Asia-Pacific
Economic Cooperation

APEC Expert Workshops on CCUS-EOR

Asia-Pacific Economic Cooperation
Energy Working Group's Expert Group on Clean Fossil Energy

February 2015

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APEC Energy Working Group

February 2015

EWG 15/2013A

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APEC#215-RE-04.1

Acknowledgements

Development Technologies International wishes to thank the speakers and participants in the workshops for their contributions to this effort. We would also like to thank our partners who co-sponsored and hosted the workshops under this project.

Our partners Renmin University of China's School of Environment and Natural Resources, The Global CCS Institute, China Petrochemical Corporation (Sinopec Group) Ltd., and Shaanxi Yanchang Petroleum (Group) Co., Ltd. co-sponsored the first workshop in Beijing on November 10-11, 2014. The University of Chicago Center, Beijing hosted the workshop.

The Southern Company's and Mississippi Power's Kemper County Energy Facility hosted, and together with the Global CCS Institute co-sponsored, the second workshop held in Kemper County, Mississippi on February 2-3, 2015. The U.S. Department of Energy supported the workshop by providing financial support for local transportation to the Kemper County Energy Facility.

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1. Introduction and Project Objectives

1.1 Introduction

According to the International Energy Agency (IEA), CCS is the only technology that can achieve deep carbon dioxide (CO_2) emissions reductions from fossil fuel use in power plants and other large-scale emitters, while minimizing the overall costs of the portfolio of abatement options. The IEA has forecast that CCS will need to contribute one-fifth of the required global emission reductions by 2050 to limit the impact of global warming. Given the large potential of CCS, developing APEC economies need to start gaining a good understanding of all aspects of CCS, including technical, economic, financial, legal, regulatory, and social issues, and to increase their capacity to assess the potential of implementing this technology within their own economies.

At present, in the absence of a price on carbon, the economics of CCS do not favor deployment unless a project receives some form of financial support. There are, however, situations where captured CO_2 can be sold and utilized, rendering the project economics more attractive. The most practicable example of carbon capture, utilization, and storage (CCUS) is for enhanced oil recovery (EOR), where CO_2 is used to stimulate the production of oil from reservoirs (CCUS-EOR) with declining production.

Based on available data, China – the world's largest emitter of CO_2 – offers perhaps the greatest opportunity in the APEC region for CCUS-EOR. Committed to reducing its emission levels, China is exploring various CCS options and CCUS-EOR can become a key stepping stone towards the deployment of large-scale CCS in APEC. Owing to China's own indigenous research and development efforts in CCS/CCUS technologies, China is increasingly hosting international cooperative projects in CCS/CCUS and has much learning to offer other APEC economies.

This APEC project aims to bring CCUS-EOR greater prominence internationally, with particular emphasis on near-term opportunities in China and other developing APEC economies. This project seeks to support APEC economies in developing and implementing CCUS-EOR by building capacity among stakeholders in government, industry, and academia within the APEC region. As described in greater detail below, the project comprised two workshops hosted in two APEC economies - China and the United States.

The CCUS-EOR Expert Workshops held under this project featured active, first-of-a-kind CCUS-EOR projects in both developed APEC economies (United States and Canada) and developing APEC economies (China and Mexico). The objective is to bring together experts from leading projects from APEC economies to share experience and information, as well as explore potential for future collaboration. Over the course of both workshops, representatives from eight APEC economies participated in the meetings.

China, which has great interest in CCUS-EOR and has several CCUS projects underway, was the location for the first workshop convened in Beijing at Peoples University of China. Hosting the

discussions at Peoples University of China, which is centrally located in Beijing, enabled broader engagement among industry and experts organization participants.

The second workshop was held in the United States at Southern Company / Mississippi Power's Kemper County Energy Facility in Mississippi, which was substantially completed in the later part of 2014. The facility will capture ~ 65 percent of its CO_2, or ~3 million metric tonnes per year, for transport via a 60-mile pipeline to EOR operations. Holding the U.S. workshop at one of the world's leading CCUS-EOR sites provided hands-on learning, enhanced knowledge exchange, and promoted formation of relationships and enabling frameworks for further collaboration.

