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

FINAL REPORT

APEC Energy Working Group

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APEC Energy Working Group Project EWG 05/2010A
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Final Report

Workshops in Viet Nam and Mexico

Prepared by ICF International

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Asia-Pacific Economic Cooperation

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Viet Nam

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Asian Development Bank (ADB) – Dr. Pradeep Tharakan, Dr. Bill Gunter, Craig Hart, Doug Macdonald, and Tina Pascual.

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Executive summary

Two capacity building workshops on Carbon Capture and Storage (CCS) were held: in Hanoi, Viet Nam, in December 2011, and in Mexico City, Mexico, in June 2012, as part of the Asia Pacific Economic Cooperation's (APEC) ongoing series of CCS capacity building workshops in developing APEC economies.

The December 2011 workshop in Viet Nam was held jointly with the Asian Development Bank (ADB), because the ADB was working closely with the governments and national experts in Southeast Asian economies, including Viet Nam, on a Regional Technical Assistance (RETA) program on CCS. By holding a joint workshop with the ADB, the APEC team aimed to maximize the synergies between its capacity building activities and the ADB's RETA program. The ADB was responsible for the meeting venue and local logistics, whereas the APEC team, comprising ICF International (APEC Consultant) and the APEC Project Overseer, was responsible for the workshop program and contents, the course materials and workshop handouts, and for engaging the international experts. Both parties were involved in preparing the lists of participants.

Prior to the Viet Nam workshop, ICF reviewed, edited and updated the existing APEC CCS Training Modules by adding additional material and updating references, based on input from the Project Overseer.

The Viet Nam workshop was moderated and facilitated by ICF. The first day of the workshop covered more general CCS topics, including technical, legal, regulatory and community outreach issues, whereas the second day of the workshop was more focused on aspects resulting from the ADB RETA study on Viet Nam. Invited international experts and the ADB consultants gave presentations and were available to answer questions throughout the workshop.

The joint workshop was successful and there was a good mix of government and industry representatives, with nearly all of the participants coming from Hanoi. Participants rated nearly all sessions highly, and there was interest in having more workshops, particularly focused on CO_2 use and on gas processing. Some suggested that the workshops should provide more detailed information, particularly on enhanced oil recovery (EOR), financing and public awareness. Most of the international experts who presented at the workshop felt that the workshop was well structured, well organized and covered all core CCS areas well. A list of potential future options for continuing CCS capacity building in Viet Nam is provided in this report.

Initially, it was planned that this APEC project would comprise two additional workshops, namely in Thailand and another APEC economy in southeast Asia. However, due to scheduling issues these workshops had to be cancelled in March, 2012.

In early April 2012, APEC decided instead to support a CCS workshop in Mexico City, based on a request from the Federal Electricity Commission (CFE), which had been considering to hold CCS capacity building workshops aimed at university students. The workshop in Mexico

City was much pedagogical in nature than the workshop in Viet Nam and focused on providing detailed technical information on the storage of CO_2 to undergraduate students in the geological sciences.

ICF and APEC helped organize the agenda and invited speakers for the workshop, and CFE arranged the logistics. No additional changes were made to the Training Modules, but additional reference materials were added to the course package for the participants.

The workshop was held in Mexico City in an auditorium of CFE's Technology Museum. The workshop was moderated and facilitated by CFE staff, who played a key role in ensuring the success of the workshop. The first day of the workshop covered the basics of CCS and CO_2 storage, including background information on climate change and the role of CCS, fundamentals of storage, site selection, capacity assessment, and the scientific basis of CCS. The second day of the workshop started with a discussion of risk assessment and monitoring and verification aspects of CO_2 storage, and then examined the relevance of CCS as it relates to enhanced oil recovery (EOR) in Mexico. At the end of the workshop, a focus group of CFE, Global CCS Institute, ICF, APEC, and professors from various Mexican universities held a meeting to develop a consensus and action plan for introducing CCS into the university curriculum in Mexico.

The workshop was attended by more than 220 people, including, students, professors, CFE staff, policy makers, scientists, etc. The focus group on the second day was attended by about 22 participants, including many university professors.

Contents

1 Project Description

1.1 Project Background

Future demand for coal for power generation in the APEC region is expected to rise dramatically, in contrast to other fossil fuels. The 2009 APEC Energy Outlook[1] indicates that power generation from coal will rise from 5,300 TWh in 2005 to 8,600 TWh in 2030, with the share of coal in the power sector expected to further increase, particularly in developing APEC economies[2].

Overall, coal and oil are expected to remain as the dominant sources of primary energy supply for APEC economies. APEC economies are considering coal as an important option because of the large and well-dispersed coal reserves, existing large installed base of coal-production capacity, low-cost and stable economics associated with coal, and the availability of a range of advanced power generating technologies that can limit the environmental impacts of coal. Furthermore, in many of the APEC developing economies, concerns about energy security is also driving a push towards utilizing domestic resources, which is often coal.

At the same time, coal is a high-carbon fuel and increased use of coal employing current coal combustion or gasification technologies implies a higher rate of carbon dioxide (CO_2) emissions. Increasing atmospheric concentrations of CO_2 and other greenhouse gases are very likely a primary cause of rising global temperatures.[3] Mitigating global warming will require deep reductions in global CO_2 emissions, especially from coal use. Therefore, technologies that enable us to capture and store CO_2 emissions from coal are critical if we wish to continue the use of coal, while at the same time minimizing CO_2 emissions to the atmosphere. APEC Leaders have also acknowledged that challenges of economic growth, energy security and climate change are fundamentally interlinked, and agreed to promote policies for cleaner coal use and carbon capture and storage (CCS) technologies in their Sydney declaration.[4]

Although CCS technologies are not yet fully commercial, parts of the technology are already commercial, and there are global efforts to demonstrate the technology on a large scale. Indeed, the key challenges lie in integration and technology risk-reduction through large-scale demonstration projects. The APEC developing economies have pledged to cooperate on joint research, development, demonstration, deployment and transfer to CCS technologies, although their engagement will likely be based on the differences in economic and social conditions among the economies and be consistent with the common but differentiated responsibilities and respective capabilities of these economies.[4]

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[1] http://publications.apec.org/publication-detail.php?pub_id=946

[2] APEC developing economies include: Brunei Darussalam; Chile; People's Republic of China; Hong Kong, China; Indonesia; Malaysia; Mexico; Papua New Guinea; Peru; The Republic of the Philippines; Singapore; Chinese Taipei; Thailand; Viet Nam.

[3] Fourth Assessment Report, IPCC, 2007.

[4] http://www.apec.org/apec/leaders__declarations/2007/aelm_climatechange.html

Many APEC developing economies are planning to build new coal-fired power plants in the future, and CCS is an option that can be relevant in the medium-to-long term as the demand for significant (>90%) reductions in GHG emissions becomes warranted. Although the Asia Pacific Energy Research Centre's (APERC) Business-As-Usual scenario does not envision a role for CCS before 2030,[5] the International Energy Agency's (IEA) 450 Scenario[6] expects that about 7% of the low-carbon electricity in APEC economies in 2030 will be from CCS.[7]

Furthermore, the depletion of oil and gas fields across the globe has given a new impetus to CO_2-based enhanced oil recovery (EOR) techniques that help to prolong the life of hydrocarbon extraction and recover additional hydrocarbons from existing oil and gas fields, while at the same time storing CO_2. This EOR technique is often considered to be an important step in the demonstration of long-term CO_2 storage techniques.

In view of the above, the APEC Experts Group on Clean Fossil Energy (EGCFE) has focused over the past decade on assessing and promoting the role of CCS in APEC economies. The EGCFE has undertaken a series of activities with the goal to build capacity within APEC developing economies to understand the technology, its potential and its challenges, so that policymakers can consider CCS as part of their medium-to-long term energy strategies.

1.2 EGCFE CCS Capacity Building Efforts

APEC EGCFE projects have assessed the geological storage potential of CO_2 in APEC economies (Phase I – EWG 06/2003); developed course materials to promote and transfer CCS technologies to developing APEC economies (Phase II – EWG 02/2004); and organized and hosted several capacity-building course workshops in South Korea, China, Mexico, and Indonesia (Phase II – EWG 02/2004, Phase III – EWG 07/2005 and Phase IV – EWG 09/2008). The reports for these projects are available at www.egcfe.ewg.apec.org.

This project (Phase V – EWG 05/2010A) was initially aimed at continuing the capacity building program with workshops in Thailand, Viet Nam, and another economy in Southeast Asia. ICF International responded to the request for proposals by APEC and was contracted to carry out the project. The first workshop was held in Vietnam in December 2011, but the subsequent workshops in Thailand and a third economy had to be cancelled due to scheduling problems, which became apparent by the end of March 2011.

In April 2011, after the Southeast Asian workshops were cancelled, APEC decided to refocus its efforts on Mexico, and the Phase V project was oriented towards educating Mexican undergraduate students in the geological sciences about CCS and storing CO_2. A workshop was held in coordination and cooperation with the Federal Electricity Commission (CFE) of Mexico. CFE staff played a critical role in organizing and hosting the workshop in Mexico City

[5] http://www.ieej.or.jp/aperc/2009pdf/Outlook/Outlook_Volume_I_4E.pdf

[6] The IEA 450 Scenario from the IEA's *World Energy Outlook 2009* sets out an energy pathway consistent with limiting the increase in temperature to 2° C, thereby allowing the concentration of atmospheric CO_2 to be stabilized at less than 450 ppm.

[7] http://www.ieej.or.jp/aperc/2010pdf/PES.pdf

in June 2011. The Global CCS Institute supported the workshop by providing financial support to CFE. A second workshop was initially scheduled to be held in Hermosillo, Mexico, in September 2012. However, this workshop had to cancelled, as additional financial support for this workshop to cover expenditures outside the APEC budget was unavailable.

Thus, the Phase V – EWG 05/2010A project completed two workshops—one in Viet Nam with ADB and one in Mexico with CFE.

1.3 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 original project objectives were:

- To complete three capacity building workshops (in Viet Nam, Thailand and a third APEC economy)
- To achieve a greater understanding by workshop participants of CCS and its options, key issues, and the potential for national implementation of CCS;
- To develop host economy-focused workshop materials, building on existing course materials such as training modules and references;
- To deliver a final report on the workshop, which will describe the results of the workshop and provide recommendations on how to further advance CCS knowledge dissemination;

1.4 Main Deliverables

- Updated course materials
- Workshop in Viet Nam
- Workshop in Mexico
- Workshop report

1.5 Summary of Phase V Project

The workshop in Hanoi, Viet Nam, was held jointly with the Asian Development Bank (ADB), which had separately initiated a Regional Technical Assistance (RETA) program and was working closely with the governments and national experts in Thailand, the Philippines, Indonesia and Viet Nam to explore the potential for CCS in these economies. By holding a joint workshop with the ADB, the APEC team aimed to maximize the synergies between its capacity building activities and the ADB's RETA program. As such, the linkage with the ADB and the availability of the ADB reports on the feasibility of CCS in these economies ensured that the workshop in Viet Nam could be more focused than the previous workshops,

allowing for a more targeted set of issues to be covered in the workshop. On the other hand, the logistics and preparation for this workshop was more complex, given that both APEC and ADB interests had to be met.

ADB was responsible for the meeting venue and local logistics in Viet Nam, whereas the APEC team, comprising ICF and the Project Overseer, was responsible for the workshop program and contents, the training materials, the workshop handouts (binder and CD), and for engaging the international experts. Both parties were involved in preparing the lists of participants.

The workshop in Mexico (Mexico City) was held in coordination with the Federal Electricity Commission (CFE), which had recognized the need for CCS capacity building in the Mexican higher education system, with a focus on the science of storing CO_2. APEC and CFE initially decided to meet this need with two workshops aimed at undergraduate students. However, for the reason outlined above, only one workshop was realized. Unlike the Viet Nam workshop, the workshop in Mexico City was much more pedagogical in nature and did not cover any legal, regulatory or policy aspects. Instead, the focus was on the science behind storing CO_2 and on providing an opportunity for Mexican students to gain an understanding of the kinds of subjects that they need to study in order to come part of a future CCS workforce.

CFE staff was instrumental in the organization and facilitation of the workshop. APEC and ICF invited expert speakers on various topics and coordinated the presentations. APEC, ICF, and CFE were responsible for the content of the workshop. ICF provided to CFE the course materials, updated reference materials and the presentations—which were subsequently provided in CDs and workshop binders to the participants.

This workshop was attended by over 216 participants, mostly students and university professors. All had an opportunity to interact with the world-renowned experts present at the workshop. The workshop in Mexico City can certainly be considered as one of the largest and most successful capacity workshops on CCS undertaken by APEC. A follow-up 'invitation-only' session with about several university professors was held to develop a consensus on potential follow-up activities in Mexico and discuss how to get CCS integrated into the university curriculum.

2 Course Material

2.1 Training Module Updates

Based on input from the Project Overseer, the modules from Phase IV were reviewed and updated so that they reflected recent developments in CCS. With the update in Phase IV, the modules did not require major changes, but the modules were edited for accuracy, better grammar, and updated references. A new APEC reference number was assigned to the updated training module.

The edits to the modules included the following:

- **Introduction to CO_2 capture and geological storage in energy and climate policy** – Edits to ensure better language and flow. Updated references and added new references to IPCC reports and European CCS Directive and its implementation. Appendix to the Introduction was removed, and instead a reference was provided to the Global CCS Institute's State of CCS reports.

- **Module 1 CO_2 capture and storage overview** – Edits for better language and flow in the module, along with new references and language from IPCC reports.

- **Module 2: Post combustion flue gas separation -** Edits for better language and flow. New diagram on options for carbon capture, which sets the stage for the next module as well. New diagram on post-combustion technology groups from EPRI. More detailed discussion on the chilled ammonia process.

- **Module 3: CO_2 capture – Pre-combustion (decarbonisation) and oxyfuel technologies** – Edits for better language and flow. Additional discussion on drawbacks of post-combustion capture options as well as disadvantages of precombustion and oxyfuel options. Updated diagrams on schematics for the processes from Vattenfall.

- **Module 4: CO_2 compression and transport to storage site** – Updated discussion on water content and other impurities in the CO_2 stream. A new table on CO_2 pipeline specification.

- **Module 5: CO_2 storage options and trapping mechanisms -** Edits for better language and flow. Additional discussion on issues associated with storage in depleted gas and oil fields.

- **Module 6: Identification and selection of suitable CO_2 storage sites -** No edits to this module by ICF.

- **Module 7: Key steps in developing and implementing a CO_2 capture and storage project** – A new figure indicating the steps involved in the lifecycle of a storage project. A new figure and details on an approach to assess the impact of impurities in a CO_2 stream. A new section on "Investment Issues and Risks in developing a CO_2 storage project". Updated references.

- **Module 8 to Module 14:** -- There were no edits in these modules, as they were already well updated.

2.2 Other Reference Materials

In addition to the training modules, there were key Reference Materials on CCS provided to workshop participants on the CD. All references from Phase IV were included, and additional references were added. The full list of references for both the Viet Nam and Mexico workshops are reproduced in Appendix 2, and the additional references (beyond Phase IV) were:

- CARBON CAPTURE AND STORAGE: Legal and Regulatory Review (Edition 2) International Energy Agency © OECD/IEA 2011
- Technology Roadmap: Carbon Capture and Storage in Industrial Applications International Energy Agency © OECD/IEA 2011
- Cost and Performance of Carbon Dioxide Capture from Power Generation International Energy Agency © OECD/IEA 2010
- Best Practices for Public Outreach and Education for Carbon Storage Projects, National Energy Technology Laboratory, US Department of Energy
- Communication and Engagement Toolkit for CCS Projects, CSIRO
- CCS Guidelines, World Resources Institute
- The Global Status of CCS 2011, Global CCS Institute
- Defining CCS Ready: An Approach to An International Definition, Global CCS Institute
- CCS Ready Policy: Considerations and Recommended Practices for Policymakers, Global CCS Institute
- North American Carbon Storage Atlas, First Edition, 2012

2.3 Availability of Course 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.

3 Joint APEC-ADB Workshop in Viet Nam

3.1 Workshop Overview

The workshop was held at the Sofitel Plaza Hotel in Hanoi, Viet Nam, in coordination with the ADB, and was entitled "APEC/ADB Joint Workshop, Carbon Capture and Storage in Viet Nam". The workshop was held on 13-14 December 2011. Initial plans in August 2011 had called for holding the Viet Nam workshop back-to-back with a CCS workshop in Bangkok, Thailand, in late 2011. However, due to the flooding in Bangkok in November 2011 and other factors, including the unavailability of the ADB RETA report on Thailand and delays in the workshop approval by the Viet Nam Ministry of Industry and Trade (MOIT), it was decided, less than three weeks before the event, to postpone the Thai workshop and only hold the workshop in Viet Nam.

Prior to the workshop, ICF had reviewed the training modules and updated them. In preparing a potential list of participants, ICF relied on ADB RETA contacts and participants lists from a previous CCS workshop hosted by Alstom and the Global CCS Institute in 2010 as well as a USAID/APEC clean coal workshop in 2008.

An invitation and agenda for the workshop were prepared in coordination with the ADB and the APEC Project Overseer. These were translated into Vietnamese and, as soon as MOIT approval was obtained, 105 copies were sent by ICF to potential participants by email, postal mail and by personal invitations. The workshop binders were prepared ahead of time and consisted of presentations by speakers, speaker biographies, and the Executive Summary of the ADB RETA report on Viet Nam. The workshop binder contents, the training modules and CCS references were all burned onto a CD, which was provided to workshop participants.

A day before the Joint APEC-ADB workshop, the ADB presented its RETA CCS report on Viet Nam to the government and their stakeholders. The government approved the non-confidential parts of the report for presentation and discussion at the Joint APEC-ADB workshop. The workshop was structured such that the first day featured a general introduction and discussion of all major CCS issues, whereas the second day focused on specific findings and issues pertaining to Viet Nam as identified by the ADB RETA study. Many of the international experts spoke and played an active role in the workshop on both days. On the last day, a panel discussion focused on options for fostering continued interest in and support for CCS in Viet Nam.

3.2 Workshop Program and Speakers

The workshop, which was moderated and facilitated by ICF's Dr. Ananth Chikkatur, was conducted in sessions, with presenters at each session available for questions through the workshop moderator at the end of the session. There was at least five minutes of time provided for questions and answers. Many participants engaged the speakers afterwards during the break and lunch time in informal discussions.

New presentations were prepared for the workshop to reflect the updated training modules, the ADB RETA study, and the participation of new presenters. The workshop

presentations in Viet Nam covered all the major areas of CCS technology and issues relating to CCS implementation. See Appendix 6 for the detailed agenda for both days.

Day 1.

In the morning opening session, several key officials from the Viet Nam government attended, including Mr. Lê Tuấn Phong, Deputy Director General, Ministry of Industry and Trade (MOIT) and Dr. Bui Cach Tuyen, Vice Minister, Ministry of Natural Resources and Environment (MONRE). Also attending was Mr. Andrew Head, Deputy Country Director, Viet Nam, Asian Development Bank. Mr. Phong replaced Mr. Hoang Quoc Vuong, Vice Minister for Energy, MOIT, as the latter offical was unable to attend the workshop at the last minute. Mr. Phong's speech was in Vietnamese; the translated version is provided in Appendix 3. Following Mr. Phong was Andrew Head, who welcomed the participants and described ADB's activities in Viet Nam. His speech is also included in Appendix 3.

Following the opening session, Dr. Frank Mourits, Natural Resources Canada, described APEC's programs on CCS and the role of this workshop in capacity building. Dr. Pradeep Tharakan, ADB, then discussed ADB's RETA on CCS, and Dr. Ananth Chikkatur, ICF, discussed the APEC training modules and how they could be used by participants. There was a large contingent of reporters present during the opening and first session, indicating the general interest of the Vietnamese public about CCS and its potential role in Viet Nam.

Other presenters on Day 1:

- Justine Garrett, IEA, France, discussed the importance of CCS as a greenhouse gas mitigation option, drawing on the IEA's CCS Roadmap findings.
- Dr. Stanley Santos, IEAGHG, U.K, presented an overview of capture technologies, their status and challenges.

