.movecbm.eu/

CACHET

- 28 participants, one from China (Dalian Institute of Chemical Physics, Chinese Academy of Sciences).
- Three year integrated research project aiming to develop technologies to reduce GHG emissions from power stations by 90%.
- Reference: http://www.cachetco2.eu/index.html

CAGS – China Australia Geological Storage of CO_2 Project

- Aims to help accelerate the development and deployment of CCS in China and Australia.
- Initiated and funded by Australian Government under the Asia-Pacific Partnership on Clean Development and Climate.
- Reference: http://www.asiapacificpartnership.org/pdf/Projects/CFETF/PSU/CFE-06-01.pdf

Research Projects

Research into CCS, mainly in relation to the capture of CO_2, is occurring in China. A small list of organisations conducting research into CCS is given below. Again this is not meant to be a comprehensive list, but as an indication of the type of research being conducted.

Tsinghua University

- Post-combustion capture
- Enhanced oil recovery using CO_2
- Oxyfuel for pulverised coal (PC) boilers
- Policy and economic analysis for CCS

Huazhong University

- Oxyfuel for pulverised coal boilers

Chinese Academy of Sciences

China National Petroleum Corporation

Southeast University

- Oxyfuel for Circulating Fluidized-Bed (CFB) boilers

North China Electric Power University

- Oxyfuel combustion in CFB and PC boilers
- Integrated power generation with CCS
- Adsorbents
- Post combustion capture

Huangeng group

- Pre-combustion (IGCC) technologies
- Post-combustion capture technologies

Issues Related to CCS in China

- Large number of stationary point sources. Requires considerable infrastructure to apply CCS to the major stationary point sources
- Proximity to potential storage varies within China. Along the south-east coast, proximity to potential storage candidates isn't as favourable compared to the north-east coast
- No regulation in place regarding CCS
- Policy and financial drivers needed
- Impact of CCS on coal and electricity prices
- Public perception of the need of CCS
- The view that CCS is immature in the short term, and could likely be substituted in the long-term with alternative energy (Reiner & Liang 2009)

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