Workshop I	Hosted by Peoples University of China, Beijing
Workshop II	Hosted by Southern Company / Mississippi Power at the Kemper County Energy Facility, Kemper County, Mississippi, United States

This project continues a series of APEC CCS capacity building workshops that started in 2005. APEC workshops held under the title "Increasing the Knowledge and Awareness of Carbon Capture and Storage: Capacity-Building in the APEC Region" were hosted in Korea (Phase II – EWG 02/2004), China and Mexico (Phase III – EWG 07/2005), Indonesia and China (Phase IV – EWG 09/2008), Viet Nam and Mexico (Phase V – EWG 05/2010A), and Mexico (Phase VI - EWG 17/2013).

1.2 Project Objectives

The overall objective of this project was to organize Expert Workshops to share experiences in and disseminate the most up-to-date information from APEC, the Carbon Sequestration Leadership Forum (CSLF), and other international fora, to identify opportunities for use of CO_2 from CCS-equipped fossil fuel power generation in developing APEC economies, especially for enhanced oil or gas recovery.

Towards meeting this overall objective, the workshops were structured with the following features:

- Organize (i) a workshop/field study in a developed APEC economy with CCUS experience and (ii) an expert workshop in China to share up-to-date information on CCUS- EOR. This information is to include knowledge gained from operating CCUS-EOR projects and knowledge shared in international forums by other international organizations, such as the CSLF, GCCSI, and the IEA.

- Illustrate the concepts of CCUS-EOR, using information from (i) large-scale operating CO_2-EOR projects using natural CO_2 and (ii) large-scale CO_2 capture projects, in operation or under design, with integrated power and/or energy production.

- Promote and accelerate knowledge transfer by (i) identifying near-term CCUS-EOR demonstration opportunities in China and/or other developing APEC economies and discuss project economics pertaining to commercial, coal-fired power plants integrated with commercial EOR operations, as a viable model for CCUS demonstration and advancement, and (ii) sharing the experiences of integrating large-scale CCUS-EOR to enhance the understanding of critical aspects of the business case, project design, engineering, technology selection and procurement, risk management, and safety and monitoring measures.

- Identify a potential framework or approach to access existing knowledge assets accumulated by industry from large-scale CCUS demonstration projects to benefit future CCUS projects in the APEC region.

- Build connections and enabling frameworks among government, industry and expert organizations.

- Provide advice and input to the APEC Expert Group on Clean Fossil Energy that will form the basis for a multi-year work plan to support CCUS-EOR in China and other developing APEC economies.

1.3 Recommendations for Future Action

Based on workshop discussions, workshop participants drawn from government and industry identified several topics that would be particularly valuable for their economies:

- exchange among CCUS-EOR industry participants focusing on operational issues;
- workshop on safety issues in CCUS-EOR operations;
- enhancing environmental performance of industry operations;
- public information and outreach training; and
- economics and regulatory workshop.

These suggestions for future action reflect deepening interest in CCUS-EOR at the operational stage as well as the evolving policy environment in which both energy security and environmental compliance are emerging as dual goals in APEC economies, such as China, Mexico, and the United States.

2 Workshop 1: Beijing, China

2.1 Workshop Overview

November 10-11, 2014
Beijing, People's Republic of China
Venue: Renmin University of China and University of Chicago Center Beijing
Total of 80 participants and speakers
Of the total participants, 36 were female (45 percent)
Seven APEC Economies represented at the workshop: Australia; Canada; Hong Kong, China; Malaysia; People's Republic of China; Republic of Korea; and United States

This 2-day workshop comprised an introductory day aimed primarily at students and a second high-level workshop aimed at industry and government. Because of the different audiences, a total of 80 participants attended over both days.

The first-day "Nuts and Bolts" introduction to CCUS-EOR was attended by 47 participants from academia and research, as well as industry and government, institutions.

The second day was a high-level session was attended by 45 participants primarily from industry and research institutions involved in CCUS-EOR, as well as from government and academia.

DAY 1 Introduction to CCUS-EOR

The workshop covered a range of topics in order to build capacity among participants to better understand the basic technology and policy issues associated with CCUS-EOR in APEC economies. The workshop opened with presentations by Tsinghua University, Renmin University of China, the University of North Dakota's Energy Research Center, and the Global CCS Institute.

The presentations covered the following topics:

- Climate Mitigation and Economic Role and Need for CCUS-EOR
- Overview of CO_2-EOR and Advanced CO_2-EOR Technology Developments
- CO_2 Trapping Mechanisms
- CCUS-EOR Monitoring Approaches
- CCUS-EOR Permanency and Operational Safety

DAY 2 High-Level Session

The workshop featured exchange of expertise among APEC economies on the development of CCUS projects in Canada, China, and the United States.