During the morning tea break, many reporters who were present at the opening session interviewed Dr. Frank Mourits, Dr. Pradeep Tharakan and Andrew Head. Following the break, two more presentations were made before lunch:

- Dr. Stanley Santos, IEAGHG, U.K, presented an overview of CO_2 transportation issues.
- Dr. Bill Gunter, ADB Consultant, Canada, discussed aspects of storage fundamentals, including fluid flow and trapping mechanisms and site screening and selection.

Following lunch, there were three presentations:

- Christopher Short, Global CCS Institute, Australia, presented on the economics and financing of CCS, focusing in particular on the business case for CCS. He also highlighted the uncertainty and variability of current cost estimates.
- Justine Garrett, IEA, France, discussed the legal, regulatory and permitting issues, the IEA Model Regulatory Framework, and various issues around long-term liability.
- Simone Carr-Cornish, CSIRO, Australia, discussed aspects related to public awareness and community consultation, with the introduction of the CCS toolkit developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for the Global CCS Insititute.

Following the afternoon tea break, there were two more presenters:

- Christopher Short, Global CCS Institute, Australia, presented on the status of CCS, based on the Global CCS Institute's 2011 report.
- Pham Dong Giang, Sales Manager, Alstom Viet Nam, discussed Alstom's CO_2 capture technologies, their development and status.

Day 2.

On the second day, the primary focus was on the findings from the ADB RETA report on Viet Nam. For this reason, the ADB consultants were the main presenters. However, where possible, speakers from Day 1 (called discussants in this context) initiated discussions on the ADB presentations, relating these to the general discussions on Day 1. This was meant to provide a good integration between Day 1 (general CCS discussions) and Day 2 (economy-specific discussions).

The presenters and discussants in Day 2 included:

- Nguyen Anh Dung, Institute of Energy, Viet Nam, discussed the role of CCS in Viet Nam by presenting an overview of the energy status in Viet Nam (supply, demand, GHG and CO_2 emissions) and energy scenarios that could support CCS.
- Doug Macdonald, ADB Consultant, Canada, presented the key highlights from the ADB RETA study on capture opportunities and challenges in Viet Nam. Stanley Santos, IEAGHG, U.K, was the discussant.
- Dr. Bill Gunter, ADB Consultant, Canada, presented on the storage opportunities and challenges in Viet Nam from the ADB RETA report.
- Dr. Bill Gunter also presented on opportunities and challenges in Viet Nam regarding the productive use and storage of CO_2, which includes CO_2-enhanced oil recovery (EOR) and enhanced coalbed methane (ECBM) recovery.
- Craig Hart, ADB Consultant, U.S., discussed the legal, regulatory and permitting challenges to CCS in Viet Nam, along with a summary of overall challenges in the Southeast Asia. Justine Garrett, IEA, France, was the discussant.
- Simone Carr-Cornish, CSIRO, Australia, presented on the guiding principles of engagement and application to Viet Nam, based on the CCS toolkit.
- Dr. Pradeep Tharakan, ADB, Philippines, spoke on possibilities for financing CCS in Southeast Asia, including the role of ADB.
- Simplicio P. Caluyong, Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP), Thailand, discussed the capacity building needs in CCOP economies, the role of CCOP in promoting CCS, and the importance of a CCS project in the region.

The last session included a Panel Discussion, featuring ADB team members (Dr. Pradeep Tharakan, Doug Macdonald, Dr. Bill Gunter and Craig Hart) and Mr. Mai Dinh Trung, Deputy Director, Energy Department, MOIT, as panelists.

Dr. Pradeep Tharakan, ADB, and Dr. Frank Mourits, Natural Resources Canada, made the final closing comments – they thanked all attendees and stated they were looking forward to further interaction with Viet Nam on CCS.

3.3 Workshop Attendance

The joint workshop was successful and there was a good mix of government and industry representatives. The first day had the most attendance, with a large number of journalists and reporters being present. Attendance thinned out in the afternoon of Day 1, and a smaller number attended Day 2 of the workshop.

Overall attendance was negatively impacted by three factors: 1) due to the late approval by MOIT, very limited time was available (less than ten days) for inviting participants and ensuring their attendance; 2) lack of travel/lodging support for participants from outside Hanoi; and 3) scheduling conflicts due year-end priorities. Consequently, most of the participants were from Hanoi.

The attendance numbers are summarized in the tables below. A full list of participating organizations is provided in the Appendix 4.

Day 1

Group	Participants
Vietnamese Participants	34
International Participants	12
Total registered	46

Day 2

Group	Participants
Vietnamese Participants	16
International Participants	12
Total registered	28

3.4 Workshop Feedback

Formal feedback was obtained from surveys distributed to participants on both Day 1 and Day 2. Only a limited number of participants filled out and handed back the surveys to ICF. While not a big sample, the feedback on how the workshop sessions had contributed to the knowledge of how to implement CCS in Viet Nam was overall positive.

On Day 1, nine participants turned in the responses, although many more had attended. Nearly all sessions received high ratings, expect for *Economics and Financing* and *Status of CCS Projects*, both of which received mostly medium ratings. There were contradictory responses in the comments – for example, some participants wanted fewer details on CO_2

capture technologies and legal/regulatory issues, whereas others wanted more. There was an interest in having more workshops, particularly focused on CO_2 use and on gas processing. One participant suggested having more workshops in Ho Chi Minh City, with the involvement of Petrovietnam Exploration Production Corporation (PVEP).

On Day 2, there were seven responses, of which nearly all respondents gave either high and/or medium rating to all of the sessions. Most rated the *Panel Discussion* at the medium level, and one person rated the *Legal, Regulatory, Public Awareness*, and *Panel Discussion* at the low level. Some of the suggestions called for more details, including additional information on EOR, financing, and public awareness issues.

A more comprehensive summary of the feedback can be found in the Appendix 5.

Most of the international experts who presented at the workshop felt that the workshop was well structured, well organized, and covered all core CCS areas well.

It was suggested that it is important to further engage with participants in discussion. The limited discussion (especially on the second day) was due in part to the relatively low number of attendees.

For future workshops on CCS in Southeast Asian economies, depending on the profile/interests of the relevant economy, more specific areas such as CCS and EOR or Bio-Energy with Carbon Capture and Storage (BECCS) should be considered. Also, engaging government officials involved early in the process would be useful.

There was also some feedback that the print of the presentations in the workbook was not large enough and difficult to read.

3.5 Follow-Up Activities and Recommendations for Advancing CCS in Viet Nam

- Develop a CCS pilot project in Viet Nam. 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.

- In order to increase the interest for CCS technology in Viet Nam, there is a need for organizing more workshops, which would provide more basic information and comprehensive knowledge in this area. Universities or academic institutions play an important roles in disseminating CCS technology in associated with government bodies and related industries. Therefore, bodies such as APEC, CCOP, the ADB, 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 coordinate activity with other capacity-building organizations.

- Obtain support from Petro-Viet Nam for CCS studies and pilot projects.

- Local governments would need to take an active role in supporting CCS capacity building activities, including providing travel support for local participants, so they can participate when workshops are held elsewhere in Viet Nam.

- New approaches and technology development in Viet Nam seem to flourish when supported by top government agencies (as supporters and catalysts) in combination with solid advocacy from universities, which are the disseminators of knowledge in the society and industry. Future approaches to stimulate increased CCS technology awareness and uptake in Viet Nam must involve a top/well-known university, which would play a central coordinating role for CCS technology.

- Future workshops on CCS technology should also be held in Ho Chi Minh City – the home of many industries with large CO_2 emissions. Ho Chi Minh City has been identified as one of the top Asian coastal cities that are most affected by climate change. The local government is paying close attention to climate change adaptation and mitigation measures. Ho Chi Minh City University of Technology could be the potential academic organization that could support the organization of CCS workshops in the near future.

4 APEC-CFE Workshop in Mexico

4.1 Workshop Overview

The APEC-CFE workshop was held at the MUTEC (Museo Tecnológico de CFE), which is CFE's Technology Museum in the Chapultepec Park in Mexico City, and was entitled "APEC-CFE Workshop for Introducing CO_2 Geological Storage in Earth Sciences Undergraduate Programs". The workshop was held on 27-28 June 2012. The Mexico workshop became part of the Phase V project after the workshops with ADB were canceled due to scheduling conflicts in late March 2012. Planning for the workshop started in May 2012, with the agenda and the selection of speakers to be invited for the workshops.

The updated training modules were used for the Mexico City workshop, with the addition of the new North American Carbon Storage Atlas as part of the reference material. In preparing a list of potential expert speakers, ICF relied on the APEC Project Overseer's contacts and presenters from a CSLF workshop, which was held in Mexico City in March 2012. Participants for the workshops were invited by CFE, based on their interactions with various universities. The Global CCS Institute provided financial support for expenditures that could not be covered by APEC, and the workshop was officially sponsored by CFE and the Foundación ProCiencias de la Tierra (Pro Earth Sciences Foundation – FECIT).

The agenda for the workshop was prepared by APEC and ICF, in coordination with CFE and FECIT. It was translated into Spanish and placed on the FECIT website, as soon as it was finalized. FECIT website has the agenda, as well as the presentations and APEC handouts to participants, at http://www.fundacionprocienciasdelatierra.org/

The workshop binders were prepared ahead of time and consisted of the agenda, speaker biographies, and the presentations by speakers. The workshop binder contents, the training modules and CCS references were all burned onto a CD, which was provided to workshop participants.

The workshop was structured such that the first day featured a general introduction to the role of CCS in climate change mitigation and a discussion of the basic science behind CCS technology, whereas the second day focused primarily on specific issues pertaining to Mexico, especially the role of EOR as an initial avenue for deploying CCS in Mexico. Many of the international experts spoke and played an active role in the workshop on both days. On the last day, an invitation-only roundtable discussion focused on options for introducing CCS in the curriculum of Mexican universities.

4.2 Workshop Program and Speakers

The workshop was moderated and facilitated by CFE (Mauricio Pico Medina), with several presentations in each session of the day. More than five minutes were provided for questions and answers at the end of each presentation. Many participants engaged the speakers afterwards during the break and lunch time in informal discussions. The workshop

had simultaneous translation so that speakers and participants could communicate in both Spanish and English.

New presentations were prepared for the workshop to reflect the pedagogical nature of the workshop, and to provide the basics for the students. The workshop presentations in Mexico City covered all the major areas of storage technology, with an exploration of issues relating to CCS and EOR implementation in Mexico. See Appendix 6 for the detailed agenda for both days.

Day 1.

In the morning opening session, the workshop was kicked off by brief opening remarks by Gustavo Arvizu Lara, Manager of Civil Engineering Studies (GEIC) of CFE, on the importance of the workshop for Mexico. Following the opening remarks, Dr. Ananth Chikkatur (ICF) described the role of Asia Pacific Economic Cooperation (APEC) and its structure and programs. In the area of clean fossil fuels, there is a multiphase program on CCS, until recently led by Canada, to study and evaluate the potential of capture and geological storage in the APEC region and raise awareness around this technology. He also discussed the APEC training modules and how they could be used by participants.

Other presenters in the first session on Day 1:

- Dr. Amparo Martinez Arroyo, UNAM, Mexico, provided the background on greenhouse gas emissions and climate change impacts and mitigation options, globally, as well as in Mexico.
- Dr. Steve Whittaker, Global CCS Institute, Australia, discussed the importance of CCS as a greenhouse gas mitigation option, drawing on the Global CCS Institute's work and the IEA's CCS Roadmap findings. He presented the modeling results by the IEA of atmospheric CO_2 concentrations under different scenarios. He highlighted different emission reduction alternatives and emphasized the need to implement them together.

Following the morning tea break, two more presentations were made by Dr. Stefan Bachu, Alberta Innovates - Technology Futures, Canada. These two presentations covered the fundamentals of CCS, including fluid flow and trapping mechanisms, and the various considerations behind site screening and selection. He explained the four phases of CCS: capture, compression, pipeline transport, and subsurface injection and storage. He explained that the information needed to understand and ensure that storage is safe, secure and acceptable may take about 9-10 years. Assessments can be conducted at different scales and resolutions, including country, basin, regional, local and site scales. He listed the criteria for site selection, concluding that the safety and security of storage, capacity, injectivity, the ability to meet regulatory requirements, including monitoring and accessibility, and project economics are the basis for the selection of a site.

Following lunch, Dr. Bachu gave another talk where he presented the methodology and options for storage site capacity assessment. He explained the four levels of capacity assessment: theoretical, effective, practical and feasible, and elaborated on the factors that need to be considered for the capacity estimation of each.

All three of his presentations were very well received and there were a number of clarification questions and comments from the audience.

After the break, the following speakers presented:

- Dr. Oscar Jimenez, CFE, presented a talk on Geophysics and Geomechanics of storage sites on behalf of Prof. Modesto Montoto, Spain, who was unable to attend the workshop at the last minute.
- Neil Wildgust, PTRC, Canada, discussed the various aspects of geochemistry that is needed to evaluate the suitability of storage sites, as well as for monitoring and verification of storage. He explained the chemical reactions that take place in the reservoir once CO_2 is injected, such as dissolution depending on temperature and salinity of the formation water, mineral precipitation of carbonates

Dr. Moises Davila, CFE, Mexico, then summarized the highlights of all of the presentations of the day, and laid the groundwork for presentations on the second day.

Day 2.

The first part of the second day continued the presentation of the basics behind CCS, with three presentations:

- Dr. Steve Whittaker, Global CCS Institute, discussed the role of "Monitoring and Verification (MV)" throughout the geological storage process to ensure the integrity of the storage site. He noted that the monitoring tools include geophysics, geochemistry, geomechanics, remote sensors and well logs.
- Neil Wildgust, PTRC, Canada, presented the potential risks for the different stages of CCS. He concluded that risk analyses for geological storage should be specific for each storage site. He ended his presentation by showing a case study on Weyburn, Canada.
- Wesley Peck, UNDEERC, U.S., explained the different mechanisms of oil recovery, and highlighted the role of tertiary recovery or enhanced oil recovery (EOR), which comprises the injection of miscible/immiscible fluids (CO_2), or chemical or thermal (steam flooding) methods to recover another 10-15% of the oil from reservoirs. The presentation concluded with a few examples.

In the next sessions, the focus of the workshop was on the potential for CCS in Mexico. Specifically:

- Dr. José Miguel González Santaló, IIE, and Mexico's CSLF representative, explained the basic principles of CCS, gave a historical review of the introduction of this technology in Mexico, and mentioned the institutions that are participating in developing this technology in Mexico. He stressed the importance of developing CCS and elaborated on future prospects for CCS in Mexico.
- Vicente Arévalo Mendoza, CFE, explained that CO_2 emissions are related to the industrial development of an economy. He noted that it is the emissions from stationary sources that are to be captured and transported to geological storage sites.

- Dr. Moses Dávila, CFE, showed the progress of Mexico's knowledge of this technology, as reflected in a several published papers. He noted the commitment of the government of Mexico to actively participate in reducing greenhouse gases. He highlighted the work that Mexico has done in selecting potential sites for storage. Studies are now being initiated to complete the Region stage, where Sabinas and Burgos Basins are being considered. In addition, Dr. Dávila showed the results of a preliminary analysis of the environmental impact of a coal-fired plant with CCS.
- Rodolfo Lacy, Mario Molina Center, Mexico, outlined the objectives of the first planned demonstration project of CCS in Mexico, which will involve CO_2-EOR and use facilities at PEMEX and CFE. Mr. Lacy discussed the selection of two potential sites (Poza Rica and Tuxpan), the assessment of costs, the need for an environmental impact assessment, a risk assessment, and monitoring technologies.

The workshop was then officially closed. Afterwards, representatives of the universities attended a Round Table, together with the representatives from APEC, ICF, Global CCS Institute, CFE, Ministry of Energy of Mexico and the FECIT. The objective was to reach an agreement for introducing CCS in the study programs for geology and geophysics engineering in Mexico.

The following five action items were agreed upon:

- All schools will begin implementing, formally or informally, the inclusion of CCS in the study programs of geology and geophysics from next semester (August-December 2012).

- The Global CCS Institute will provide a book on climate change, which is currently being developed with a strong component on CCS, to be used as a textbook in the study programs.

- The Global CCS Institute will provide support for developing workshops on CCS to train teachers of universities offering geology and geophysics university programs in Mexico.

- The Ministry of Energy of Mexico will coordinate the activities arising from points 2 and 3 between universities and Global CCS Institute.

- The National Association of Colleges and Schools of Engineering (ANFEI) will be invited to take part in the activities undertaken in the future with the intention to introduce the topic of CCS in Mexican universities in disciplines that apply this technology beyond of the earth sciences.

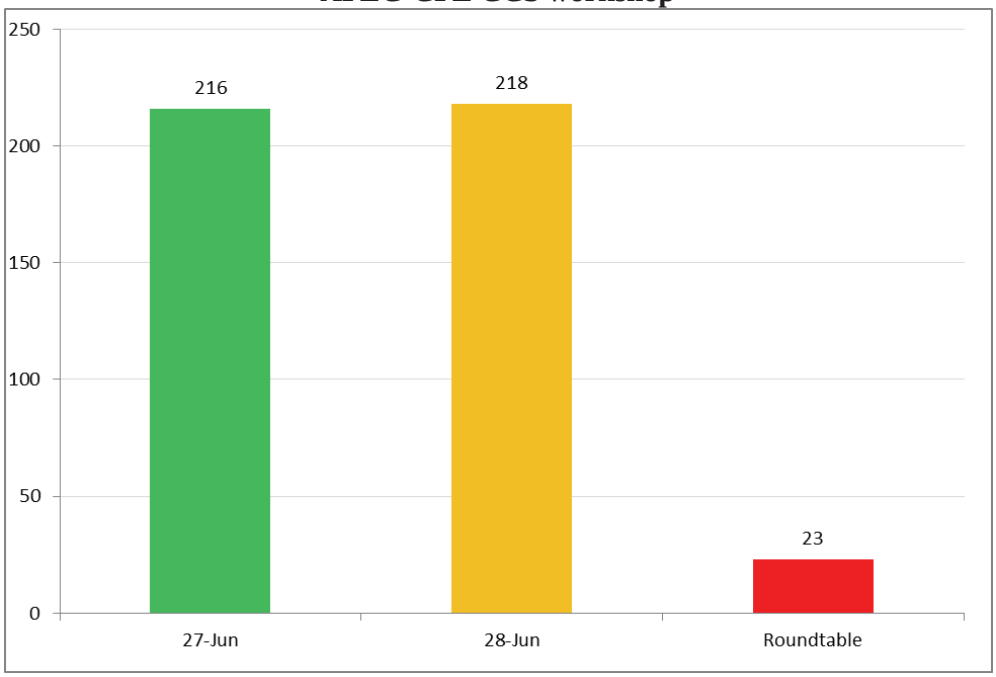
4.3 Workshop Attendance

The APEC-CFE workshop was one of most successful capacity building workshops in this APEC program, based on the large number of participants in the workshop. The attendance level was maintained on both days, indicating the high level of interest in the topic—see

figure below. CFE had also arranged for a certificate of attendance to be provided to the students at the end of the workshop—which further enhanced the interest and attendance.

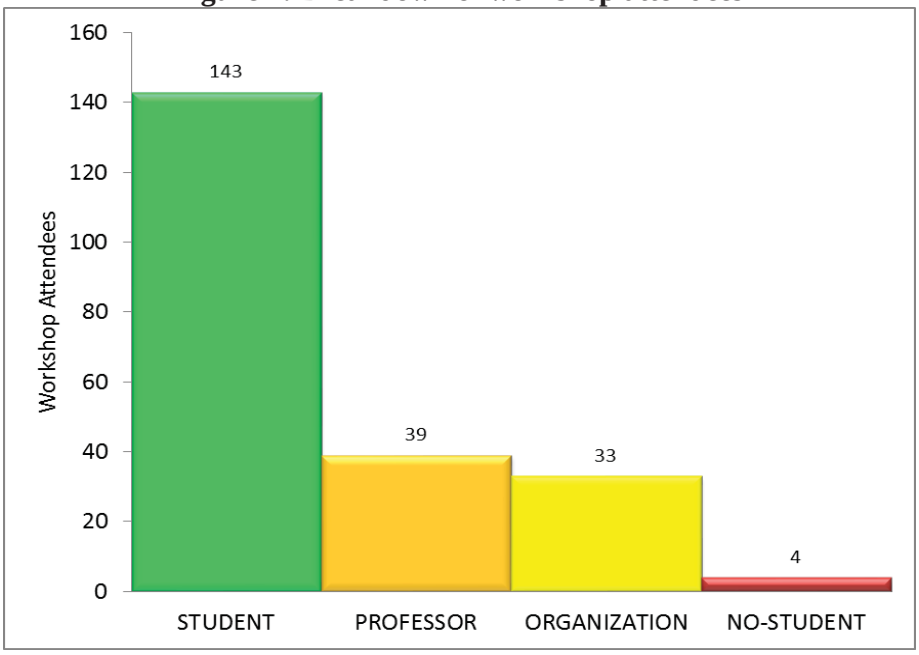
The attendance numbers are summarized in the figures below. More than 216 participants attended the two day workshop, and a total of 22 participants took part in the invitation-only roundtable—see Figure 1. A more detailed list of the participants in the roundtable is shown in Appendix 8.

Figure 1: Total Number of Participants on Day 1, Day 2, and Roundtable meeting at the APEC-CFE CCS workshop



As shown in the graph below, the majority of the attendees were students (about 65%) and professors (18%). The rest of the attendees (17%) were part of the organization and expert speakers.

Figure 2: Breakdown of workshop attendees



As shown in Figure 3 below, the majority of the attendees (about 60%) were from in and around Mexico City and 35% travelled from outside of Mexico City. Very few of the participants (4%) were from outside of Mexico—this segment was comprised mostly of the expert speakers. The large contingent of attendees who travelled from outside of Mexico City for the workshop indicates the high level of interest in the topic.

Figure 3: Location of workshop attendees

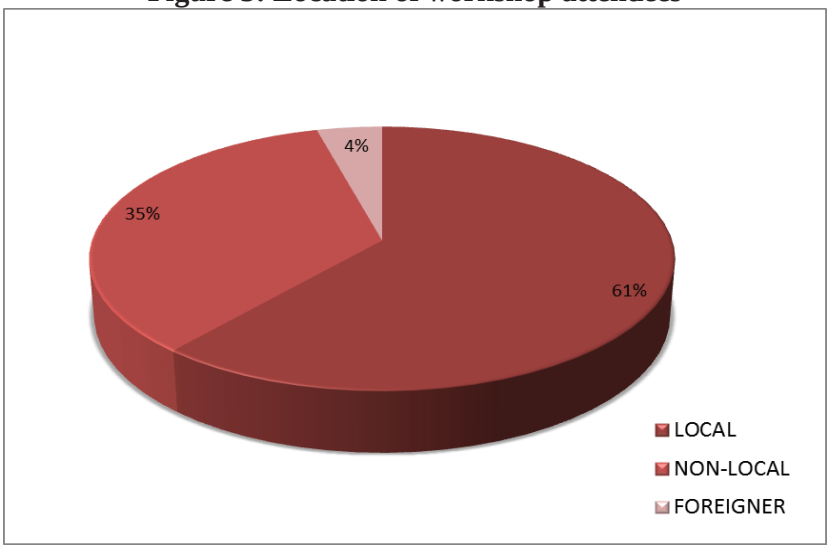


Table 1 below shows the total number of participants from different universities and institutions who attended the workshop.[8]

Table 1: Breakdown of workshop attendees by Universities and other Institutions

UNIVERSITY/INST	STUDENT	PROFESSOR	OTHERS	TOTAL
Instituto Politecnico Nacional	58	12	0	**70**
Universidad Nacional Autónoma de México	30	6	0	**36**
Universidad Autonoma del Estado de Hidalgo	14	12	0	**26**
Universidad Autónoma de Guerrero	17	1	0	**18**
Benemérita Universidad Autónoma de Puebla	14	1	0	**15**
Instituto Tecnologico de Cd Madero	9	3	0	**12**
Universidad Autónoma de San Luis Potosí	1	2	0	**3**
Universidad Autonoma de Chihuahua	0	2	0	**2**
SENER	0	0	4	**4**
CFE	0	0	24	**24**
APEC	0	0	1	**1**
Global CCS Insititute	0	0	2	**2**
CSLF -IIE	0	0	1	**1**
ICF International	0	0	1	**1**
Alberta Innovates, Canada	0	0	1	**1**
Energy & Environmental Research Center, University of North Dakota	0	0	1	**1**
Mario Molina Center	0	0	1	**1**
Petroleum Technology Research Centre, Canada	0	0	1	**1**
TOTAL	**143**	**39**	**37**	**219**

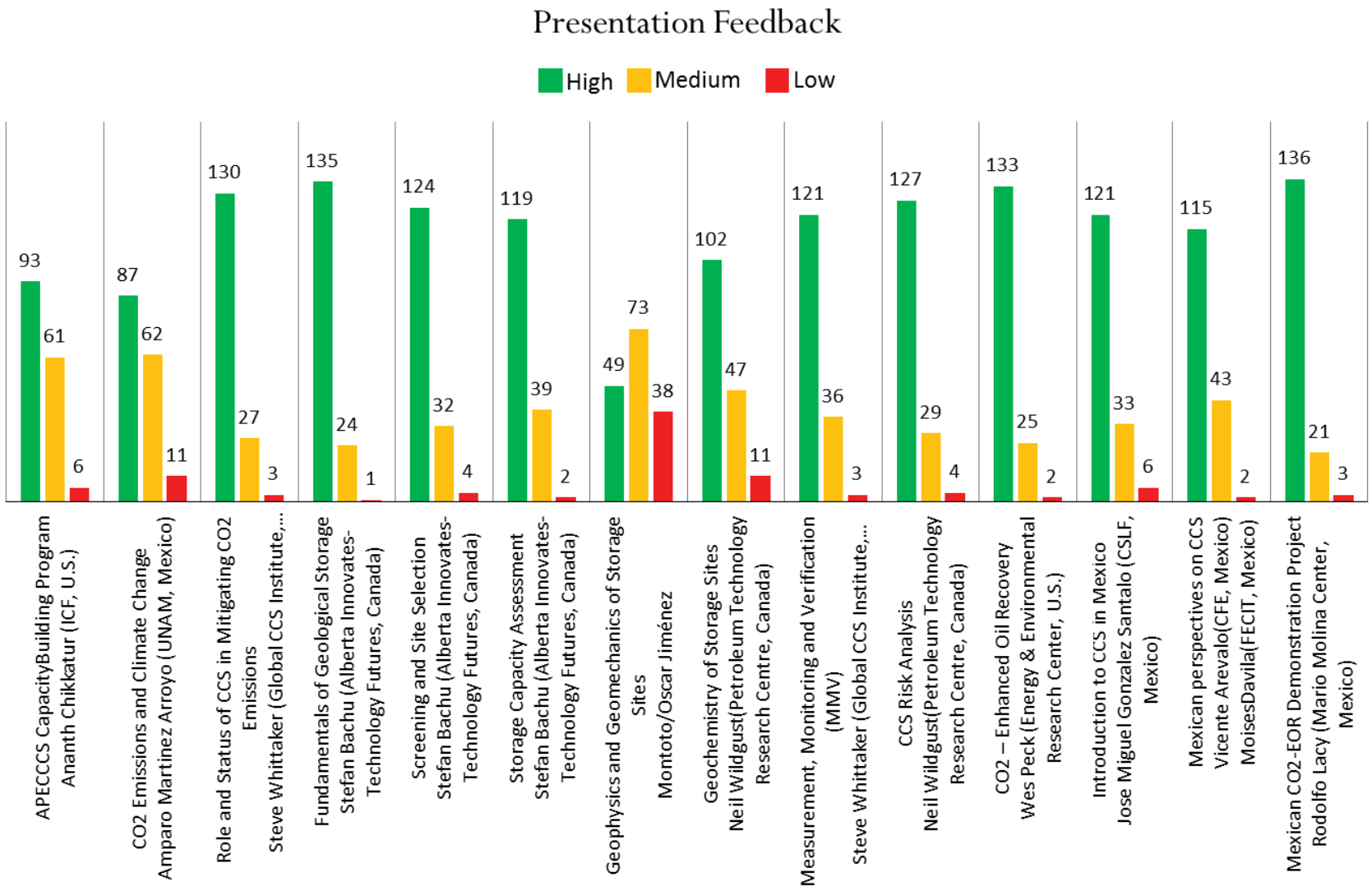
4.4 Workshop Feedback

Formal feedback was obtained from surveys distributed to participants, and most of the participants filled out and handed back the surveys to CFE. The large sample size provides an interesting insight into the perceived relevance of the different presentations.

As shown in Figure 4, the talks on the role of CCS (Dr. Steve Whittaker), the basics of CCS (by Dr. Stefan Bachu), MV (Dr. Steve Whittaker), CCS risks (Wes Peck), and the EOR presentations (Wesley Peck and Rodolfo Lacy) rated very high. Talks on the role of CCS in Mexico were also rated high, but the talks on geomechanics and geochemistry were not rated as high by the participants. The introductory presentation, highlighting the institutional structures within APEC and the history of APEC CCS capacity building activities within APEC, was not rated high either—perhaps because this was not as relevant to the students (although this might have been more interesting to policy makers). The details on the relationship between climate change and GHG emissions was also not rated very high, as the students might have known much of the information already.

[8] Note that the participant makeup was slightly different on Day 1 and Day 2.

Figure 4: Feedback on various presentations at the Mexico Workshop



In addition to the ratings of the different presentations, attendees provided various suggestions to improve the workshops, which are summarized below. In many cases, there were many responses, and only the top few responses are listed below and more detailed responses are provided in Appendix 9.

In terms of suggestions to improve the workshop, the top three suggestions were to:

1) Send the workshop presentations to the translators a few days before in order to allow for better translation;
2) Have longer time available for questions; and
3) Divide the topics by application areas and explain better how the different disciplines studied by students interact with future professional opportunities in CCS

Suggestions for additional topics to be covered in future workshops included:

- Methods of CO_2 sequestration
- Environmental impacts of leakage and remediation
- Modeling and software used for site selection and injection of CO_2
- Geomechanics, geotectonics, and geothermal
- Comprehensive analysis of a specific project

More detail was requested in the following areas:

- Criteria for selection and characterization of storage sites
- Enhanced Oil Recovery, and associated risk analysis for EOR
- CO_2 capture methods

In terms of activities for improving CCS knowledge in Mexican universities, the top responses were to:

- Publicize CCS in print media aimed at the Universities
- Conduct additional workshops once or twice a year
- Invest in CCS training of teachers in earth sciences
- Invest in CCS R&D
- Develop projects where international experts and Mexican students can participate together

Many of the respondents felt that information related to global CO_2 emissions were not necessary and that there were many repetitions of the basic concepts by several presenters—indicating the need for more coordination among the expert speakers.

A large number of attendees noted that the workshop was very well organized, with high-level specialists presenting their knowledge to the students. Some requested that similar workshops be held on other topics, such as renewable energy sources, etc.

All of the international experts who presented at the workshop felt that the workshop was well structured, well organized, and covered all core CCS storage areas well. It was suggested that it is important to have additional presentations highlighting the ongoing demonstration projects across the globe, so that the students can place the theoretical discussions in context of ongoing activities.

After the workshop, CFE (with APEC and ICF support) developed a summary of the workshop, which is on the FECIT webpage, and is also reproduced here in Appendix 10.

4.5 Follow-Up Activities and Recommendations for Advancing CCS in Mexico

- Hold similar workshops on CCS in other parts of Mexico to engage students and professors in other regions of Mexico.

- Hold additional focused workshops in Mexico City on specific CCS-related topics.

- CFE and the Mexican universities, in coordination with the Global CCS Institute and other agencies, to follow through on the five-point action plan developed during the roundtable discussion

    - All schools to begin implementing, formally or informally, the inclusion of CCS in the study programs of geology and geophysics from next semester (August-December 2012).

    - Global CCS Institute to provide a book on climate change, which is currently being developed, with a strong component of CCS, to be used as a textbook in the study programs.

    - Global CCS Institute to provide support for developing workshops on CCS to train teachers of universities offering geology and geophysics university programs in Mexico.

    - The Ministry of Energy of Mexico to coordinate the activities arising from points 2 and 3 between universities and Global CCS Institute.

    - National Association of Colleges and Schools of Engineering (ANFEI) to be invited to take part in the activities undertaken in the future with the intention to introduce the topic of CCS in Mexican universities in disciplines that apply this technology beyond of the earth sciences.

- Deeper involvement of PEMEX and SENER in CCS related educational activities in Mexico

5 Conclusion

The Phase V workshops in Viet Nam and Mexico were successful in enhancing the CCS-related capacity in both of the countries.

The Mexico workshop, in particular, is an important contribution to the understanding of Carbon Capture and Storage in Mexico. It shows how an economy that is deeply interested in CCS can help build the demand for knowledge among its educational institutions, and how APEC can meet this demand through its capacity building activities. The workshop is an indication of how APEC can engage with educational institutions and policy makers globally to support CCS development.

Pilot projects and involvement of oil and gas industries are necessary for continued interest in CCS in APEC developing countries. The workshops have shown that there is pent-up demand for more such workshops, and these workshops will be successful if they are well coordinated with local institutions.

APEC's training modules and capacity building activities have played an important role in supporting the buildup of capacity in the developing countries, and APEC needs to continue to engage with ADB, Global CCS Institute, CSLF, IEA, and other agencies to synergistically promote CCS knowledge and development.

Appendices

Appendix 1: List of Acronyms

ADB	Asian Development Bank
ANFEI	National Association of Colleges and Schools of Engineering, Mexico
APEC	Asia Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
BECCS	Bio-Energy with Carbon Capture and Storage
CCOP	Coordinating Committee for Geoscience Programmes in East and Southeast Asia
CCS	Carbon dioxide Capture and Storage
CFE	Comisión Federal de Electricidad (Federal Electricity Commission), Mexico
CO_2	Carbon Dioxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
CSLF	Carbon Sequestration Leadership Forum
ECBM	Enhanced Coalbed Methane
EGCFE	APEC Experts Group on Clean Fossil Energy
EOR	Enhanced Oil Recovery
FECIT	Foundación ProCiencias de la Tierra (Pro Earth Sciences Foundation), Mexcio
IEA	International Energy Agency
IEAGHG	IEA Greenhouse Gas R&D Programme, United Kingdom
IIE	Instituto de Investigaciones Eléctricas (Electricity Research Institute), Mexico
IPCC	Intergovernmental Panel on Climate Change
MOIT	Ministry of Industry and Trade, Viet Nam
MUTEC	Museo Tecnológico de CFE (Technology Museum of CFE), Mexico
MV	Monitoring and Verification of injected CO_2
OECD	Organisation for Economic Co-operation and Development
PEMEX	Petróleos Mexicanos, Mexico
PTRC	Petroleum Technology Research Centre, Canada

PVEP	Petrovietnam Exploration Production Corporation, Viet Nam
RETA	Regional Technical Assistance of ADB
SENER	Secretaría de Energía (Energy Secretariat), Mexico
UNAM	Universidad Nacional Autónoma de México (National Autonomous University), Mexico
UNDEERC	University of North Dakota Energy & Environmental Research Center, United States

Appendix 2: Reference Materials

Reference documents included on the CCS Course CD:

• **Technology Roadmap. Carbon capture and storage. International Energy Agency © OECD/IEA 2009**
• **CARBON CAPTURE AND STORAGE: Legal and Regulatory Review (Edition 2) International Energy Agency © OECD/IEA 2011**
• **Technology Roadmap: Carbon Capture and Storage in Industrial Applications International Energy Agency © OECD/IEA 2011**
• **Cost and Performance of Carbon Dioxide Capture from Power Generation International Energy Agency © OECD/IEA 2010**
• **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**
• **Geological Storage of Carbon Dioxide – Staying Safely Underground, IEAGHG**
• **Carbon Capture and Storage – Meeting the Challenge of Climate Change, IEAGHG**
• **Best Practices for Public Outreach and Education for Carbon Storage Projects, National Energy Technology Laboratory, US Department of Energy**
• **Communication and Engagement Toolkit for CCS Projects, CSIRO**
• **CCS Guidelines, World Resources Institute**
• **The Global Status of CCS 2011, Global CCS Institute**

• **Defining CCS Ready: An Approach to An International Definition, Global CCS Institute**
• **CCS Ready Policy: Considerations and Recommended Practices for Policymakers, Global CCS Institute**
• **North American Carbon Storage Atlas, First Edition, 2012**

Appendix 3: Opening Speeches in the APEC-ADB workshop in Viet Nam

Opening Speech by Mr. Le Tuan Phong,
Deputy Director General of Directorate of Energy, Ministry of Industry and Trade
at APEC-ADB CCS workshop in Viet Nam on 13-14 Dec. 2011

Mr. Andrew Head, Deputy Country Director, ADB Resident Mission – Viet Nam,
Distinguished Guests,
Ladies and Gentlemen,

Climate change, a challenge to whole globe, has been urging the world and each country to apply effective adaptation measures to mitigate its impacts. Vietnam is one of countries strongly impacted in coming years by climate change which threatens our main economic zones.

In sustainable development tendency towards low carbon economy against climate change, application of GHG emission reduction measures, carbon capture and storage (CCS) technologies is considered by many countries as playing important role.

CCS technology with 3 main elements, carbon capture, transport and storage are technically feasible and step by step become commercialized in developed countries (with pilot projects mainly deployed in developed countries). In order to disseminate this technology, the technological, legal and policy mechanism aspects need to be internationalized, especially for developing countries like Vietnam: the first step is to assess potential and seek for legal frame, policy mechanism in order to overcome barriers (if any).

Ladies and gentlemen,

In recent time, some studies on CCS in developing countries have been being carried out, in which TA-RETA 7575 by ADB for 4 countries (the Philippines, Indonesia, Thailand and Vietnam). Yesterday, Ministry of Industry and Trade and Asia Development Bank held a meeting on reviewing Report of this project whose some contents will be presented at this workshop.

Ladies and Gentlemen,

Like in other economies, coal fired power plants are considered as one of main and large CO_2 emission resources in Vietnam. In 2010, over half of installed capacity in Vietnam power system are thermal power of which coal fired power plants account for 18.5%, gas and oil fired power plants account for 36.6%. According to PDP VII, by 2020 the share of coal fired TPPs' installed capacity in Vietnam power system will be increased to about 41.5 %. In period 2012 – 2015, 18 coal fired power plants with total capacity of 36.5GW will be added and in period 2021 – 2030, 10.6GW of coal fired TPPs will be added.

According to experts' assessment, in 2010, Vietnam's CO_2 emission is about 150.9 million tons, of which 65 million tons CO_2 from agriculture (accounting for 43%), next energy sector – 52.7 million tons of CO_2 (accounting for 35 %). In 2009, CO_2 emission from fossil fuel is estimated increased by 113% in comparison to year 2000. In energy sector, coal fired power plants contribute 54 % of CO_2 emission and gas fired power plants contribute 40%. Each kWh of Vietnam contributes 0.52 kg CO_2 emission. According to medium scenario, Ministry

of Natural Resources and Environment estimated that GHG emission from energy sector by 2020 is 224 million tons CO_2 equivalent.

The other main industries contribute about 10 million tons of CO_2 emission/year, including cement 6.6 million tons/year, steel 2.5 million tons/year and limestone exploitation 0.8 million tons/year.

Ladies and Gentlemen,

Study RETA 7575 which is carried out by expert team has assessed and analyzed 60 CO_2 emission sources (of which 31 thermal power plants) with total CO_2 emission of about 64 million tons/year and it is aware that Vietnam has technical potential of CCS technology application but with many challenges. Application of CCS technologies can be combined with gas-lift technology in order to increase benefits of oil exploitation in Vietnam. RETA 7575 TA study proposed some steps of CCS application roadmap for Vietnam.

On behalf of leaders of MOIT, I wish researchers to complete study and make specific recommendations for dissemination of CCS technology in Vietnam and other countries in the region.

Thank you for attention and wish you good health!

JOINT APEC/ADB WORKSHOP
CARBON CAPTURE AND STORAGE IN VIET NAM

13-14 December 2011
Opening Remarks by Andrew Head, Deputy Country Director for Viet Nam

Mr. Le Tuan Phong, Deputy Director General, Energy Department, MOIT,

Dr. Frank Mourits, Co-Chair of the APEC Expert Group on Clean Fossil Energy,

Distinguished Colleagues,

Ladies and Gentlemen – Good Morning.