The workshop opened with presentations on opportunities for international cooperation in

APEC developing economies on CCUS-EOR technologies, and opportunities for addressing greenhouse gas emissions through capture, use and storage technologies. These presentations were given by Dr. REN Xiangkun, who supervised China's first CCUS-EOR storage project as part of Shenhua's Direct Coal Liquefaction project in Ordos, Mongolia, and Dr. XU Shisen of the Huaneng GreenGen 250-MW integrated gasification combined cycle (IGCC) project, which will capture and test CCUS-EOR applications as part of the project.

The second part of the morning session focused on China's efforts in CCUS-EOR, comprising presentations by Sinopec and Shaanxi Yanchang focusing on EOR opportunities in existing fields in China. China University of Petroleum presented on the development of international standards for CCS and CCUS-EOR through the International Standards Organization. Following discussion, presenters responded to questions from workshop participants and discussed issues among themselves.

During the afternoon session, experts from Canada and the United States presented experience from the Weyburn-Midale CCS project (North Dakota and Saskatchewan), and the Plains CO_2 Reduction (PCOR) Partnership Program's Bell Creek (Montana) CCS projects funded by the U.S. Department of Energy's National Energy Technology Laboratory Regional Carbon Sequestration Partnership Program. Following presentations, presenters and participants discussed the U.S. and Canadian experience and responded to questions focusing on the economic and storage potential of CCUS-EOR, as well as the safety record of the CCUS industry in North America.

The afternoon session included presentations by Tsinghua University, Beijing Normal University, and the Global CCS Institute and discussion on the differences in monitoring and modeling between saline-aquifer storage applications and oil-field CCUS-EOR applications.

The workshop concluded with a presentation covering legal and regulatory issues in the CCUS-EOR field in general and in the context of China, in particular.

2.2 Workshop Agenda

APEC EXPERT WORKSHOP ON CCUS-EOR
BEIJING, PEOPLE'S REPUBLIC OF CHINA

Workshop Day 1: Introduction to CCUS-EOR

Monday 10 November 2014	
10:00 AM	Welcome Craig Hart, Renmin University of China
10:10 AM	Overview of CO_2-EOR and Advanced CO_2-EOR Technology Developments John HARJU, Energy & Environmental Research Center
11:30 AM	Coffee Break
11:45 AM	CO_2 Trapping Mechanisms XU Raina, Tsinghua University
12:15 AM	CCUS-EOR Monitoring Approaches Neil WILDGUST, Global CCS Institute
1:00 PM	Workshop Day 1 Close and Lunch

Workshop Day 2: High-Level Experts Session on CCUS-EOR

Tuesday 11 November 2014	
8:30 AM	**Registration**
9:00 AM	**Welcome and Overview of APEC Expert Group on Clean Fossil Energy and its CCUS Activities** **Craig HART, Renmin University of China**
9:15 AM	**CCUS Policy & Opportunities for Cooperation** **REN Xiangkun, Beijing Baoju Energy Sci-Tech Co., Ltd.** **Beijing Sanju Environmental Protection & New Materials Co., Ltd.**
9:45 AM	**Sourcing CO_2 in China** **XU Shisen, China Huaneng Clean Energy Research Institute**
10:15 AM	**Coffee Break**
10:30 AM	**CCUS-EOR Development in China** **YU Kai, China Petrochemical Corporation (Sinopec Group)** **GAO Ruimin, Shaanxi Yanchang Petroleum (Group) Co., Ltd.** **PENG Bo, China University of Petroleum, Beijing**
12:30 AM	**Lunch**
13:30 PM	**CO_2-EOR vs. Saline Storage / Monitoring** **Neil WILDGUST, Global CCS Institute** **ZHANG Keni, Beijing Normal University** **XU Raina, Tsinghua University**
15:00 PM	**Coffee Break**
15:15 PM	**Lessons from Integrated CCUS** **John HARJU, Energy & Environmental Research Center** **Neil WILDGUST, Global CCS Institute**
16:30 PM	**CCUS Legal & Regulatory** **Craig HART, Peoples University of China**
16:50 PM	**Closing Remarks** **Craig HART, Peoples University of China**
17:00 PM	**Workshop Close**

2.3 Speaker Biographies

Dr. GAO Ruimin

Shaanxi Yanchang Petroleum (Group) Co., Ltd.