My name is Andrew Head, and I am the Deputy Country Director for the Asian Development Bank here in Viet Nam. On behalf of the ADB, I would like to welcome you all to this Joint ADB- APEC Workshop on Carbon Capture Storage. I would also like to acknowledge the leadership of the Ministry of Industry and Trade and APEC, which helped convene this workshop. We also have with us representatives from our partner organizations: the International Energy Agency (IEA), the IEA Greenhouse Gas R&D Programme (IEAGHG) and the Global CCS Institute, as well as colleagues from various Ministries in Viet Nam, the academe, and the private sector.

ADB resumed operations in Viet Nam in 1993. Since then we have committed over $8.4 billion in loans, $187 million in technical assistance, $139 million in grants, and $217 million in private sector operations. ADB's operations cover energy, water, transport, agriculture and environment, education, public sector management and health sectors.

Over the next five years, as Viet Nam continues on its development path, ADB is keen to provide ongoing financing and technical assistance in a variety of areas related to clean energy and climate change, including: energy efficiency programs, sustainable transport such as the Hanoi and Ho Chi Minh City metro systems, improved land use and biodiversity conservation programs, and development of tools for climate risk assessment and adaptation planning.

Vietnam is on the front lines of the ongoing struggle to balance economic growth with environmental protection. Viet Nam is one of the fastest growing economies in Asia and continued economic development will require the consumption of larger amounts of energy, much of which will be generated by coal-fired plants. This will increase the country's greenhouse gas emissions significantly.

But climate change has increasingly emerged as a significant risk to economic development. And Viet Nam, with its long coastline and large river deltas – where most of the population and economic activity is concentrated – is particularly susceptible.

A study by the Ministry of Natural Resources and the Environment (MONRE) in June 2009 predicts that by the end of the 21st century the average temperature in the country will rise by 2.3 degrees Celsius, with increasing rainfall during the wet season and less rainfall during the dry season. Sea level is expected to rise by 75 centimeters compared

with the average from 1980–1999, which could affect significant amounts of the population in the Mekong and Red River delta areas.

There is a real and urgent need to limit the environmental cost of energy generation from fossil fuels – and the government of Viet Nam recognizes this. Viet Nam is the first country in all of Southeast Asia to launch a national program to address climate change aimed at both mitigation and adaptation. The National Target Program (NTP) on Climate Change announced by the Prime Minister at the Copenhagen Climate meetings requires all ministries, provinces and cities to develop climate change action plans. The very ambitious goals of the NTP now need to be turned into specific technologies, programs and practices – and this is where carbon capture and storage or CCS is particularly relevant.

CCS offers the alluring prospect of producing much-needed electricity from fossil fueled power plants with almost no carbon emissions to the atmosphere. In addition, this approach can be applied to chemicals, steel and cement plants, and to natural gas processing facilities.

There are significant challenges that need to be addressed first however. This technology is expensive, not fully commercial, and implementing these projects requires coordinated action among various industrial sectors and ministries. However, we cannot wait for these approaches to be perfected before bringing them to developing Asia. We need to start taking steps now. This means testing and piloting capture technologies in new coal-fired power plants and gas processing facilities. In terms of storage, we need to look for opportunities where we can combine capture technologies with enhanced oil recovery so that we increase oil production and offset some of the costs of storage. CCS needs to be placed next to renewable energy and energy efficiency and needs to be considered part of a comprehensive approach to managing energy-related emissions.

In December 2010, ADB initiated a regional program with a budget of $1.25 million to work closely with the government and national experts in Thailand, the Philippines, Indonesia and Viet Nam to explore the potential for CCS. This workshop is financed by the ADB's CCS fund and the Global Carbon Capture and Storage Institute supported by the Government of Australia.

With a full 2-days program ahead of us, I wish everyone productive deliberations and substantive outcomes for this workshop.

Thank you. Xin Cam On.

Appendix 4: Participant List (Viet Nam Workshop)

	Last Name	First Name	Title	Position	Organization	Address	Phone/Fax	Email	Atten - dance
1	Bui Cach	Tuyen	Dr (Mr)	Vice Minister	Ministry of Natural Resources and Environment (MONRE)	83 Nguyen Chi Thanh street, Dong Da district, Hanoi	Tel: 84 4 39423899; Mob: (84) 907 995559	buicachtuyen@gmail.com	
2	…	Cuong	Mr	Mr. Tuyen's Vice Minister Secretary	Ministry of Natural Resources and Environment (MONRE)	83 Nguyen Chi Thanh street, Dong Da district, Hanoi	Mob: +84 988066568	cuongtcx6@gmail.com	Day 1, replaced Mr. Tuyen
3	Pham Dong	Giang	Mr	Sales Managers	ALSTOM Holdings	Suite 18, 18th Floor, HCO Building, 44 Ly Thuong Kiet street, Hoa Kiem District, Hanoi	Mob: (84) 914569811	giang.pham-dong@power.alstom.com	Day 1 & 2
4	Nguyen Xuan	Hien	Mr	Senior Sales Managers	ALSTOM Holdings	Suite 18, 18th Floor, HCO Building, 44 Ly Thuong Kiet street, Hoa Kiem District, Hanoi		-	Day 1
5	Lê Tuấn	Phong	Mr.	Deputy Director General	General Department of Energy, Ministry of Industry and Trade (MOIT)	54 Hai Ba Trung, Hoan Kiem, Hanoi		PhongLT@moit.gov.vn	Day 1
6	Mai Dinh	Trung	Mr.	Deputy Director	PMU of Reproduced Energy for Rural Power, Ministry of Industry and Trade (MOIT)	54 Hai Ba Trung Street, Hoan Kiem District, Hanoi	Mob: +84 912019056	trungmd@moit.gov.vn	Day 1 & 2
7	Nguyen Van	Minh	Mr	???	General Department of Hydro Meteorology and Climate Change	8 Pháo Đài Láng, Hà Nội.		nvminh.dmhcc@gmail.com	Day 1
8	Nguyen Le	To Nga	Ms.	Expert	Petro-Chemical Dept, PVN	18 Láng Hạ - Ba Đình - Hà Nội		-	Day 1 & 2
9	Tong Canh	Son	Mr.	Lab. Manager	Institute for Science and Design, Vietsopetro	105 Lê Lợi, Phường 6, thành phố Vũng tàu, Việt Nam	Mob: +84 913 045021	sontc.nd@vietsov.com.vn	Day 1 & 2

	Last Name	First Name	Title	Position	Organization	Address	Phone/Fax	Email	Atten - dance
10	Le Dinh	Hoe	Mr.	Expert	Institute for Science and Design, Vietsopetro	105 Lê Lợi, Phường 6, thành phố Vũng tàu, Việt Nam	Mob: =84 908590407	hoeld.ad@vietsov.com.vn	Day 1
11	Nguyen Van	Hoang	Mr.		Petro Vietnam Power Corporation (PV-Power VN)	VPI Tower, 173 Trung Kinh, Cau Giay, Hanoi, Vietnam		nguyenvanhoang@pv_power.vn	Day 1
12	Nguyen Thi	Bich Ngoc	Ms	Expert	VPI	VPI Tower, 173 Trung Kinh, Cau Giay, Hanoi, Vietnam	_	ngocntb@vpi.pvn.vn	Day 1
13	Tran Chau	Giang	Ms	Deputy Manager	Division of Science & Strategy,Vietnam Petroleum Institute (PVI)	VPI Tower,173 Trung Kinh, Cau Giay district, Hanoi, Vietnam	+(84 4) 378 43061 - 37841727 – 37841728 Mobile: +84 912585526	giangtc@vpi.pvn.vn	Day 2
14	Nguyen The	Hung	Dr.	In-charge	Science and Strategy Division, VPI	VPI Tower,173 Trung Kinh, Cau Giay district, Hanoi, Vietnam	Mob: +84 913248580	hungnt@vpi.pvn.vn	Day 1
15	Nguyen Thi	Van	Ms.	Deputy Manager	Science and Strategy Division, VPI	VPI Tower,173 Trung Kinh, Cau Giay district, Hanoi, Vietnam		vannt@vpi.pvn.vn	Day 1 & 2
16	Dinh Thanh	Chung	Mr.	Expert	VPI	VPI Tower,173 Trung Kinh, Cau Giay district, Hanoi, Vietnam	Mob:+84 989085606	chungdt@vpi.pvn.vn	Day 1 & 2
17	Hoang Hai	Thanh	Mr.	Deputy Head Division	Division of Research & Development, PVGas	PV Gas Tower, No. 673 Nguyen Huu Tho Street, Phuoc Kien Commune, Nha Be District, HCM, Vietnam	Mob: +84 918850690	thanh.hh@pvgas.com.vn	Day 1 & 2
18	Nguyen The	Chinh	Dr (Mr.)	Deputy Director General	Institute for Strategy and Policy on Natural Resources and Environment (ISPONRE)	1116 Hoang Quoc Viet, Cau Giay, Hanoi	Tel: +84 4 37931629 (ext 555) Fax: +844 37931730 Mob: 0913307559	ntchinh@isponre.gov.vn; thechinhnguyen@yahoo.com	Day 1
19	Nguyen Trong	Thuc	Mr		VINCOMIN	226 Le Duan Street, Hanoi	Mob: +84 982357750	thucnt@vinacominpower.vn	Day 1

	Last Name	First Name	Title	Position	Organization	Address	Phone/Fax	Email	Atten - dance
20	Kieu	Kim Truc	Mr.	Deputy General Manager	VINACOMIN, Division of Science, Technology and Development Strategy	226 Le Duan Street, Hanoi	+84 912 268 457	kktruc@vinacomin.vn	Day 1
21	Nguyen Tien	Chinh	Dr (Mr.)	General Manager	Division of Science, Technology and Development Strategy, Vietnam National Coal Mineral Industries Group (VINACOMIN)	226 Le Duan Street, Dong Da, Hanoi	+84 435 180141 - (84)438 510780	chinhnt@vinacomin.vn	Day 1
22	Nguyen	Chi Quang	Mr.	Deputy Manager	Aluminum Division, VINACOMIN	226 Le Duan Street, Hanoi			Day 1
23	Philippe	Le Canut	Mr.	Representative Office Manager	Electricite de France South East Asia Division	HCO Building Suite 1705, 17th floor 44b, Ly Thuong Kiet, Hoan Kiem, Hanoi	Tel +84 4 39345591	philippe.le-canut@edf.fr	Day 1 & 2
24	Tran Le	Minh	Mr.		PECC3	32 Ngo Thoi Nhiem Street, District 3, HCMC	Mob: +84 963848362	minhtl@pecc3.com.vn	Day 1
25	Le Thi Ngoc	Quynh	Ms	Deputy Director	Department of Science, Technology and Environment, EVN	18 Trần Nguyên Hãn - Hoàn Kiếm - Hà Nội	Mobile: +84 96579986	quynhltn@evn.com.vn	Day 1
26	Pham Thi	Thuy	Mr	Expert	VEPA, Centre for Environmental Monitoring, Data & Information (CEMDI)	No. 7 Xã Đàn Đống Đa, Hà Nội		phamthuy@vea.gov.vn	Day 1 & 2
27	Phan Xuan	Duong	Mr.	Deputy General Director	Vinh Tan 3 Energy JC (VTEC)		Mob: +84 903436338	duong.phan@vinhtan3.com	Day 1 & 2
28	Henry	Hui	Mr.	Technology Engineer	Vinh Tan 3 Energy JC (VTEC)			duong.phan@vinhtan3.com	Day 1
29	Vu Lan	Anh	Ms	Economist	British Embassy			-	Day 1

	Last Name	First Name	Title	Position	Organization	Address	Phone/Fax	Email	Atten - dance
30	Nguyen An	Dung	Mr	Expert	Institute of Energy	No. 6 Ton That Tung, Dong Da, Hanoi		dungna_ie@yahoo.com	Day 1 & 2
31	Nguyen Van	Thang	Mr	Expert	IMH			vvthang@IMH.ac.vn	Day 1 & 2
32	Le Thanh	Y	Mr	Expert	Dept of Economic Dept			thanhy41@yahoo.com.vn	Day 1 & 2
33	Dao Thi	Hien	Ms	Expert	EVN	18 Trần Nguyên Hãn - Hoàn Kiếm - Hà Nội	Tel: =84 4 22201236	hiendt-kem@evn.com	Day 1
34	Le Kim	Thai	Ms	Expert	Environmental Protection Fund	42 Kim Ma Thuong, Ba Dinh, Hanoi	Mob: +84 903672974	sunriseinvietnam@gmail.com	Day 1
35	Tran Thanh	Phuong	Ms	Engineer	VPI			phuongtth@vpi.pnv.vn	Day 2
36	Dao Minh	Trang	Ms	Researcher	Center for Meteorology and Climatology - IMHEN	62/23 Nguyen Chi Thanh street, Dong Da District, Hanoi, Vietnam		daominhtrang@gmail.com	Day 2
37	Andrew	Head		Deputy Country Director	Asian Development Bank				Day 1
	International Experts and Speakers								
38	Pradeep	Tharakan		Specialist	Asian Development Bank, Philippines				Day 1 & 2
39	Frank	Mourits		Specialist	Natural Resources Canada				Day 1 & 2
40	Ananth	Chikkatur		Specialist	ICF, U.S.		1-703-218-2593	achikkatur@icfi.com	Day 1 & 2

	Last Name	First Name	Title	Position	Organization	Address	Phone/Fax	Email	Atten - dance
41	Justine	Garrett		Specialist	IEA, France				Day 1 & 2
42	Stanley	Santos		Specialist	IEAHG, U.K.				Day 1 & 2
43	Bill	Gunter		Consultant	ADB				Day 1 & 2
44	Christopher	Short		Specialist	Global CCS Institute, Australia				Day 1 & 2
45	Simone	Carr-Cornish	Ms.	Specialist	CSRIO, Australia		Tel: +07 3327 4077	simone.carr-cornish@CSIRO.au	Day 1 & 2
46	Douglas	Macdonald		Consultant	ADB		Tel: +1403 9737678	macdonald@telnsplanet.net	Day 1 & 2
47	Craig	Hart		Consultant	APEC, U.S.				Day 1 & 2
48	Maria Cristina	Pascual	Ms	Consultant	Asian Development Bank, Philippines				Day 1 & 2
49	Simplicio P.	Caluyong		Project Coordinator	CCOP, Thailand		Tel: +66(0)81 8270527	sum@ccop.or.th	Day 1 & 2

Appendix 5: Participant Feedback (Viet Nam workshop)

Workshop Feedback (Day1)

Results from the feedback forms have been entered in the template used to solicit feedback from participants on Day 1. A total of 9 participants provided their feedback. However, not everyone provided feedback on all parts of the workshop.

Joint APEC-ADB Carbon Capture and Storage in Viet Nam Workshop

We would be grateful for your feedback on this workshop

Name _____ Organisation _____

I attended Day 1

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 1			
1 Welcome and Opening Address		3	6
2.1 Introduction to APEC's CCS Programme		3	6
2.2 Introduction to the ADB CCS Technical Assistance - Facilitating CCS deployment in Southeast Asia	1	2	6
2.3 Introduction to CCS and the APEC training modules		4	5
3 Importance of CCS as a greenhouse gas mitigation option		3	6
4 Capture Technology Overview - Status and Challenges		2	7
5 CO_2 Transportation		3	6
6 Storage Fundamentals		3	4
7 Economics and Financing of CCS		6	3
8 Legal, Regulatory and Permitting issues	1	2	6
10 Status of CCS projects around the world	1	6	2
11 Alstom CO_2 Capture Development Status	1	2	3

Comments

How could the sessions be improved?

- Need to improve Economics and Financing Session and Legal, Regulatory and Permitting Session
- CO_2 Transportation needs improvement

Please list any areas that should be covered in future workshops

- Regulatory session
- CCS in Petroleum areas
- Details on CO_2 Transportation
- Gas processing facilities and problem of corrosion during transportation
- More details on capture for coal and gas power plants, and storage fundamentals
- Ho Chi Minh City, PVEP should be involved
- Workshop on CCS in energy
- Workshops on CCS in agriculture

What topics would you like more detail about?

- Legal and Regulatory issues
- Economics and Financing of CCS
- Details on CO_2 Capture Technology
- Transportation of CO_2
- Gas Facilities

Which sessions contained too much detail for you?

- Legal, Regulatory, and Permitting issues
- Capture and Transportation of CO_2

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

- I think that our country needs to develop CCS
- Use CO_2 for EOR
- How to use captured CO_2
- Power, Gas, Industrial, and Oil & Gas Facilities
- In the field of forest plantations

Please provide any other comments

- It is good for the workshop on CCS in my country and the need to hold more for Viet Nam on CCS in the field of agriculture and forest plantations
- More details about using captured CO_2 in future workshop
- CCS is very important with the issue of environment and important when applied in the production of oil and gas. Need to continue development to pilot projects.

Thank you for your time.

Workshop Feedback (Day 2)

Results from the feedback forms have been entered in the template used to solicit feedback from participants on Day 2. A total of 7 participants provided their feedback. However, not everyone provided feedback on all parts of the workshop.

Joint APEC-ADB Carbon Capture and Storage in Viet Nam Workshop

We would be grateful for your feedback on this workshop

Name _____ Organisation _____

I attended Day 2

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			
12 Welcome and Summary of Day 1		1	4
13 Role of CCS in Viet Nam		2	5
14 Capture opportunities and challenges in Viet Nam		2	5
15 Storage opportunities and challenges in Viet Nam		1	6
16 Productive use and storage of CO_2		3	4
17 Legal, Regulatory and Permitting Challenges to CCS in Viet Nam	1	2	4
18 Public awareness and community consultation issues in Developing Economies	1	3	3
19 Financing CCS in Viet Nam and Southeast Asia	1	1	5
20 Capacity Building Needs in Viet Nam		3	4
21 Panel Discussion – Towards CCS Projects in Viet Nam		4	3
22 Closing Comments		2	2

Comments

How could the sessions be improved?

- Have one day instead of two days for the workshop
- Presentations can be shorter and illustrative to attract more audience
- More participation from the industrial sector, if possible

Please list any areas that should be covered in future workshops

- Areas are quite excellent
- Ho Chi Minh City and PVEP should be involved.
- Have a working group
- Discussion on reaction of CO_2 with storage reservoir rocks.

What topics would you like more detail about?

- CCS Technology
- Funding for CCS
- Legal, Regulatory, and Financing
- Social issues and financing balance for CCS projects.

Which sessions contained too much detail for you?

- No
- Importance of CCS and Public Awareness
- Second part of Storage session
- Social issues and financing balance for CCS projects.

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

- Funding
- Technology
- Technical Background
- CO_2 removal in PM3-CAA, in the block 111, 112, 113, 117,118,119; combine with EOR in the Cun Loy basin

Please provide any other comments

- Some handouts in the book were not available (in particular 19 and 2nd part of 15). Otherwise, very interesting workshop.

Thank you for your time.

Appendix 6: Workshop Agenda – Viet Nam

Asia-Pacific Economic Cooperation

Ministry of Industry and Trade
Socialist Republic of Viet Nam

Asian Development Bank

Joint APEC/ADB Workshop
"Carbon Capture and Storage in Viet Nam"
13 - 14 December 2011 – Sofitel Plaza Hotel, Hanoi

13 December 2011 (Day 1)			
Session	**Time**	**Presentation**	**Speaker**

1	**8:30-8:50**	**Welcome and Opening Address**
		• Welcome attendees
		• Importance of this CCS workshop for Viet Nam
		  o Role of CCS in Viet Nam's emission mitigation options
		• Introduce key organisers
		  o APEC
		  o ADB
		  o ICF International
			Hoang Quoc Vuong
			Vice Minister for Energy
			Ministry of Industry and Trade
			
			Andrew Head
			Deputy Country Director
			ADB Resident Mission
			Viet Nam

2.1 **2.2** **2.3**	**8:50-9:30**	**Introduction to APEC's CCS Programme** **Introduction to the ADB CCS Technical Assistance -** Facilitating CCS deployment in Southeast Asia **Introduction to CCS and the APEC training modules**	***Frank Mourits*** Natural Resources Canada ***Pradeep Tharakan*** Asia Development Bank, Philippines ***Ananth Chikkatur*** ICF, U.S.
3	**9:30-10:00**	**Importance of CCS as a greenhouse gas mitigation option** • Importance of CCS for GHG mitigation globally– drawing on the International Energy Agency CCS Roadmap findings • Role of CCS in broader energy sector planning • Questions & Answers	***Justine Garrett*** IEA, France

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Asia-Pacific Economic Cooperation

Ministry of Industry and Trade
Socialist Republic of Viet Nam

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4	**10:00-10:45**	**Capture Technology Overview - Status and Challenges** • Technology Overview • Systems Integration and power station requirements • Capture-Ready considerations • Challenges in capture technology development • Questions and answers	***Stanley Santos*** IEAGHG, U.K.
5	**10:45-11:00**	**CO_2 Transportation** • Compression and Transportation	***Stanley Santos*** IEAGHG, U.K.
	11:00-11:15	**Morning Tea**	
6	**11:15-12:00**	**Storage Fundamentals** • Storage options • Fluid flow and trapping mechanisms • Site screening and selection • Measurement, monitoring and Verification (MMV) • Natural analogues • Question and answers	***Bill Gunter*** Consultant, Canada
7	**12:00-12:45**	**Economics and Financing of CCS** • The costs of CCS • Impact of CO_2 utilization • Financing of existing projects and CCS business models • Barriers to financing CCS in developing countries • Funding sources and structures • Questions & answers	***Christopher Short*** Global CCS Institute, Australia
	12:45-14:00	**Lunch – Ming Palace Restaurant (2nd Floor), Sofitel Plaza Hotel**	

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8	**14:00-14:45**	**Legal, Regulatory and Permitting issues** • Legal and Regulatory Challenges for CCS • IEA Model Regulatory Framework • Case studies of successful regulatory regimes • Questions & Answers	***Justine Garrett*** IEA, France
9	**14:45-15:30**	**Public awareness and community consultation** • Purpose of communicating and engaging on CCS • Current levels of CCS awareness and acceptance (Global and Southeast Asia) • Consequences of misperceptions • Introduction to the CCS toolkit – a best practice guide • Questions and answers	***Simone Carr-Cornish*** CSIRO, Australia
	15:30-15:45	**Afternoon Tea**	
10	**15:45-16:30**	**Status of CCS projects around the world** • Overview of Status of CCS Report by Global CCS Institute • Highlights of specific case studies • Question and Answers	***Christopher Short*** Global CCS Institute, Australia
11	**16:30-17:00**	**Alstom CO_2 Capture Development Status**	***Pham Dong Giang*** Sales Manager Global Power Sales Alstom Vietnam
	17:00	**Close of Day 1**	

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"Carbon Capture and Storage in Viet Nam"
13 - 14 December 2011 – Sofitel Plaza Hotel, Hanoi

14 December 2011 (Day 2)			
Session	**Time**	**Presentation**	**Speaker**
12	**8:30-9:00**	**Welcome and Summary of Day 1** • Welcome attendees • Summary of Day 1 • Highlight differences between Day 1 and Day 2 • Question and Answers	***Ananth Chikkatur*** ICF, U.S. ***Frank Mourits*** Natural Resources Canada ***Pradeep Tharakan*** Asian Development Bank, Philippines
13	**9:00-9:45**	**Role of CCS in Viet Nam** • Overview of the energy status in Viet Nam (supply, demand, GHG and CO2 emissions) • Energy and environmental polices (focused on GHG mitigation if any) • Status of power industry and other large emitters • Potential role of CCS in Viet Nam • Question and Answers	***Nguyen Anh Dung*** Expert of International Relation Department Institute of Energy, Viet Nam
14	**9:45-10:35**	**Capture opportunities and challenges in Viet Nam** • Summary of ADB report on capture in Viet Nam • Questions & Answers	***Doug Macdonald*** Consultant, Canada ***Stanley Santos*** (discussant) IEAGHG, U.K.
	10:35-10:50	**Morning Tea**	
15	**10:50-11:30**	**Storage opportunities and challenges in Viet Nam** • Summary of ADB report on Storage in Viet Nam • Source-Sink Matching • Questions and answers	***Bill Gunter*** Consultant, Canada

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16	**11:30-12:00**	**Productive use and storage of CO2** • CO_2-EOR / ECBM Opportunities in Viet Nam • Question and answers	***Bill Gunter*** Consultant, Canada
17	**12:00-12:50**	**Legal, Regulatory and Permitting Challenges to CCS in Viet Nam** • Summary of Southeast Asia legal and regulatory framework • Summary of ADB report on legal and policy issues in Viet Nam • Roadmap for Viet Nam for developing CCS • Questions & answers	***Craig Hart*** Consultant, U.S. ***Justine Garrett*** (Discussant) IEA, France
	12:50-14:30	**Lunch – Le Panorama (19th Floor), Sofitel Hotel**	
18	**14:30-15:15**	**Public awareness and community consultation issues in Developing Countries** • Case studies informing the CCS toolkit • Prospective challenges in applying the toolkit in developing countries • Kinds of research and collaboration required for developing a CCS toolkit for developing countries • Roadmap for Viet Nam (based on ADB report) • Questions & Answers	***Simone Carr-Cornish*** CSIRO, Australia
19	**15:15-16:00**	**Financing CCS in Viet Nam and Southeast Asia** • Financing options for CCS in Viet Nam • Relevance of CDM • ADB's CCS Fund • Potential projects in Southeast Asia • Project proposal process • Questions & Answers	***Pradeep Tharakan*** Asian Development Bank, Philippines
	16:00-16:15	**Afternoon Tea**	

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20	**16:15-16:40**	**Capacity Building Needs in Viet Nam** • Importance of Capacity Building in Southeast Asia and Viet Nam • Capacity Building options available	***Simplicio P. Caluyong*** CCOP Thailand
21	**16:15-17:00**	**Panel Discussion – Towards CCS Projects in Viet Nam** • Summary of the ADB Roadmap for Viet Nam • Panel Discussion • Questions and Answers	***Pradeep Tharakan*** ***Doug Macdonald*** ***Bill Gunter*** ***Craig Hart*** ***MOIT***
22	**17:00-17:15**	**Closing Comments**	***Pradeep Tharakan***, ADB ***Frank Mourits***, APEC
	17:15	**Close of Day 2**	

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Biography for Expert Speakers
Joint APEC-ADB Workshop on Carbon Capture and Storage in Vietnam
December 13-14, Ha Noi, Viet Nam

Frank Mourits
Natural Resources Canada
Dr. Frank Mourits is a Senior Science &Technology Advisor with the Office of Energy R&D at Natural Resources Canada. This is the office that coordinates and funds all federal research, development and demonstration in Canada, including CCS. Frank's main domestic roles include being the federal coordinator for the Weyburn-Midale CO2 monitoring and storage program and managing the preparation of the North American Carbon Storage Atlas, together with the US and Mexico. Internationally, Frank is the Deputy Chair of the APEC Expert Group on Clean Fossil Energy. He initiated APEC's CCS program in 2004 and has since been overseeing various CCS projects, including this series of capacity building workshops.

Frank has a Master's degree in Chemistry from the University of Amsterdam and a Ph.D. in Chemistry from the University of Regina in Canada.

Pradeep Tharakan
Asian Development Bank
Pradeep Tharakan is a Climate Change Specialist with the South East Asia Energy Division of the Asian Development Bank (ADB). He is responsible for designing and implementing technical assistance activities (TA) and loan programs on geothermal energy deployment, off-grid renewables and carbon capture and storage in several S.E. Asian countries. Prior to this, Pradeep served as the Deputy Team Leader for the United States Agency for International Development's ECO-Asia Clean Development and Climate Program, where he was responsible for clean energy deployment and greenhouse gas (GHG) reductions activities in six Asian countries.

Doug Macdonald
ADB Consultant
Mr. Doug Macdonald, P. Eng., has 40 plus years of experience in the petroleum industry that spans almost every aspect of the business, from exploration plays to the gasoline pump.
Doug's wide experience, providing a valuable view of how technology fits into economic reality, has resulted in many major assignments both within and outside the petroleum industry, in the area of technical due diligence and evaluation of emerging processes. Since 1999 a large part of Doug's work has involved key roles in various aspects of Carbon Dioxide Capture and Storage (CCS) technology. He has managed or been an active participant in studies in Canada, Europe, Brazil, China, SE Asia and the Middle East.

Doug holds a B.A.Sc. (Toronto) and a M.Sc. (Wales) in Chemical Engineering. He has worked on both the client and consulting sides of the business, most recently with SNC-Lavalin inc, one of the world's largest engineering firms. Mr. Macdonald retired in March 2006 and continues to provide services to SNC-Lavalin and other clients on a contract basis. He is resident in Calgary, Canada.

William (Bill) Gunter.
ADB Consultant
Dr. William D. Gunter received his BSc and MSc degrees in geology from the University of New Brunswick, Canada and his PhD in geochemistry from the Johns Hopkins University, USA. He currently is a Professional Geologist practicing in Alberta, an international consultant on Carbon

Dioxide Capture and Geological Storage (CCS) and the Principal Consultant for the Alberta Innovates Technology Futures on CO2 Geological Storage. His expertise is in geochemical processes (stressing use of field data, experiments and modelling) as they impact on the environment, and on the oil and gas industry. He has authored more than 70 publications are available in the public domain on geological storage of CO2, a major contributor to greenhouse gas (GHG) emissions. He co-chaired the Federal Canadian Capture and Geological Storage Roadmapping consultations which led to two reports, *CANiSTORE (2004)* and *CANiCAP (2005)*. He also was a Lead Author on the IPCC (Intergovernmental Panel on Climate Change) special report on CO2 Capture and Storage. During 2007, he was a member of the Canadian Federal-Provincial ecoENERGY task force's Technology working group and in 2008 served as a member of the Alberta Government's "Capture and Geological Storage of GHG Emissions" working group and the "Provincial Energy Strategy Advisory" committee.

Dr. Stanley Santos
IEAGHG
Stanley Santos holds a Ph.D. in Mechanical Engineering from Portsmouth University (United Kingdom) and M.Sc./B.Sc. in Chemical Engineering from De La Salle University (Philippines). He is originally from Manila, Philippines; and currently working for the IEA Greenhouse Gas R&D Programme based in UK. He is globally recognised as one of the leading experts in the field of CO_2 Capture Technologies (particularly in Oxyfuel Combustion Technology – one of the leading CO_2 capture options considered by power generation industry worldwide as mitigation option for greenhouse gas emissions).

Dr. Santos is a Techno-Economist and Combustion Engineer. His expertise broadly covers the power generation, oil refining, iron and steel, and cement industrial sectors. He is also known for his work on biomass conversion especially applied to power generation industry and has contributed to the discussion regarding "Bio-CCS" and "Negative" emissions within the European Union.

As the leading expert of oxyfuel combustion technology – he has various involvements in all the leading international projects worldwide - this includes projects in Australia (Callide), Germany (Schwarze Pumpe and Janschwalde), Spain (CIUDEN) and USA (FutureGen2). He is a Guest Managing Editor of International Journal of Greenhouse Gas Control (IJGCC) and he has led and produced the Special Edition of IJGCC on "Oxyfuel Combustion Technology – Working toward Demonstration and Commercialisation".

Christopher Short
Global Carbon Capture and Storage Institute
Chris Short, as Chief Economist, Global Carbon Capture and Storage Institute, is responsible for advice on economic and policy issues relating to accelerating the development of CCS as a mitigation response to climate change. He joined the Institute at its establishment in July 2009 and has been instrumental in shaping the work and activities of the organisation.

Chris has worked in Government across an extensive range of issues. Over the past 15 years, he has led a range of work on diverse topics including commodity markets and international trade, globalisation and market access, energy market reform and energy security, and drivers of domestic industry growth. He has represented Australian interests in a wide range of fora at both the international and national levels.

Previously, as General Manager, Energy Policy Branch in the Australian Government Department of Resources and Energy, he was responsible for economic advice and policy formulation in relation to Australia's domestic energy sectors. His role encompassed strategic energy policy development,

energy efficiency policy together with development and program support for renewable energy technologies.

Justine Garrett
International Energy Agency
Justine Garrett is a legal analyst in the Carbon Capture and Storage Unit of the International Energy Agency, Paris, where she advises on the legal aspects of carbon capture and storage. Justine manages the IEA's International CCS Regulatory Network, is lead author of the IEA's Carbon Capture and Storage Legal and Regulatory Review and assisted in drafting the IEA Carbon Capture and Storage Model Regulatory Framework. Prior to joining the IEA in February 2010, Justine worked as a commercial lawyer at Minter Ellison Lawyers in Canberra, Australia. She holds a Master of Laws from the Sorbonne in Paris and a Bachelor of Laws/ Bachelor of Arts from the Australian National University.

Craig Hart
ADB Consultant
Craig Hart is a practicing attorney and faculty at Johns Hopkins University's Energy Policy and Climate program. He has over 15 years experience practicing law in the fields of project finance, carbon finance and capital markets. He has represented project developers in the United States geologic sequestration demonstration projects, in China on IGCC power projects, and has advised industry groups and international organizations on CCS policy and regulation in the United States and Asia. He is currently conducting separate studies of CCS regulation for APEC and the Asian Development Bank covering 9 developing countries. He holds a Ph.D. from the Massachusetts Institute of Technology and a J.D. from the University of California at Berkeley.

Ananth Chikkatur
ICF International
Dr. Ananth Chikkatur is with the consulting firm ICF International, working in the energy and environmental sectors. Dr. Chikkatur has a Ph.D. in Physics from Massachusetts Institute of Technology (MIT) and B.S. in Physics from University of Rochester. After completing his doctorate in 2002, Dr. Chikkatur spent a year in India to learn first-hand about energy and development issues. In 2004, Dr. Chikkatur joined Harvard Kennedy's School's Energy Technology Innovation Policy (ETIP) project as a post-doctoral Research Fellow, and joined ICF in December 2008. At ETIP, Dr. Chikkatur's research focused on devising better policies for advancing cleaner coal-power technologies in India, in addition to broader energy policies in India, including promoting energy efficiency and reducing greenhouse gas emissions. At ICF, Dr. Chikkatur works on power sector and carbon capture and storage (CCS) projects, including projects for the U.S. EPA and the European Commission. His interests include technology innovation, cleaner coal-power technologies, energy efficiency, small-scale/rural energy systems, and the politics of, and responses to, climate change.

Simone Carr-Cornish
CSIRO
Simone Carr-Cornish has a degree in Business Management (Honours) from the University of Queensland and joined CSIRO's Science into Society group in 2006. Since joining CSIRO Simone has been involved extensively in researching and engaging with the community about existing and emerging low emission energy technologies, including carbon capture and storage. Activities that Simone has been involved in, include:

- Surveys of the Australian populations preferences for low emission energy technologies
- Facilitated workshops with communities about climate change mitigation and energy technologies such as carbon capture and storage

- Partnerships with energy distributors to explore the adoption of distributed energy technologies
- Prize for best article in the Australasian Journal of Environmental Management, 2007–08: 'Exploring the acceptance of a domestic distributed energy market in Australia'.
- Co-author of presentations for the Greenhouse Gas Control Technologies (GHGT) conference series
- Speaker on CCS Awareness at the meeting of the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP), 16-17 November 2009, Bangkok, Thailand.

Currently Simone is managing the engagement aspect of CSIRO's ARRC/Pawsey Geothermal Demonstration, Australia's largest planned demonstration of Geothermal energy.

Nguyen Anh Dung
Institute of Energy

Nguyen Anh Dung received the bachelor degree in Hanoi University of Technology in 2003 and master degree in Asian Institute of Technology in 2009. At the present, he is the expert of International Relation Department - Institute of Energy.

He worked as power distribution management in Hanoi Power Company in 2003 and researcher and expert in Institute of Energy from 2004. The main activities in Institute are implementation the research and project on power system operation and planning, power market development, renewable energy and energy efficiency and conservation.

Appendix 7: Workshop Agenda – Mexico

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APEC-CFE PROGRAMA DEL TALLER INTRODUCTORIO DE ALMACENAMIENTO GEOLÓGICO DE CO_2 EN PROGRAMAS DE ESTUDIO DE CIENCIAS DE LA TIERRA

27-28 June 2012

MUTEC (Museo Tecnológico de CFE)

Ciudad de México, D.F., México

Día 1 27 June 2012	Introducción al Almacenamiento Geológico de CO_2 (CCS)
8:45 - 9:30	Comentarios de apertura Gustavo Arvizu Lara *(CFE, México)*
	APEC Programa de Desarrollo de Capacidad en CCS en Recursos Humanos Ananth Chikkatur *(ICF, U.S.)*
9:30 - 10:15	Emisiones de CO_2 y Cambio Climático Amparo Martínez Arroyo *(UNAM, México)*
10:15 - 11:15	Rol y estado de CCS en Mitigación de Emisiones de CO_2 Steve Whittaker *(Global CCS Institute, Australia)*
11:15 - 11:35	Break
11:35 - 12:20	Fundamentos del Almacenamiento Geológico Stefan Bachu *(Alberta Innovates-Technology Futures, Canada)*
12:20 - 13:40	Selección y Caracterización de Sitios Stefan Bachu *(Alberta Innovates-Technology Futures, Canada)*
13:40 - 15:10	Comida
15:10 - 16:30	Estimación de Capacidad de Almacenamiento Stefan Bachu *(Alberta Innovates-Technology Futures, Canada)*
16:30 - 16:50	Break

Sociedad Geológica Mexicana A.C. 1904

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Día 1 (Continuación)	Introducción al Almacenamiento Geológico de CO_2 (CCS)
16:50 - 17:40	Geofísica y Geomecánica de Sitios de Almacenamiento (El ponente será anunciado)
17:40 - 18:30	Geoquímica de Sitios de Almacenamiento Neil Wildgust *(Petroleum Technology Research Centre, Canada)*
18:30 - 18:40	Resumen del Día 1 Moisés Dávila *(FECIT, México)*

Día 2 28 June 2012	Introducción al Almacenamiento Geológico de CO_2 (CCS)
09:00 - 10:00	Medición, Monitoreo y Verificación (MMV) Steve Whittaker *(Global CCS Institute, Australia)*
10:00 - 11:00	Análisis de Riesgo en CCS Neil Wildgust *(Petroleum Technology Research Centre, Canada)*
11:00 - 11:20	Break
11:20 - 12:20	CO_2 – Recuperación de Yacimientos Exhaustos de Petróleo (EOR) Wesley Peck *(Energy & Environmental Research Center, U.S.)*

Día 2 (Continuación)	CCS en México
12:20 - 13:20	**Introducción a CCS en México** **José Miguel González Santaló *(CSLF, México)***
13:20 - 14:50	Comida
14:50 - 16:20	**Perspectivas de CCS en México** **Vicente Arevalo *(CFE, México)*** **Moisés Dávila *(FECIT, México)***
16:20 - 17:05	**Proyecto demostrativo de CO_2-EOR en México** **Rodolfo Lacy *(Mario Molina Center, México)***
17:05 - 17:15	**Resumen del Taller y Comentarios Finales** **Moisés Dávila*(FECIT, México)***
Día 2 (Continuación)	**Mesa redonda de acuerdos para introducir el tema de CCS en el sistema educacional de México (Sólo Por Invitación)**
17:30 - 17:40	**Introducción a las Iniciativas Educacionales de México en CCS** **Moisés Dávila *(FECIT, Mexico)***
17:40 - 18:00	**Convenio del Global CCS Institute's en México** **Alice Gibson *(Global CCS Institute, Australia)***
18:00 - 18:30	**Acuerdos para introducir el tema de CCS en el sistema educacional de México**

Asia-Pacific Economic Cooperation

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APEC-CFE WORKSHOP FOR INTRODUCING CO_2 GEOLOGICAL STORAGE IN EARTH SCIENCES UNDERGRADUATE PROGRAMS

27-28 June 2012
MUTEC (Museo Tecnológico de CFE)
Mexico City, D.F., Mexico

Day 1 27 June 2012	Introduction to CO_2 Geological Storage
8:45 - 9:30	**Opening Remarks** Gustavo Arvizu Lara *(CFE, Mexico)*
	APEC CCS Capacity Building Program Ananth Chikkatur *(ICF, U.S.)*
9:30 - 10:15	**CO_2 Emissions and Climate Change** Amparo Martinez Arroyo *(UNAM, Mexico)*
10:15 - 11:15	**Role and Status of CCS in Mitigating CO_2 Emissions** Steve Whittaker *(Global CCS Institute, Australia)*
11:15 - 11:35	Break
11:35 - 12:20	**Fundamentals of Geological Storage** Stefan Bachu *(Alberta Innovates-Technology Futures, Canada)*
12:20 - 13:40	**Screening and Site Selection** Stefan Bachu *(Alberta Innovates-Technology Futures, Canada)*
13:40 - 15:10	Lunch
15:10 - 16:30	**Storage Capacity Assessment** Stefan Bachu *(Alberta Innovates-Technology Futures, Canada)*
16:30 - 16:50	Break