Dr. Ruimin Gao serves as the President and Deputy Secretary of CPC in the Research Institute of Shaanxi Yanchang Petroleum (Group) Co., Ltd., Deputy Director of Technology and Equipment Committee of Chinese Petroleum Society, Secretary-General and Executive Director of

Professional Committee of Oil and Gas Development in Shaanxi Petroleum Society. Dr. Gao has worked in oil and gas development for 30 years with specialization in CCUS. He holds 25 patents, has presided over a number of major projects, including the "Technology Demonstration of CCS and EOR of Shanbei Coal-Chemical Industry" sponsored by National Key Technology R&D Program, "Key technical research of exhaust gas CCUS of coal-fired power plant" sponsored by Planning of National 863 R&D Program, "Demonstration Project of Sino-Australian International Cooperation on CCUS Integration" sponsored by Institute of Australian Carbon Capture and Storage. He won a Second Prize for National Science and technology Progress, 17 Provincial Science and Technology achievement awards, including for CO_2 fracturing and oil-based mud drilling in the Lacustrine Shale Gas recognized at the international leading level. President Gao has several major achievements in efficient exploration and development on oil and gas fields with very/ultra-low permeability, especially in the technologies of oil and gas drilling and enhancing oil recovery which received significant effect after field application. He made outstanding contributions to improve production in Yanchang Oilfield and regional economic development.

John Harju
Energy & Environmental Research Center
John Harju is the Associate Director for Research at the EERC, where he oversees the activities of a science and engineering team focused on research, development, demonstration, and commercialization of technologies related to oil and gas production and CO_2 enhanced oil recovery capture and sequestration, among others. In this capacity, he oversees the activities of the EERC's Oil and Gas Group, as well as strategic initiatives, such as the Bakken Production Optimization Program, the Plains CO_2 Reduction (PCOR) Partnership, and the Partnership for CO_2 Capture (PCO_2C). Harju is a member of the National Petroleum Council and serves on the U.S. Department of Energy's Unconventional Resources Technology Advisory Committee, which provides advice to the Secretary of Energy on the development and implementation of activities related to unconventional natural gas and other petroleum resources. He is the outgoing chair of the Interstate Oil and Gas Compact Commission (IOGCC) Energy Resources, Research, and Technology Committee and serves on IOGCC's Carbon Capture and Geological Storage Task Force.

Craig Hart
Renmin University of China, School of Environment and Natural Resources
Craig A. Hart is the ENN Group Associate Professor at the School of Environment and Natural Resources, Renmin University of China, and a lecturer at Johns Hopkins University's Energy Policy & Climate program. In addition, Craig is a practicing attorney in the fields of project finance, carbon finance and capital markets. He has represented project developers in energy and carbon management projects in the United States, Asia, and China, including on IGCC power projects under China's 863 Program. He has advised industry groups and served as a

consultant to international organizations, including the United Nations Development Program, the Asian Development Bank, and the APEC Expert Group on Clean Fossil Energy on CCS permitting in APEC economies. He holds a Ph.D. from the Massachusetts Institute of Technology and a J.D. from the University of California at Berkeley.

Dr. PENG Bo
China University of Petroleum

Dr. PENG Bo, Ph.D. (Dalian University of Technology, China, 1996), Dr. Science (University of Bergen, Norway, 2005), Professor, Vice Dean of Enhanced Oil Recovery, Director of the Laboratory of CO_2 Storage and EOR (Beijing key Laboratory), China University of Petroleum. Convener for CCS-ISO/TC265 WG4: Quantification and Verification; Editor for International Journal of Greenhouse Gas Control. Dr. Peng's research fields include CO_2 Geo-storage and Enhanced Oil Recovery, Enhanced Oil Recovery Engineering, Oilfield Chemistry. He is one of the leading experts developing "the CCUS Technology Roadmap in China". He has supervised a series National research projects supported by National High technology R&D program (863) "CO_2-EOR Key Systemic Technology", National Basic Research Program (973) "CO_2 Immigration and reaction while CO_2 Storage in the reservoir", Ministry of Land and Resources, China Geological Survey Key Research Program "Geological Survey and Evaluation for CO_2 storage in China Oil and Gas Reservoir", and National Science and Technology Infrastructure Program (NSTIP) "Regulation for CO_2 immigration while geo-storage." Dr. Peng is also the project leader for projects sponsored by the Ministry of Education, Petro-China, SINOPEC, and China National Offshore Oil Corporation (CNOOC). He has been actively involved in various international cooperation projects in the CO_2 Storage and EOR field, including the China-Australia CAGS project, China-UK NEZC project, and China-Europe COACH project. He has published over 100 papers both in domestic and overseas academic journals, holds five patents for inventions in China. Dr. Peng regularly speaks at international conferences on CCUS-EOR issues.

Dr. REN Xiangkun
Beijing Baoju Energy Sci-Tech Co., Ltd.
Beijing Sanju Environmental Protection & New Materials Co., Ltd.

Dr. REN Xiangkun is Chairman of the Board of Beijing Baoju Energy Sci-Tech Co., Ltd. and Vice President of Beijing Sanju Environmental Protection & New Materials Co., Ltd.. Heis a 2014 recipient of the U.S. Department of Energy, Office of Fossil Energy's Annual China CCUS Prize. In addition, Dr. Ren is a Professor and Senior Engineer, Chief Expert of CleanCoal Research Group, Energy Field, Program "863" sponsored by the Ministry of Science and Technology of China, and part-time President of the Low Carbon Energy Research Institute, China University of Mining and Technology. Dr. Ren has specialized in R&D, engineering, and commercialization of coal chemical and clean-coal technology for many years. Previously, he

served as the Director of Shenhua's Coal Liquefaction Research Center and Chairman of the Shenhua Coal-to-Oil Research Center Co., Ltd., and managed many R&D projects, provided technical support, and supported new business development in the field of coal liquefaction and coal chemicals. He is also one of the main Chinese participants of Annex II, Sino-U.S. Fossil Energy Protocol.

Neil Wildgust
Global CCS Institute
Mr. Wildgust is a geologist with over 25 years of industrial and research experience in mining and industrial minerals, hydrogeology and CO_2 geological storage. Prior to joining the Institute earlier this year as Principal Manager for Storage, Neil was Chief Project Officer at the Petroleum Technology Research Centre in Saskatchewan, Canada, where he managed projects including the Weyburn-Midale CO_2 Monitoring and Storage Project. Neil holds a BSc (Hons) degree in geology from Southampton University and an MSc in Applied Environmental Geology from Cardiff University

Dr. XU Ruina
Tsinghua University
Dr. XU Ruina is an Associate Professor at the Institute of Energy, Environment and Economy of Tsinghua University, focusing on CCUS systems and climate change mitigation. She is also Deputy Director, Beijing Key Laboratory for CO_2 Utilization and Reduction Technology. She plays a key role in CCUS research in China and is involved with China's key technologies R&D program of the Eleventh Five-Year Plan on Climate Change and Energy Strategy and was a lead contributor to China's CCUS R&D Roadmap. Dr. Xu is in charge of the project, Potential Impact of CCS on China's Energy System and Relevant Policy Studies, and is involved in three CCUS international collaborations, including EU GeoCapacity, COACH, and NZEC. Dr. Xu received her Ph.D. from Tsinghua University in thermal engineering, fluid flow, heat and mass transfers in microporous media. She is (co-) author for more than 30 articles published in peer-reviewed journals, and four books related to CCS published in China.

Dr. XU Shisen
China Huaneng Clean Energy Research Institute
Dr. Xu Shisen, Ph.D., Research Professor, graduated from thermal power engineering of the Xi'an Jiaotong University of P.R. China. He is currently the President of China Huaneng's Clean Energy Research Institute, leading projects on coal gasification, CO_2 capture, and IGCC's key technologies. He also has completed more than 20 national science and technology research and State 863 projects as the leading director, was one of the experts of National 10^{th} Five Year Plan 863 projects on clean coal technologies, and is one of the experts of the National 11^{th} Five Year Plan 863 projects on coal gasification and co-production technologies. Dr. Xu is in charge

of R&D for "GreenGen" and carbon capture project of China Huaneng Group Corporation. Dr. Xu is the inventor of "two-stage pressurized entrained flow gasification with dry feed," developed China's first 10-MWth pressurized entrained flow gasification system with dry feed in National 10th Five Year Plan 863 project as the leading director, developed China's first 2000-t/d pressurized entrained flow gasification system with dry feed as the leading director in the National 8th, 9th, and 10th Five Year Plan 863 projects. Now, he is the leading director of the "250-MW IGCC power plant demonstration and experimental project" in the National 11th Five Year Plan 863 project and the chief technical leader of China's first IGCC power plant. Regarding the international cooperation, he managed "China-U.K. technical cooperation: ABGC technology development and application," "China-U.K. technical cooperation: coal gasification technology development and application " and "China-U.K. technical cooperation: trace elements in coal combustion and gasification." He is responsible for managing the "China-Australia technical cooperation: CO_2 capture technology in advanced energy system," and is the Chinese leading manager of "China-EU COACH project." In 2008, Dr. Xu was in charge of developing China's first carbon capture unit for a coal-fired power plant (3000-5000 t/a). In 2009, he was in charge of developing world's largest carbon capture unit (120000 t/a) at a coal-fired power plant in Shanghai. To date, he has been awarded one state level technical prize, 12 provincial/ministry level technical prizes, and 13 national patents. He has also published 120 papers in journals and conferences and 4 books.