Day 1 (Continued)	Introduction to CO_2 Geological Storage
16:50 - 17:40	Geophysics and Geomechanics of Storage Sites Speaker to be announced
17:40 - 18:30	Geochemistry of Storage Sites Neil Wildgust *(Petroleum Technology Research Centre, Canada)*
18:30 - 18:40	Wrap-up of Day 1 Moises Davila *(FECIT, Mexico)*

Day 2 28 June 2012	Introduction to CO_2 Geological Storage (Continued)
09:00 - 10:00	Measurement, Monitoring and Verification (MMV) Steve Whittaker *(Global CCS Institute, Australia)*
10:00 - 11:00	CCS Risk Analysis Neil Wildgust *(Petroleum Technology Research Centre, Canada)*
11:00 - 11:20	Break
11:20 - 12:20	CO_2 – Enhanced Oil Recovery Wes Peck *(Energy & Environmental Research Center, U.S.)*

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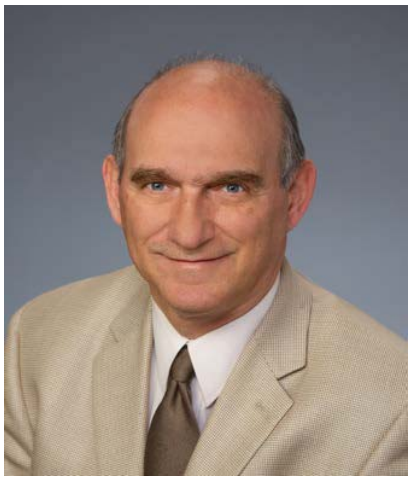
Day 2 (Continued)	CO_2 Geological Storage in Mexico
12:20 - 13:20	Introduction to CCS in Mexico Jose Miguel Gonzalez Santalo *(CSLF, Mexico)*
13:20 - 14:50	Lunch
14:50 - 16:20	Mexican perspectives on CCS Vicente Arevalo *(CFE, Mexico)* MoisesDavila *(FECIT, Mexico)*
16:20 - 17:05	Mexican CO_2-EOR Demonstration Project Rodolfo Lacy *(Mario Molina Center, Mexico)*
17:05 - 17:15	Workshop Wrap-up and Closing Comments Moises Davila *(FECIT, Mexico)*
Day 2 (Continued)	**Roundtable Discussion on Agreement to Introduce CCS in Mexican Educational System (by invitation only)**
17:30 - 17:40	Introduction to Mexico's CCS Educational Initiatives Moises Davila *(FECIT, Mexico)*
17:40 - 18:00	Global CCS Institute's Engagement in Mexico Alice Gibson *(Global CCS Institute, Australia)*
18:00 - 18:30	Agreement on Introducing CCS in Mexican Education System

SPEAKER BIOGRAPHIES

Vicente Arevalo
Federal Electricity Comission, Mexico
Civil engineer from Facultad de Ingeniería of the Universidad Nacional Autónoma de México. He has developed his professional career in Federal Electricity Commission (CFE) where he has guiding different construction projects. He was responsible of Supervision of Work and Treatment of Rock Department and he has had the position of Superintendent of Studies in Veracruz State.
At the moment he is responsible of the Energy and Sustainable Infrastructure Department where are developing different projects as: Renewable energies inventory, Carbon Capture and Storage Atlas and utilization of biogas in generation of electric power.

Amparo Martinez Arroyo
Center for Atmospheric Sciences, UNAM, Mexico
She graduated as Biologist and obtained her Master´s Degree from the Faculty of Sciences in the National Autonomous University of Mexico. She obtained a Ph.D. in Ecology from the Faculty of Biology in the University of Barcelona and accomplished a research stay in the Institute of Marine Sciences in Barcelona. She is a researcher at the Atmospheric Sciences Center (CCA), and Coordinator of the Atmospheric Aerosol Group. From December 2009 was elected the Director of the CCA.
She has been a pioneer in the study of atmosphere-biosphere interactions in aquatic systems considering processes of photosynthesis, such as biogenic emission and biogeniccapture of other climatically active gases in continental, urban, coastal and marine ecosystems.
She is an expert in analyzing environmental problems; her research includes topics such as variability and climate change. She has done an extensive outreach in spreading the scientific work in the UNAM, and has helped to establish strong relationships between science and society.



Stefan Bachu
Alberta Innovates-Technology Futures

Stefan is a Distinguished Scientist at Alberta Innovates – Technology Futures in Alberta, Canada. For the last two decades Stefan has focused his research on the potential for, and risks of CO2 storage in geological media as a mitigation strategy for reducing greenhouse gas emissions into the atmosphere. Stefan contributed as a Lead Author to the IPCC Special Report on CO2 Capture and Storage, in which capacity he is co-sharing in the 2007 Nobel Peace Prize awarded to IPCC. Stefan represented the Alberta Energy Resources Conservation Board on the Interstate Oil and Gas Compact Commission Task Force on CO2 Storage. In 2007, Stefan served on the Technical Working Group of the Canada-Alberta EcoEnergy Task Force on Carbon Capture and Storage. Since 2004 Stefan represents Canada on the Technical Group of the Carbon Sequestration Leadership Forum (CSLF), where he chaired the CSLF Task Force on CO2 Storage Capacity Estimation. Currently, Stefan co-chairs the Expert Panel that advises the Government of Alberta on Regulatory Framework Assessment for CO2 Capture and Storage.

Stefan is Associate Editor of the International Journal of Greenhouse Gas Control. He has published more than 175 papers in journals and conference proceedings, made more than 300 presentations and wrote more than 101 professional reports, of which more than half are on the subject of CO2 sequestration in geological media as a climate-change mitigation strategy.

Ananth Chikkatur
ICF International

Dr. Ananth Chikkatur is with the consulting firm ICF International, working in the energy and environmental sectors. Dr. Chikkatur has a Ph.D. in Physics from Massachusetts Institute of Technology (MIT) and B.S. in Physics from University of Rochester. At ICF, Dr. Chikkatur has worked on several projects in the power sector, with the focus on Carbon Capture and Storage (CCS). On CCS, Dr. Chikkatur has worked on and managed several projects with the European Commission to develop CCS-related guidance documents and related reports. He has also supported the U.S. Environmental Protection Agency on regulatory and public acceptance issues for CO2 geological storage. Dr. Chikkatur co-managed for the Global CCS Institute a project on defining an international recognized CCS Ready infrastructure and helped organize several stakeholder workshops across the globe. Dr. Chikkatur's interests are quite broad, and he has worked on projects related to natural gas demand, regulatory and

policy analysis in India and Mozambique, assessment several coal-fired power projects for the World Bank, and evaluation of U.S. smart grid ecosystem for U.S. Department of Energy.

Before joining ICF in 2008, Dr. Chikkatur worked on energy technology innovation policy issues at Harvard's Kennedy School of Government where his research focused on the relevance of advanced coal-power technologies, including CCS, as well as aspects related to coal mining in India. He worked collaboratively with senior policy-makers in India, and facilitated dialogue among various stakeholders. He worked on issues related to energy efficiency, reducing greenhouse gas emissions, and climate change architecture.

Moises Davila

Pro Earth Sciences Fundation (FECIT), México

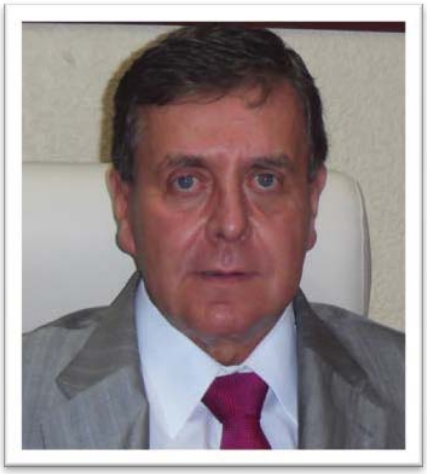
He graduated in Geological Engineering from the Autonomous University of San Luis Potosi, Mexico in 1980; he earned a Master´s degree in Engineering in 2001 and a PhD in Science from the National Polytechnic Institute in 2011. For over 32 years he has developed projects in different aspects of geology applied to the Federal Electricity Commission (CFE) and other national and international entities, from exploration of sites up to the operation. In this company he has had the position of Superintendent of Studies from 1986 to 2004, Manager of Galleries Excavation from 1991 to 1992, Manager of the Treatment and Supervision from 1998 to 2004, and since 2004 is currently a Submanager for Geological Survey. He has written several monographs and articles that have been published in indexed journals on Geological topics. He has been awarded the Adolfo LópezMateos Medal of Merit from CFE and earned Honorable Mentions for his studies in Masters and PhD, and graduated with Academic Merit from the Autonomous University of San Luis Potosi, Mexico. He is currently Vice President of the Mexican Geological Society and Founding Partner and Secretary of the Earth Pro Science Foundation.

Alice Gibson
Global CCS Institute
Alice is the Capacity Development Manager for the Global CCS Institute.

In this role she is responsible for managing the Institute's capacity development program and strategic relationships with other key capacity development providers, to achieve the objective of facilitating the deployment of CCS projects globally.

Before she came to the Global CCS Institute, Alice worked for the Australian Government Department of Resources, Energy and Tourism. She held a number of roles within the Department, including as Manager of the Mine Safety Section. In this role she managed international mine safety capacity development projects, as well as coordinated an initiative to achieve national consistency in the occupational health and safety regime in Australia's mining industry.

Rodolfo Lacy
Mario Molina Center
He graduated in Environmental Engineering from the Autonomous Metropolitan University and had a scholarship from the Rockefeller Foundation in the Environmental and Sustainable Development Leadership Program. He obtained a Masters Degree in Environmental Planning from the Massachusetts Institute of Technology. He coordinated and edited the first report on Environmental Condition in Mexico and is author of the book "Air Quality in the Mexican Valley." He was the Founding President of the College of Environmental Engineers of Mexico, General Director of the Environmental Pollution Control and Prevention Agency of the Federal Government of Mexico, D.F. and Coordinator of Advisors in the Secretary of Environment and Natural Resources. He is currently the Coordinator of Mario Molina Center for Strategic Studies on Energy and Environment.



Gustavo Arvizu Lara
Federal Electricity Commission (CFE), México
Current leader of the Gerencia de Estudios de Ingenieria Civil from CFE, which is the government area that provides studies and solutions related to infrastructure development, applying their over 30 years of acquired civil and earth sciences knowledge and expertise.

Geologist engineer and master on Business Administration, he has represented for over 25 years the earth sciences guild as the former president of the Geological Society of Mexico and current General Secretary of the Mexican Engineering Academy and the Engineers´ Association Mexican Union. He has also being member of several professional associations such as: Geological Society of America, Geotechnical Society of Mexico and the Geological Association of Mines of Mexico.

Committed to new generations of engineers, he endowed the Pro Earth Sciences Foundation which has granted more than 60 low income´s students providing them not only financial resources but also the necessary books to complete their professional education.
He has given a large number of talks in congresses as well as conferences in Mexico and overseas. He has performed academic activities at the University of Veracruz and at the National Institute of Public Management.

He has obtained several acknowledgments such as: Honourable mention at the engineering faculty at UNAM, the Best paper presented at the II Institutional Total Quality Meeting at CFE, Honourable mention and excellence diploma at the master degree as well as the Adolfo Lopez Mateos medal given by the CFE.

He also obtained a special acknowledge for its contribution on what was called “the year´s best engineering project in Mexico” and Edison Awarded project related to the Rio Grijalva´s sliding given by the UMAI and the Edison Institute respectively.

Modesto Montoto
University of Oviedo

Petrology Professor at Seville University (1971-72) and up to 2009 at Oviedo University, where currently is Honorary Professor. At this University he has been Director of the Petrology Department (1972-87), Sciences Department Dean (1975-76) and Vice-rector of "Planning and Development" (1988-89).

From 1970 to his retirement, his main field of research has been Petrophysics (research on rocks physic properties and their corresponding petrographic interpretation), leading a working team with wide national and international relationships and two main lines of research: a) Geological storage of high level radioactive wastes: research on rock microfractography, water pathways and radionuclides migration, as well as the characterization of sealing rocks using non-destructive techniques (radar and seismic tomography); b) Petrophysic characterization of Cultural Heritage Monuments stones, using non-destructive techniques.

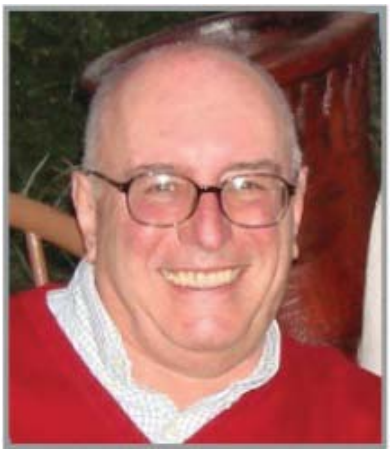
Since May 2007 he is Director of the CO2 Geological Storage Programme of "Fundación Ciudad de la Energía" (CIUDEN), depending on the three Ministries of Industry, Tourism and Commerce; Innovation and Development and Environment. He is member of several Associations and national and international Committees regarding this field.

Wes Peck
Energy & Environmental Research Center, U.S.

Wesley D. Peck is a Research Manager at the EERC, where he currently oversees a staff of geologists and GIS specialists involved in oil and gas research in the Williston Basin and the geologic characterization of central North America with respect to carbon dioxide sequestration. He received his M.S. degree in Geology from UND and his B.S. degree in Earth Science from North Dakota State University.

Mr. Peck's principal areas of interest and expertise include GIS, cartography, information graphics, geology, and digital asset management. Prior to his current position, Mr. Peck served as a research scientist at the EERC, and a graduate research assistant and a graduate teaching assistant in the Department of Geology and Geological Engineering at UND.

Mr. Peck has authored and co-authored several professional publications.



José Miguel Gonzalez Santalo
Mexico's representative to the CSLF

José Miguel Gonzalez Santalo obtained his degree in Mechanical Electric Engineering, graduating with honours in 1968 from the UNAM (Universidad NacionalAutonoma de Mexico), in Mexico City.

In 1969 he obtained a Masters Degree from the Massachusetts Institute of Technology in Boston, Massachusetts, USA, and continued on at the same university to achieve a PhD in the year 1971.

Since 1997 he has led the Mechanical System Division as its Director, at the IIE, Instituto de Investigaciones Electricas, (Electrical Research Institute) in Cuernavaca, Mexico.

Dr. Gonzalez Santalo is a Level III National Researcher, and while heading his Division at the IIE, he works in parallel with other initiatives related to his field. He has a strong conviction that CO_2 Capture and Storage is a needed technology to mitigate climate change and it is of outmost importance for humankind. So he act as Mexico's representative to the Carbon Sequestration Leadership Forum (CSLF)

Steve Whittaker
Global CCS Institute

Steve Whittaker is the Principal Manager for Carbon Storage and joined the Global CCS Institute in August 2011. He is responsible for geologic storage-related activities including project evaluation, and providing advice on characterisation and Monitoring Measurement and Verification (MMV).

Prior to the Institute, Steve was Senior Project Manager at the Petroleum Technology Research Centre in Regina, Canada. In that role he oversaw the management of all research programs, including the IEAGHG Weyburn-Midale CO2 Monitoring and Storage Project, JIVE, Aquistore, and the EOR Program. He has also worked as a petroleum exploration geologist, as an independent consultant, and as a Senior Research Petroleum Geologist for the Geological Survey of Saskatchewan. Steve was also a researcher at the universities of Saskatchewan, Queen's, and McGill in Canada.

Steve is a registered professional geologist, and holds a PhD in Geology.

Neil Wildgust
Petroleum Technology Research Centre, Canada

Neil Wildgust is Chief Project Officer for the Petroleum Technology Research Centre, Regina, and is responsible for managing the Aquistore and IEAGHG Weyburn-Midale research projects. Previously he worked for the IEA Greenhouse Gas R&D Programme, based in the UK, as Project Manager for Geological Storage and was responsible for coordinating international storage research networks and commissioning studies. He holds an MSc in Applied Environmental Geology from Cardiff University and a BSc in Geology from Southampton University, is a chartered geologist and has 25 years of industrial experience in mining, land contamination and hydrogeology.

Appendix 8: Participants in the Invitation-only Roundtable Discussion – Mexico

NUM	Nombre	Institución	E-mail
1	Frank Mourits	APEC	fmourits@nrcan.gc.ca
2	Alice Gibson	GCCSI, Australia	Alice.Gibson@globalccsinstitute.com
3	Ananth Chikkatur	ICF International	AChikkatur@icfi.com
4	JOSÉ ABRAHAM TORRES MÉNDEZ	BENEMÉRITA UNIVERSIDAD AUTÓNOMA DE PUEBLA	ing_abrahamtorres@hotmail.com
5	RAFAEL ACOSTA QUEVEDO	CFE	racosta_37@hotmail.com
6	VICENTE ARÉVALO MENDOZA	CFE	vicente.arevalo@cfe.gob.mx
7	OSCAR JIMÉNEZ SALAS	CFE	oscar.jimenez@cfe.gob.mx
8	José Miguel González Santaló	CSLF -IIE	gsantalo@iie.org.mx, rgalan@iie.org.mx
9	ALBERTO ARIAS PAZ	FACULTAD DE INGENIERÍA UNAM	ariaspaz@unam.mx
10	Héctor Ricardo Castrejón Pineda	Facultad de Ingeniería, UNAM	rcastr@unam.mx
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17	Evodio Pedro Castañeda Ovando	Universdad Autonoma del Estado de Hidalgo	castanedaovando@yahoo.com.mx
18	ANGÉLICA OVIEDO GARCÍA	UNIVERSIDAD AUTÓNOMA DE CHIHUAHUA	aoviedo@uach.mx
19	MARÍA ISABEL VÁZQUEZ GONZÁLEZ	UNIVERSIDAD AUTÓNOMA DE CHIHUAHUA	mvazquez@uach.mx
20	Alejandro Hermelindo Ramirez Guzman	Universidad Autónoma de Guerrero	halessandro2@hotmail.com
21	Guillermo Javier Castro Larragoitia	Universidad Autónoma de San Luis Potosí	gcastro@uaslp.mx
22	Javier Muñoz Quintana	Universidad Autónoma de San Luis Potosí	jmunoz@uaslp.mx

Appendix 9: Participants Feedback – Mexico Workshop

Suggestions to Improve the Workshop (Numbers in Parenthesis indicates number of similar comments)
To send materials before the workshop to the translator to avoid errors in technical terms (24)
To Include in the program, longer time for questions (18)
To divide the topic by application areas, and explain how it will interact the professions in the future (8)
The information is very detailed, perhaps in some presentations there were many definitions that could be omitted (7)
To expand the workshop to more days, and consider the participation of students in the workshop (6)
To use more artwork in presentations to expose more clearly the concepts, e.g., videos, photos, animations. It would improve fluency and comprehension of the presentations (6)
To include speakers in the economic, legal and political area to impulse investment from the government in CCS (4)
To start the workshop presenting the state of the art in CCS (3)
The presentations could be improved by considering in every presentation; an introduction, followed by generalities and end up with examples or details (3)
To involve other professions related to the subject, since it is an alternative that should include various disciplines such as chemistry, physics and even consultants to conduct environmental impact studies and risk (3)
To invite other national and international organizations that have conducted studies or projects on CCS (2)
To submit a previous guide to the audience for an easy comprehension of the presentations (2 or 3 days before), and in order to clarify more doubts during the questions session (2)
To provide to students those files mentioned in the papers, such as: Mexican Atlas of CO_2 and others that may be a good reference to learn more about CCS (2)
To organize round tables at the end of each day with students, professors, and others to share concerns and knowledge about the subject, and enrich the workshop by inviting politician to the workshop (2)
To conduct workshops where students can give a diagnose about the geological feasibility of hypothetical study cases (1)
To make widely spread the information about the workshop (1)