Mr. YU Kai
China Petrochemical Corporation (Sinopec Group)
Mr. YU Kai is Deputy General Manager of the Eastern China Branch of Sinopec.

Professor ZHANG Keni
Beijing Normal University
Dr. ZHANG Keni, professor at Beijing Normal University, is a well known expert in reservoir simulation. He received his Ph.D. degree in Groundwater Hydrology from the University of Manitoba, Canada. He has led numerous projects for parallel reservoir simulator development involving complex mathematical computational modeling in both the unsaturated and saturated zones, on both at small and large scale. Since 2000, Dr. Zhang has been involved in a variety of research projects that have focused on computing techniques to simulate multi-component and multiphase fluid flow in the fields of nuclear waste disposal, CO_2 geologic sequestration, gas-hydrate research, and groundwater hydrology.

2.4 List of Workshop Participants

November 10, 2014

Surname	First name	Organization
ABU BAKER	Mulyani	Renmin University of China
BAO	Jie	Renmin University of China
CAI	Xinyu	Beijing University
CHEN	Pintian	Renmin University of China
DU	Wanjun	Renmin University of China
DU	Xiyao	CNOOC Research Institute
DUAN	Qinghong	Renmin University of China
EDWARDS	Peter	China Carbon Forum
GUAN	Baozhu	Renmin University of China
HAN	Katherine	Beijing University
HAN	Huiqing	Siemens
HARJU	John	Energy & Environmental Research Center
HART	Craig	Renmin University of China
HE	Tianding	Renmin University of China
HE	Chenmin	Beijing University
HONG	Xiaohan	Renmin University of China
KAN	Yuwei	Airliquide
LEE	Sungyui	Renmin University of China
LI	Yanan	Renmin University of China
LI	Pengpeng	Blue Whale Energy
LI	Jianguang	EEA Fund Management Limited
LIU	Xin	CAS Institute of Policy & Management
LIU	Xuehao	Institute of Rock and Soil Mechanics, Chinese Academy of Sciences
LV	Qianmeng	Renmin University of China
QIU	Xiaoxia	Renmin University of China
SHENG	Kewen	Renmin University of China
SONG	Jing	World Resources Institute
SUN	Junping	Renmin University of China
WANG	Ke	Renmin University of China
WILDGUST	Neil	Global CCS Institute
WU	Shiyu	Renmin University of China
XIAO	Yunhan	Chinese Academy of Science, Nanjing
XIE	Wenyu	Renmin University of China
XU	Raina	Tsinghua University
YANG	Yumeng	Renmin University of China
YANG	Xiaoliang	World Resources Institute
YING	Jiahui	Renmin University of China
ZHANG	Gen	Renmin University of China

ZHANG	Xiaoli	Renmin University of China
ZHANG	Keni	Beijing Normal University
ZHANG	Jieqiong	Renmin University of China
Zhang	Qian	Chinese Academy of Social Sciences
ZHAO	Xiusheng	Tsinghua University
ZHOU	Hang	Renmin University of China
ZHU	Luona	Renmin University of China
ZHU	Jiayan	Renmin University of China
ZHU	Zihan	CNOOC Research Institute