Topics to be covered in Future Workshops (Number in parenthesis indicates number of similar comments)
Methods of CO_2 sequestration (21)
Geomechanics, geotectonic and geothermal (14)
Impact in the environment by the leakage of CO_2 and remediation (14)
Software used in the area of geophysics for site selection and injection of CO_2, as well as for methods (14)
The comprehensive analysis of a specific project, illustrating the type of conflicts which it has faced in the development of these technology (11)
The geochemistry of CO_2 with other minerals (8)
Results of geological explorations, not many statistics (7)
Possible environmental, economic and social standards (6)
Environmental impact to the neighboring ecosystems CO_2 reservoirs (6)
Territorial survey, legal and information technologies (6)
A topic that explain the role that universities and students play in this process (5)
Criteria for identifying sites for CCS and examples of results obtained in the short, medium and long term (5)
Injection methods and data processing (5)
Digital image processing, geographic information systems, and drilling and modeling (5)
To talk about the profitability, if there is a monetary earning in the CCS technology (5)

Topics to be covered in More Detail in Future Workshops (Number in parenthesis indicates number of similar comments)
Criteria for selection and characterization of sites for CO_2 storage (25)
Enhanced Oil Recovery (17)
CO_2 capture methods, show technologies require to capture and injecting CO_2 (14)
Risk Analysis of EOR (12)
Geochemistry (11)
Type of studies perform for monitoring CO_2 storage (11)
To expose more detail the method "geophysical" in the process of CCS (11)
Geological limitations that come up at storing CO_2 (7)
CO_2 behavior once in the reservoir (7)
Subject of international political agreements, make more emphasis on the issues of legality in Mexico, probably arrange a round table (7)
Rock-fluid-time interaction (6)
Geomechanics (6)
Techniques for convincing the population in other countries (6)
To talk more about geothermal exploration and geohydrological exploration (5)
Benefits at geological scale for the development of CCS at a national and a global level (4)
To present a range of to show the benefits and major problems they have faced (4)
Cost-effectiveness of CCS in Mexico (4)
To talk about the miscibility of CO_2 in a more detailed way (1)

Topics that were too Detailed (Number in parenthesis indicates number of similar comments)
The numbers relating to global CO_2 emission (33)
The basic concepts were repeated constantly (30)
Everyone gave their point of view about what the CCS is, which seemed redundant (16)
Estimation storage capacity (9)

What is needed to improve CCS knowledge in Mexico? (Number in parenthesis indicates number of similar comments)
To publicize the subject by print media aimed at the Universities (32)
To conduct workshops once or at least twice a year (21)
Investment in research and development (19)
Investment of the government in training on CCS for teachers in earth sciences (19)
Development of representative project experiments on CCS in which international experts and Mexican students can participate together (18)
To organize more workshops for the dissemination of the most interesting global topics nowadays, as it is the subject of CCS (12)
To include CCS in the curriculum as a subject in the environmental area (11)
To implement CCS in earth sciences universities so that students can develop thesis projects on the subject (8)
Incentives for young students of last semesters in earth sciences to developing CCS thesis (6)

Additional Comments (Number in parenthesis indicates number of similar comments)
Thanks a lot, the workshop was well organized and the speakers were high level specialists in the subject (39)
Very good organization and material support (22)
A second workshop to see the results of the demonstration project in Mexico (19)
Please organize other workshops on renewable energy sources and it development in Mexico and in the world (17)
Nice intention introduce this topic as it raises awareness to all students of earth sciences on the importance of understanding issues such as CCS (15)
Excellent opportunities offered to us the students. Thanks for this great opportunity (14)
I would like this workshop is performed during more time and with fewer sessions per day. if possible, include the demonstration of methodologies, and the presentation of the different software used in the relevant areas (9)

The workshop is very good, I loved it, I learned things that I had no idea that are being done and less that there are projects currently performed, and that there is an initiative for developing many more projects. I would like you to create a web page, to see new projects or articles about this topic (9)
It would be nice to undertake another workshop involving other sectors of society, such as; political, social, economic and scientific areas, to enrich the different points of view of each sector and take appropriate decisions in the areas that should be involved at applying this technique (7)

Appendix 10: CFE-FECIT Summary of Mexico Workshop

INTERNATIONAL CARBON CAPTURE AND STORAGE WORKSHOP FOR INTRODUCING CCS IN EARTH SCIENCES PROGRAMS IN MEXICO

CFE – APEC - Global CCS Institute

MUTEC (CFE Museum of Technology), Mexico City, DF, Mexico, June 27th to 28th, 2012.

Climate change, as a result of human activities, is real and happening, as evidence continues to mount that the earth is warming. Rising global temperatures are accompanied by changes in weather patterns and climate. These changes include unusual patterns of rainfall and floods, more frequent and severe heat waves, droughts, warming oceans, melting ice caps and rising sea levels. For the specific case of Mexico, in the northern region, a large number of cities and towns have experienced serious problems with their water supply because of prolonged droughts, while the southeast, due to the increase in the number of hurricanes, suffers from heavy floods every year, which completely destroy infrastructures and homes.

Most scientists agree that global warming is caused primarily by increasing concentrations of greenhouse gases in the atmosphere and that human activities are responsible for most of these increases. Carbon dioxide (CO_2) is the main greenhouse gas and results mainly from burning fossil fuels to produce energy. As world energy production from fossil fuels accelerates due to the increased industrialization of developing countries and global population growth, so does the atmospheric concentration of CO_2. Reducing the emissions of CO_2 into the atmosphere and stabilizing our planet's climate has now become a key challenge facing mankind in the 21st century.

Carbon Capture and Storage (CCS) is one of the key technological options currently being contemplated to reduce emissions of CO_2 into the atmosphere. Other options include switching to low- or zero-carbon energy sources (such as renewable and nuclear energy), improving energy efficiency and lowering energy demand (energy conservation). The CCS process includes the capture of CO_2 emitted by large industrial producers (power plants, oil refineries, cement plants, steel plants, etc.) and storing it in deep geological formations.

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Formations considered suitable for storing CO_2 include permeable rocks saturated with brine (saline formations), depleted oil or gas fields, and coal beds that are not commercially exploitable.

The identification and selection of suitable sites for storing significant volumes of CO_2 are key issues in considering the CCS option. The identification and selection includes geological assessments of storage systems at different scales.

Global emissions of CO_2 and other greenhouse gases have been estimated at 42 Gt per year (2008 data). CO_2 emissions from the energy sector constitutes 65% of the total (including generation, energy extraction and consumption), while electricity generation accounts for about 24%.

Approximately 80% of the electricity produced in Mexico is generated using fossil fuels (mainly natural gas, fuel oil, coal and diesel), which causes over 100 Mt of CO_2 to be emitted to the atmosphere. Although there are plans to increase the use of renewable energy sources to generate electricity in order to avoid the use of fossil fuels, the country's reality forces us to realize that energy from renewable resources will continue to provide only a marginal contribution for at least two more decades. Nevertheless, the Federal Electricity Commission (CFE) has shown great interest in developing renewable energy technologies.

Given these challenges, it is clear that Mexico must remain at the forefront of studies on CCS. However, the dissemination of this subject of interest in education and research institutes in the country is at an early stage.

In order to explain the principles of and advances in the development of this technology to students, scientists and national professors, and especially to promote the inclusion of this subject within the curriculum in academic institutions, an "International Workshop on Carbon Capture and Storage" was held in June 2012 at the location of the Museum of Technology (MUTEC).

The workshop was initiated and funded as part of an Asia Pacific Economic Cooperation (APEC) CCS capacity building program. It was co-organized by APEC and CFE, with financial support from the Global CCS Institute, and sponsored by CFE and the Fundación ProCiencias de la Tierra (Pro Earth Sciences Foundation). ICF International, a consulting firm in the U.S., supported APEC and CFE in organizing the workshop. This workshop was attended by over 240 participants, including scientists, professors and students. All had an opportunity to interact with the world-renowned experts present at the workshop

The workshop began on June 27th with opening remarks of Gustavo Arvizu Lara, Manager of Civil Engineering Studies (GEIC) of the CFE.

It continued with a presentation by Dr. Ananth Chikkatur (ICF International), who discussed the role of Asia Pacific Economic Cooperation (APEC) and its structure and programs. In the area of clean fossil fuels, there is a multiphase program on CCS, led by Canada, to study and evaluate the potential of capture and geological storage in the APEC region and raise awareness around this technology. He also highlighted the elements of the CCS training modules that were developed by APEC and provided to the participants of the workshop on a CD.

Dr. Amparo Martínez Arroyo then described the composition, structure and evolution of the atmosphere, as well as the determinants of the planetary atmosphere, illustrating through graphics the increased concentration of greenhouse gases in the atmosphere, the efficiency of natural sinks (vegetation and oceans) and the decrease in the efficiency of carbon sequestration by the oceans due to global warming. These factors are resulting in the atmospheric concentration of CO_2 increasing at a rate of 0.4-0.5% annually.

Dr. Steve Whittaker of the Global CCS Institute presented the modeling results by the International Energy Agency (IEA) of atmospheric CO_2 concentrations under different scenarios. He showed that unless we reduce emissions of greenhouse gases into the atmosphere, we will not be able to keep the rise in the average global temperature below the 2°C target. He highlighted different emission reduction alternatives and emphasized the need to implement them together.

Dr. Stefan Bachu, who represents Canada on the Carbon Sequestration Leadership Forum (CSLF) and was a member of the Intergovernmental Panel on Climate Change that won the 2007 Nobel Peace Prize Award, presented three topics; "CCS Fundamentals", "Site Selection" and "Capacity Estimation." He explained that the geological storage process of CO_2 basically consists of four phases: capture, compression, pipeline transport, and subsurface injection and storage. He explained that site selection and characterization – the information needed to understand and ensure that storage is safe, secure and acceptable – may take about 9-10 years to be completed. He also explained that assessments can be conducted at different scales and resolutions, including country, basin, regional, local and site scales. He listed the criteria for site selection, concluding that the safety and security of storage, capacity, injectivity, the ability to meet regulatory requirements, including monitoring and accessibility, and project economics are the basis for the selection of a site. Finally, he explained that there are four levels of assessment: theoretical, effective, practical and feasible, and elaborated on the factors that need to be considered for the capacity estimation of each.

The day's presentations concluded with a talk by Neil Wildgust, who represented the Petroleum Technology Research Center (PTRC). In his presentation, called "Basic Geochemistry", Neil explained the chemical reactions that take place in the reservoir once CO_2 is injected, such as dissolution depending on temperature and salinity of the formation water, mineral precipitation of carbonates by reacting with calcium, magnesium and iron silicates. He stressed that geochemical trapping is very difficult to predict, as it is only observed in the laboratory, and nature may take hundreds or thousands of years to take effect. He further explained the role of geochemistry in the process of monitoring CO_2 in the reservoir. Examples include measuring compositional changes over time in the saline aquifer and soil monitoring and leak detection of CO_2 at the surface. He also showed a few examples (Weyburn and Sleipner) where geochemical analyses are used as a monitoring tool.

Dr. Moses Davila closed the session activities of Day 1 by presenting a summary of the highlights of the day.

On June 28th, the second day of activities, the presentations started with a second participation by Dr. Steve Whittaker, who this time talked about "Monitoring and Verification (MV)". He explained that these procedures are critical throughout the geological storage process to ensure the integrity of the storage site. MV is performed during the stages of pre-injection, operation and post-injection. Mathematical models are used to predict the behavior of CO_2 in the reservoir rock. If the model results do not match the measurements, the model must be adjusted using new data, thus performing an iterative process. The monitoring tools include geophysics, geochemistry, geomechanics, remote sensors and well logs.

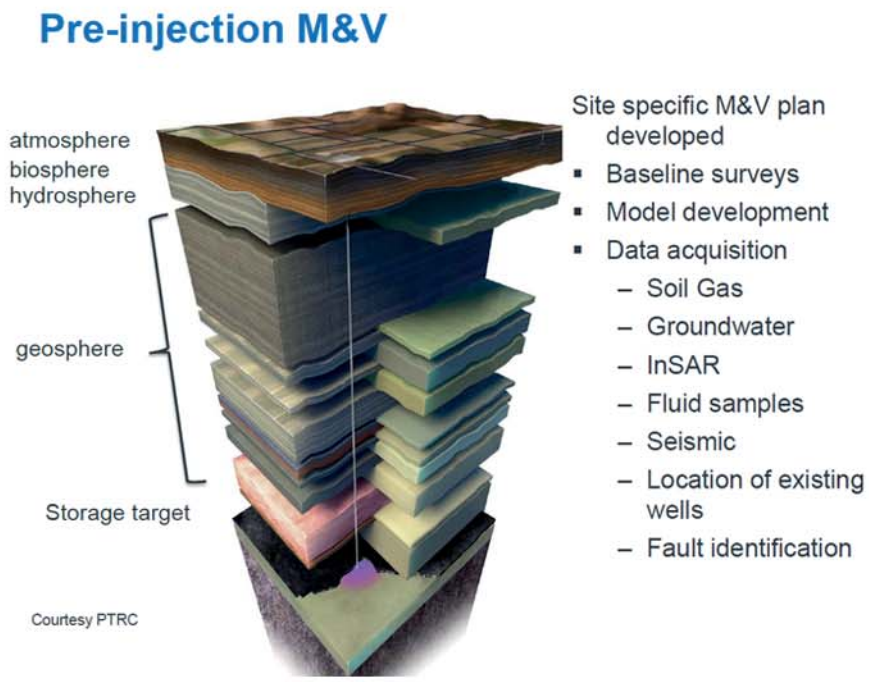
Next, Dr. Neil Wildgust from PTRC (Canada) exposed the topic "CCS Risk Analysis" in which he presented risk studies of the capture, transport and geological storage stages. Risk was expressed in terms of probability and magnitude of impact with the prior development of a predictive model of the reservoir (ranging from simple analytical equations to complex numerical models), taking into account the leakage scenarios and potential impacts to subsoil. He concluded that risk analyses for geological storage should be specific for each storage site. He ended his presentation by showing a case study on Weyburn, Canada.

Wesley Peck from the the Energy and Environmental Research Center at the University of North Dakota (U.S.) then presented on "CO_2-Based Enhanced Oil Recovery".

He explained the different mechanisms of oil recovery: (i) primary recovery, in which the natural energy of the reservoir moves the fluids toward the recovery wells; (ii) secondary recovery, in which the natural energy is supplemented by the injection of fluids produced by the same reservoir to maintain reservoir pressure and displace the oil towards the recovery wells without any interaction with the system rock/oil/brine reservoir (resulting in 10-15% more oil production); and (iii) tertiary recovery or enhanced oil recovery (EOR), which comprises the injection of fluids different from those produced by the reservoir, such as miscible/immiscible gas (CO_2), chemical or thermal (steamflooding). These fluids interact with the system reservoir rock/oil/brine and create favorable conditions for oil recovery, resulting in another 10-15% additional oil.

Furthermore, Wesley discussed the fundamentals of CO_2-EOR and noted the minimum miscibility pressure (MMP) needed to create miscibility between CO_2 and the oil reservoir. He mentioned other favourable interactions, including swelling of the oil and oil viscosity reduction, both of which make the oil more mobile. When there is a great difference in density between the injected fluid and reservoir oil, gravity segregation will likely occur, especially in horizontal reservoirs. The presentation concluded with a few examples, where this technique has been applied to enhanced oil recovery using CO_2.

Dr. José Miguel González Santaló, Mexico's representative on the Carbon Sequestration Leadership Forum (CSLF), presented a paper on "Introduction to CCS in Mexico". He explained the basic principles of CCS, gave a historical review of the introduction of this technology in Mexico, and mentioned the institutions that are participating in developing this technology in this country. He stressed the importance of developing CCS and elaborated on future prospects for CCS in Mexico.



Vicente Arévalo Mendoza, from the Federal Electricity Commission (CFE), then gave a presentation on "CO_2 emissions in Mexico," in which he explained, that CO_2 emissions are related to the industrial development of a country. He noted the position of Mexico in the world (11th place) in terms of CO_2 emissions, which coincides with Mexico's ranking in terms of the size of its economy (GDP).

He also noted the amount of CO_2 emitted by stationary sources (205 Mt of CO_2) and non-stationary sources (288 Mt of CO_2). It is the emissions from stationary sources that are to be captured and transported to geological storage sites.

Then, Dr. Moses Dávila, also from Federal Electricity Commission, in his presentation "Current Status of the Inventory of Sites for Carbon Capture and Storage in Mexico", showed the progress in Mexico's knowledge of this technology in the country, as reflected in a few papers: the North American Carbon Storage Atlas (NACSA) and the Geological Storage Atlas of CO_2 in Mexico. He noted various, national and international forums, where the government of Mexico has declared a commitment to actively participate in reducing greenhouse gases, in particular, human resources development for the possible application of CCS technology. Moreover, he noted progress is being made in studies to select potential sites for storage. So far, Mexico has completed studies at the Country stage, which identify favorable and unfavorable areas for storage, taking into account different geological aspects, such as lithology, seismicity, volcanism, geothermal activity, the presence of active faults, among others. Studies have moved to the Basin stage, where a first theoretical estimation was made of the storage capacity of CO_2 for each zone proposed as favorable provinces.

Studies are now being initiated to complete the Region stage, where Sabinas and Burgos Basins are being considered. In addition, Dr. Dávila showed the results of a preliminary analysis of the environmental impact of a coal-fired plant with CCS; the evaluation method chosen was Life Cycle Analysis, which considered various impact categories.

The session ended with a presentation on the "First Demonstration Project CCS-EOR in Mexico" by M.S. Rodolfo Lacy, who is with the Mario Molina Center. He outlined the objectives of the first planned demonstration project of CCS in Mexico which will involve CO_2-EOR and use facilities at PEMEX and CFE. Mr. Lacy covered the selection of two potential sites (Poza Rica and Tuxpan), the assessment of costs, the need for an environmental impact assessment, a risk assessment, and monitoring technologies.

After the workshop was officially closed, representatives of the universities attended a Round Table, with the representatives from APEC, ICF, Global CCS Institute, Federal Electricity Commission, Ministry of Energy of Mexico and the Fundacion ProCiencia de la Tierra. The objective was to reach an agreement for introducing CCS in the study programs for geology and geophysics engineering in Mexico.

The following five action items were agreed upon:

- All schools will begin implementing, formally or informally, the inclusion of CCS in the study programs of geology and geophysics from next semester (August-December 2012).

- Global CCS Institute will provide a book on climate change, which is currently being developed, with a strong component of CCS, to be used as a textbook in the study programs.

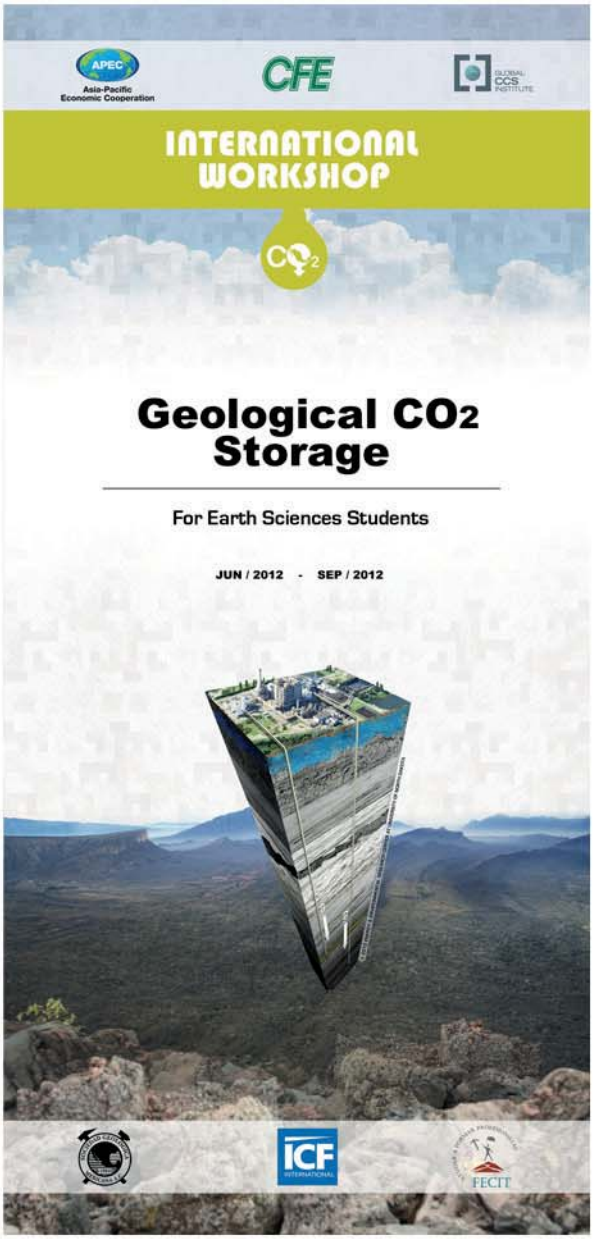
- Global CCS Institute will provide support for developing workshops on CCS to train teachers of universities offering geology and geophysics university programs in Mexico.

- The Ministry of Energy of Mexico will coordinate the activities arising from points 2 and 3 between universities and Global CCS Institute.

- National Association of Colleges and Schools of Engineering (ANFEI) will be invited to take part in the activities undertaken in the future with the intention to introduce the topic of CCS in Mexican universities in disciplines that apply this technology beyond of the earth sciences.

This workshop is an important contribution to the understanding of Carbon Capture and Storage. At the same time we hope it can serve as a stimulus to generate interest in the educational institutions which include areas related to earth sciences.

Emphasizing this objective, the organizers have scheduled a second International CCS Workshop on September 18th and 19th, 2012 in the city of Hermosillo, Sonora, Mexico.



TALLER INTERNACIONAL DE ALMACENAMIENTO GEOLÓGICO DE CO2 PARA LA INTRODUCCIÓN DEL TEMA EN PROGRAMAS DE CIENCIAS DE LA TIERRA EN MÉXICO

CFE – APEC - Global CCS Instituto

MUTEC (CFE Museo de Tecnología), Ciudad de México, DF, México, 27 a 28 junio, 2012

Es evidente que el cambio climático, como resultado de actividades humanas, es real y está ocurriendo en la actualidad. El aumento de las temperaturas globales están acompañados por cambios en los patrones climáticos. Estos cambios incluyen patrones inusuales de precipitaciones e inundaciones, olas de calor más frecuentes y severas, sequías, calentamiento de los océanos, deshielos y aumento del nivel del mar. Para el caso específico de México, en la región norte, un gran número de ciudades y pueblos han experimentado serios problemas con el suministro de agua debido a las sequías prolongadas, mientras que el sureste, debido al aumento en el número de huracanes, sufre de fuertes inundaciones todos los años, lo que destruye por completo las infraestructuras y viviendas.

La mayoría de los científicos coinciden en que el calentamiento global es causado principalmente por el aumento de las concentraciones de gases de efecto invernadero en la atmósfera y que las actividades humanas son responsables de la mayor parte de estos aumentos. El dióxido de carbono (CO_2) es el principal gas de efecto invernadero, el cual resulta principalmente de la quema de combustibles fósiles para la producción de energía. Dado que la producción mundial de energía de los combustibles fósiles se acelera debido a la creciente industrialización de los países en vías de desarrollo y crecimiento de la población mundial, también lo hace la concentración atmosférica de CO_2. La reducción de las emisiones de CO_2 a la atmósfera y estabilizar el clima de nuestro planeta se ha convertido en un reto clave que enfrenta la humanidad en el siglo XXI.

El Almacenamiento Geológico del CO_2 (CCS, por sus siglas en ingles) es una de las principales opciones tecnológicas que actualmente se contemplan para reducir las emisiones de CO_2 a la atmósfera. Otras opciones incluyen el cambio a fuentes de energía con bajas o nulas emisiones de CO_2 (como la energía renovable y nuclear), la mejora de la eficiencia energética y la reducción de la demanda de energía (ahorro energético). El proceso de CCS incluye la captura de CO_2 emitido por los grandes productores industriales (centrales eléctricas, refinerías de petróleo, fábricas de cemento, plantas de acero, etc.) y almacenarlo en formaciones geológicas profundas.

Las Formaciones Geológicas que se consideran adecuadas para el almacenamiento de CO_2 son las rocas permeables saturadas con salmuera (formaciones salinas), yacimientos de petróleo o gas agotados o en vías de agotamiento y capas de carbón no explotable comercialmente.

La identificación y selección de sitios adecuados para el almacenamiento de grandes volúmenes de emisiones de CO_2 son aspectos clave para considerar la opción de CCS. La identificación y selección incluye las evaluaciones geológicas de los sistemas de almacenamiento a diferentes escalas.

Las emisiones mundiales de CO_2 y otros gases de efecto invernadero se han estimado en 42 Gt al año (datos de 2008). Las emisiones de CO_2 procedentes del sector de la energía constituye el 65% del total (incluyendo la generación, la extracción de energéticos y sus formas de consumo), mientras que solo en la generación de electricidad es del 24%.

Aproximadamente el 80% de la electricidad producida en México se genera con combustibles fósiles (principalmente gas natural, combustóleo, carbón, y diesel), lo que ocasiona que se emitan al ambiente más de 100 millones de toneladas anuales de CO_2.

Aunque hay planes para aumentar el uso de fuentes de energía renovables para generar electricidad con el fin de evitar el uso de combustibles fósiles, la realidad del país nos obliga a darnos cuenta de que la energía procedente de fuentes renovables seguirá ofreciendo sólo una aportación marginal por los menos dos décadas más. No obstante, la Comisión Federal de Electricidad (CFE) ha mostrado un gran interés en el desarrollo de tecnologías de energía renovable.

Ante estos retos, es claro que México debe mantenerse a la vanguardia en los estudios sobre CCS. Sin embargo, la difusión de este tema de interés en la educación y los institutos de investigación en el país se encuentra en una etapa temprana.

Con la finalidad de explicar los principios y avances en el desarrollo de esta tecnología a los estudiantes, científicos y profesores nacionales, y especialmente para promover la inclusión de este tema dentro del currículo de las instituciones académicas, un "Taller Internacional sobre Captura y Almacenamiento de CO_2" fue llevado a cabo en junio de 2012 en el Museo Tecnológico (MUTEC) de CFE.

El taller fue patrocinado por el Foro de Cooperación Económica Asia – Pacífico (APEC), el Instituto Global de Captura y Almacenamiento de CO_2 (Global CCS Institute), la propia CFE y la Fundación ProCiencias de la Tierra. Este taller contó con la participación de más de 240 asistentes entre científicos, académicos y estudiantes, quienes tuvieron la oportunidad de convivir con renombrados expertos en el tema a nivel mundial.

El taller comenzó el 27 de junio con la apertura de los comentarios de Gustavo Arvizu Lara, gerente de Estudios de Ingeniería Civil (GEIC) de la CFE.

Continuó con la participación del Dr. Ananth Chikkatur, en cuya presentación expuso la función del Foro de Cooperación Económica Asia – Pacífico (APEC), su estructura y programas, entre los que destaca un programa multifase de captura y almacenamiento de CO_2 liderado por Canadá para realizar estudios y evaluar el potencial de captura y almacenamiento geológico en la región APEC y programas para incrementar la conciencia entorno a este tema.

A continuación, la Dra. Amparo Martínez Arroyo expuso la composición, estructura y evolución de la atmósfera; así como los factores determinantes de la atmósfera planetaria, exponiendo mediante gráficas el incremento en la concentración de gases de efecto invernadero en la atmósfera, la eficiencia de los sumideros naturales (vegetación y océanos) y la disminución en la eficiencia de captura de carbón por parte de los océanos, debido al calentamiento global, lo que incrementa la concentración del CO_2 en la atmósfera a una tasa de 40-45% anualmente.

Posteriormente el Dr. Steve Whittaker del Global CCS Institute expuso los distintos escenarios que, de acuerdo a la Agencia Internacional de Energía, se presentarían si no reducimos las emisiones de gases de efecto invernadero en la atmósfera; las distintas alternativas que se han considerado para reducirlas enfatizando la necesidad de realizarlas en conjunto.

El Dr. Stefan Bachu, representante de Canadá en el Carbon Sequestration Lidership Forum (CSLF) y miembro del Panel Intergubernamental para el Cambio Climático que fue ganador del 2007 Nobel Peace Prize Award por su contribución al Informe Especial del IPCC sobre captura y almacenamiento de CO_2, expuso tres temas; "Fundamentos del Almacenamiento Geológico", "Selección y Caracterización de Sitios" y "Estimación de Capacidad de Almacenamiento". Explicó que el proceso de almacenamiento Geológico de CO_2 consta básicamente de 4 fases; captura, compresión, transporte, e inyección, almacenamiento y monitoreo. También explicó que la selección y caracterización de sitios, que representa la información necesaria para entender y estar seguro de que el almacenamiento es seguro y aceptable, es del orden de 9-10 años.

Explica que existen diferentes escalas de evaluación como son: a nivel país, cuenca, región, local y sitio, también explica los criterios de selección y caracterización de sitios, concluyendo que la seguridad, capacidad e inyectabilidad, y la habilidad de conocer los requerimientos regulatorios como el monitoreo, accesibilidad y economía, son la base para la selección de un sitio. Por último explica que existen 4 niveles de evaluación de la capacidad de un sitio; teórica, efectiva, practica y factible, así como los factores a tomar en cuenta para la evaluación de la capacidad.

Las presentaciones del día concluyeron con la ponencia del Dr. Neil Wildgust perteneciente al Petroleum Technology Research Center (PTRC) denominada "Geoquímica Básica" en la cual explicó las reacciones químicas que tienen lugar en el reservorio una vez inyectado el CO_2, como son la disolución del compuesto dependiendo de la temperatura y salinidad del agua de formación, la precipitación mineral de carbonatos al reaccionar con el calcio, magnesio y hierro presentes en silicatos; recalcando que el entrampamiento geoquímico es muy difícil de predecir, pues sólo se conoce en laboratorio y en la naturaleza tomará cientos o miles de años para que se efectúe. Explicó además la función de la geoquímica en el proceso de monitoreo del CO_2 en el reservorio al medir los cambios composicionales que sufre el acuífero salino a través del tiempo y con monitoreo sobre suelos para detectar fugas del CO_2 en la superficie. También mostró un par de ejemplos (Weyburn y Sleipner) en los cuales se emplea la herramienta de la geoquímica en el monitoreo.

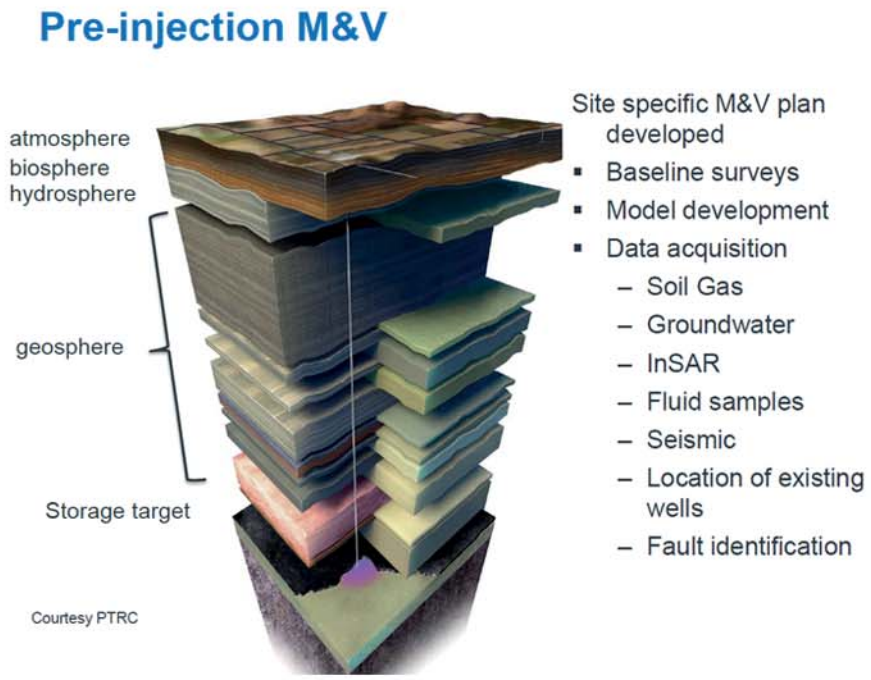
El Dr. Moisés Dávila cerró las actividades esa sesión al presentar un resumen de lo más destacado de las ponencias de ese día.

Las actividades del día 28 de junio comenzaron con una segunda ponencia del Dr. Steve Whittaker denominada "Monitoreo y Verificación". Explicó que este procedimiento es esencial en todo el proceso de almacenamiento geológico para asegurar la integridad del almacenamiento del compuesto y se lleva a cabo en las etapas de pre-inyección, operacional y post-inyección. Se deben realizar modelos matemáticos que permitan predecir el comportamiento del CO_2 en la roca almacén. En caso que no coincida el modelo con las mediciones se deberá reajustar el modelo con los nuevos datos obtenidos realizando de esta manera un proceso iterativo. Las herramientas en las que se basa el monitoreo son la geofísica, geoquímica, geomecánica, sensores remotos y registros de pozos.

Posteriormente se presentó el Dr. Neil Wildgust del PTRC de Canadá con el tema "Análisis de Riesgo en CCS" en el cual expuso los estudios de riesgos en las etapas de captura, transporte y almacenamiento geológico en términos probabilísticos y de magnitud de impacto con la elaboración previa de un modelo predictivo del reservorio (varían de simples ecuaciones analíticas a modelos numéricos complejos) tomando en cuenta los escenarios de fuga e impactos potenciales al subsuelo. Concluyó que los análisis de riesgo en el almacenamiento geológico deben ser específicos para cada sitio. Terminó su ponencia con la exposición de un caso de estudio en Weyburn, Canadá.

A continuación el Dr. Wesley Peck del Plains CO_2 Reduction Partnership (PCO2R) de USA y Canadá, con su ponencia "Recuperación Mejorada de Petróleo a base de CO_2" expuso los distintos mecanismos de recuperación de petróleo: Recuperación Primaria, en la cual la energía natural del reservorio mueve los fluidos del mismo hacia los pozos de recuperación; Recuperación Secundaria, en la que la energía natural es suplementada por la inyección de fluidos producidos por el mismo yacimiento para mantener la presión del reservorio y desplazar el petróleo hacia los pozos de recuperación sin ninguna interacción con el sistema roca/petróleo/salmuera del reservorio, con lo que se puede obtener 10-15% más de la producción de hidrocarburos; por último la Recuperación Terciaria o Recuperación Mejorada de Petróleo (EOR), es la inyección de productos diferentes a los fluidos producidos por el yacimiento, tales como CO_2, químicos o calor en forma de vapor, que interactúan con el sistema rocas del reservorio/hidrocarburos/salmuera creando condiciones favorables para la recuperación de petróleo con los que se puede recuperar un 10-15% adicionales de petróleo.

También se expusieron los fundamentos de la recuperación mejorada en base a CO_2 como la presión mínima necesitada para crear la miscibilidad entre el CO_2 y el petróleo del reservorio, cuando existe gran diferencia de densidades entre el fluido inyectado y el petróleo del reservorio se produce una segregación por gravedad, además el hecho de que el CO_2 reduce la viscosidad del petróleo haciéndolo más móvil, así como las características principales que debe tener el reservorio para poder aplicar la técnica. Concluye la ponencia con una serie de ejemplos en los que ha sido aplicada esta técnica de recuperación mejorada de petróleo por medio de CO_2.



Posteriormente el Dr. José Miguel González Santaló representante de México en el Carbon Sequestration Lidership Forum (CSLF), presentó en su ponencia "Introducción al CCS en México" los principios básicos del almacenamiento geológico de CO_2,

una reseña histórica de la introducción de este tema en México, también mencionó las instituciones que han participado en el desarrollo del tema, la importancia de desarrollar el CCS en el país y el futuro del CCS.

El M. en C. Vicente Arévalo Mendoza, perteneciente a la Comisión Federal de Electricidad (CFE), en su ponencia "Emisiones de CO_2 en México" expuso, como antecedentes, la composición de la atmósfera y la concentración de los principales gases de efecto invernadero que constituyen a la atmósfera.

Señaló la posición de nuestro país en el contexto mundial (11° lugar) en cuanto a las emisiones de CO_2, lo cual coincide con la posición de nuestro país por el tamaño de nuestra economía (PIB), también señala la cantidad de CO_2 emitida por las fuentes fijas (205 Mt de CO_2) y las fuentes no estacionarias (288 Mt de CO_2), de las cuales, las emisiones producidas por fuentes fijas, son en las que se propone efectuar la captura de CO_2 para transportarlas de ahí al sitio de almacenamiento geológico.

A continuación, el Dr. Moisés Dávila, Subgerente de Estudios Geológicos de la Gerencia de Estudios de Ingeniería Civil (GEIC) de la CFE, en su ponencia "Estado Actual del Inventario de Sitios para Almacenamiento Geológico de CO_2 en México" mostró los avances en el conocimiento de esta tecnología en el país, reflejados en un par de documentos de divulgación: el North American Carbon Storage Atlas (NACSA) y el Atlas de Almacenamiento Geológico de CO_2 en México. Señaló diferentes foros nacionales e internacionales en donde el gobierno de México ha declarado el compromiso de participar activamente en la reducción de gases de efecto invernadero, en particular, fortalecer las capacidades para la eventual aplicación de las tecnologías de la captura y almacenamiento de CO_2.

Posteriormente señaló los avances en los estudios realizados en miras de seleccionar sitios potenciales para almacenamiento. Hasta el momento se ha escalado desde la etapa País, en donde se proponen zonas favorables y desfavorables para el almacenamiento, considerando distintos aspectos

geológicos como litología, sismicidad vulcanismo, actividad geotérmica, presencia de fallas activas, entre otros; a la etapa Cuenca en donde se ha realizado una primera estimación teórica de la capacidad de almacenamiento de CO_2 en cada una de las provincias propuestas como zonas favorables. En la actualidad se están iniciando los estudios pertinentes a completar la etapa Región, en donde se están analizando prioritariamente las Cuencas de Sabinas y de Burgos. Muestra, además, los resultados de un análisis preliminar del impacto ambiental de una planta carboeléctrica teórica con CCS; el método de evaluación elegido fue el Análisis del Ciclo de Vida considerando varias categorías de impacto.

Las presentaciones terminaron con la ponencia del M. en C. Rodolfo Lacy perteneciente al Centro Mario Molina, México; denominada "Primer Proyecto Demostrativo de CCS-EOR en México", en la cual expuso los objetivos del primer proyecto demostrativo de captura de CO_2 industrial en México con la modalidad de CCS+EOR desde una central eléctrica, los antecedentes del proyecto, la selección del sitios (Poza Rica y Tuxpan) tomando en cuenta las instalaciones de PEMEX y CFE, la evaluación de costos, la necesidad de efectuar una evaluación de impacto y riesgo ambiental empleando tecnologías de monitoreo.

Provincias geológicas consideradas para evaluar por la modalidad de acuífero salino.

Después de clausurado el taller, se reunieron los representantes de las Universidades que asistieron al mismo, con los propios de APEC, el Global CCS Institute, la Comisión Federal de Electricidad, la Secretaría de Energía y la Fundación ProCiencias de la Tierra con la finalidad de llegar a acuerdos sobre la introducción del tema de CCS en los programas de estudios de las carreras de geología y geofísica en México.

Los cinco acuerdos más importantes que se tomaron fueron:

1. Todos los centros educativos representados comenzarán oficial o extraoficialmente, con la inclusión del tema de CCS en las carreras de geología y geofísica a partir del semestre próximo.

2. El Global CCS Institute proporcionará un libro de cambio climático que actualmente está desarrollando, con un fuerte componente en CCS para que sea usado como libro de texto en los programas del punto anterior mientras se forma uno exprofeso.

3. El Global CCS Institute dará apoyo para la formación de talleres con el tema de CCS para capacitar a los profesores de las universidades que imparten carreras de geología y geofísica en nuestro país.

4. La Secretaría de Energía coordinará las actividades que se desprendan de los puntos 2 y 3 entre las Universidades y el Instituto.

5. Se invitará a la asociación Nacional de Facultades y Escuelas de Ingeniería (ANFEI) a tomar parte de las actividades que se realicen en el futuro con la intención de introducir el tema de CCS en las universidades mexicanas en disciplinas en que aplique esta tecnología, más allá de las de ciencias de la tierra.

Este taller constituye una importante contribución al entendimiento de la captura y almacenamiento de CO_2. Al mismo tiempo esperamos que pueda servir como estímulo para generar el interés en las instituciones educativas en las que se incluyan áreas relacionadas con las ciencias de la tierra.

Enfatizando con este objetivo se ha programado un segundo taller los días 18 y 19 de septiembre del 2012, el cual se dará cita en la ciudad de Hermosillo, Sonora, México.