November 11, 2014

Surname	First name	Organization
CHEN	Zuhua	China Petrochemical Corporation (Sinopec Group)
CHENG	Jun	Zhejiang University
DENG	Yi	University of Chicago, Beijing Center
DIAO	Yujie	China Geological Survey Center for Hydrogeology and Environmental Geology Survey (CHEGS)
EDWARDS	Peter	China Carbon Forum
GAO	Ruimin	Shaanxi Yanchang Petroleum (Group) Co., Ltd.
HAN	Huiqing	Siemens
HARJU	John	Energy & Environmental Research Center
HART	Craig	Renmin University of China
HART	Diane	MSCI
KATER	Hugh	China Carbon Forum
LI	Jianguang	EEA Fund Management Limited
LI	Qi	Institute of Rock and Soil Mechanics, Chinese Academy of Sciences
LI	Frank	MSCI
LIANG	Rachel	China University of Mining and Technology (Beijing)
LIN	QIANGUO	Global CCS Institute
LIU	Huan	Beijing Baoju Energy Sci-Tech Co., Ltd. and Beijing Sanju Environmental Protection & New Materials Co., Ltd.
LIU	Xuehao	Institute of Rock and Soil Mechanics, Chinese Academy of Sciences
LIU	Zhaohui	Huazhong Univ. Sci. Tech/ US-China CERC-ACTC
LIU	Zhe	RCSD, CAS
MA	Lihong	Jinnuo Law Firm
PENG	Bo	China University of Petroleum, Beijing
REN	Xiangkun	Beijing Baoju Energy Sci-Tech Co., Ltd. and Beijing Sanju Environmental Protection & New Materials Co., Ltd.
SLATER	Huw	China Carbon Forum

SONG	Jing	World Resources Institute
WANG	Jinming	Zhonglinglanhai
WILDGUST	Neil	Global CCS Institute
Xie	Jian	Beijing Normal University
XU	Raina	Tsinghua University
XU	Shisen	China Huaneng Clean Energy Research Institute
YANG	Xiaohua	China University of Mining Technology, Beijing
YANG	Xiaoliang	World Resources Institute
YIN	Guangxia	Beijing Baoju Energy Sci-Tech Co., Ltd. and Beijing Sanju Environmental Protection & New Materials Co., Ltd.
YING	Jiahui	Renmin University of China
YU	Kai	China Petrochemical Corporation (Sinopec Group)
ZHANG	Keni	Beijing Normal University
ZHANG	Mo	Temple University and Tsinghua University
ZHANG	Qian	CASS Graduate School
ZHANG	Sabrina	MSCI
ZHANG	William	Airliquide
ZHANG	Libin	Siemens
ZHAO	Lifeng	Chinese Academy of Science
ZHAO	Yongpan	Shaanxi Yanchang Petroleum (Group) Co., Ltd.
ZHU	Zihan	CNOOC Research Institute
ZHU	Jiayan	Renmin University of China

2.5 Workshop Feedback

Feedback forms were completed by 50 participants rating speakers based on "how useful" the talk was for increasing the participant's knowledge of CCUS and relevance of CCUS. Based on a scale of "Low," "Medium," and "High," all speakers were rated on average as highly helpful and relevant to increasing participant's knowledge of CCUS. Comments were generally positive, suggesting focus on basic introduction of topics, detailed research, commercial, and regulatory issues for future workshops.

2.6 Workshop Presentations

3 Workshop 2: Kemper County, Mississippi

3.1 Workshop Overview

February 2-3, 2015
Kemper County, Mississippi
Venue: Mississippi Power's Kemper County Energy Facility and Meridian, Mississippi
42 Participants
Of the total participants, 11 were female (27 percent)
4 APEC Economies represented: Australia, China, Mexico, and United States

The 2-day workshop was attended by 42 participants from four APEC economies.

Day 1 Kemper County Energy Facility and Liberty Mine Tour and Sharing Experiences among China, Mexico and the United States

Day 1 featured exchange of expertise among APEC economies on the development of CCUS-EOR projects in China, Mexico and the United States.

The workshop began with a half-day tour to Southern Company / Mississippi Power's Kemper County Energy Facility and the Liberty Mine located adjacent to the plant. The Kemper County Energy Facility is a first-of-its-kind 582-MW IGCC power plant that will utilize local lignite (mine-mouth) as a fuel source. About 65 percent of the CO2 (~ 3.5 Mt/year) will be captured and transported via a 60-mile pipeline for EOR operations. The power plant features commercial demonstration and advancement of KBR's TRIG™ gasifier technology which enables use of low-rank coals or coals with high moisture or ash content, applicable to half of global coal reserves, including reserves in China.

Mr. Scott Smouse of the United States Department of Energy and Chair of the APEC Energy Work Group's EGCFE presented on the EGCFE's CCUS-related activities , and Kerry Bowers of the Southern Company and Lee Youngblood of Mississippi Power introduced the Kemper County Energy Facility and the TRIG™ gasifier technology before touring the facility and the mine.

Following the tour, the afternoon session featured presentations highlighting policy drivers and CCUS-EOR activities in China and Mexico. Dean and Professor Ma Zhong of Renmin University of China presented on China's climate and environmental policies followed by Dr. Zhao Yongpan of Shaanxi Yanchang Petroleum describing their EOR activities. Representatives of the Government of Mexico Mr. Rafael Acosta Quevedo and Ms. Jazmin Mota, both of the Federal Electricity Commission (CFE,Mexico's state-owned electricity utility), presented on Mexico's CCUS-EOR Roadmap, followed by Ms. Esmeralda Rivera Rodriquez of PEMEX on their current EOR activities and plans to develop two demonstration projects in coordination with the CFE and other agencies of the Mexican government, with support from the World Bank.

DAY 2 Technical Presentations

Day 2 of the workshop featured technical presentations by experts in various aspects of CCUS-EOR, including operations, geological assessment and monitoring, legal and regulatory, and standards setting.

The workshop opened with a presentation by Ms. Pamela Tomski of the Global CCS Institute on the status of CCS projects worldwide with focus on projects and policy drivers in North America. Mr. Michael Godec of Advanced Resources International then provided an overview of CCUS-EOR in both a regional and global context, focusing on the economics of CCUS-EOR projects. Mr. Keith Bowman of Tellus Operating Group described their experience conducting EOR operations in the United States and internationally, and discussed operating considerations and decisions that an EOR operator must make in order to operate a successful project.

In the afternoon session, Ms. Vanessa Nuñez-Lopez of the Bureau of Economic Geology, The University of Texas at Austin, presented on monitoring and verification approaches, and later on EOR case studies based on BEG's experience conducting field experiments and implementing projects. Craig Hart of Renmin University of China presented on contracting practices for the purchase and sale of CO_2 in the context of CCUS-EOR operations, discussing economic and regulatory terms reflecting current practice. Mr. Steve Carpenter gave an overview of how standards play an important role in affecting industry practices and trade in CCUS-EOR operations and services, and described the ongoing standards setting process under the International Standards Organization, ISO TC-265: Carbon dioxide capture, transportation, and geological storage.

3.2 Workshop Agenda

APEC EXPERT WORKSHOP ON CCUS-EOR
KEMPER COUNTY, MISSISSIPPI, UNITED STATES

Monday 2 February 2015	
8:15 AM	Bus departs Meridian to Kemper County Energy Facility
9:00 AM	APEC's Energy Working Group, Expert Group on Clean Fossil Energy Activities Scott SMOUSE, US Department of Energy
9:20 AM	Overview of the Kemper County Energy Facility Lee YOUNGBLOOD, Mississippi Power TRIG Technology Kerry BOWERS, Southern Company Kemper and Liberty Mine Tour
12:30 PM	Return to Meridian by Bus
1:30 PM	Lunch
3:00 PM	CCUS-EOR Drivers and Experience – China MA Zhong, Renmin University of China ZHAO Yongpan, Shaanxi Yanchang Petroleum (Group) Co., Ltd.
4:00 PM	CCUS-EOR Drivers and Experience – Mexico Jazmin MOTA, Ministry of Energy, Mexico Rafael ACOSTA QUEVEDO, Federal Commission of Electricity Esmeralda RIVERA RODRIGUEZ, PEMEX
5:00 PM	Wrap-up and Day 1 Close Craig HART, Renmin University of China

Tuesday 3 February 2015	
9:30 AM	**Introduction** **Craig HART, Renmin University of China**
9:35 AM	**Global Status of CCUS and Large-Scale Integrated CCUS Projects** **Pamela TOMSKI, Senior Advisor, Policy & Regulatory – The Americas, Global CCS Institute**
10:05 AM	**Overview of CCUS-EOR in Regional and Global Markets** **Mike GODEC, Advanced Resources International**
10:50 AM	**Break**
11:10 AM	**CCUS-EOR Decision-Making Approaches** **John Keith BOWMAN, EOR Manager, Tellus Operating Group**
12:00 PM	**Lunch**
1:00 PM	**Monitoring, Verification and Accounting (MVA) Approaches** **Vanessa NUÑEZ-LOPEZ, Research Scientist Associate, Bureau of Economic Geology, The University of Texas at Austin**
1:45 PM	**Monetizing CO2-EOR: CO2Off-take Contracts** **Craig HART, Renmin University of China**
2:30 PM	**CO2-EOR Case Studies** **Vanessa NUÑEZ-LOPEZ, Research Scientist Associate, Bureau of Economic Geology, The University of Texas at Austin**
3:30 PM	**Break**
3:45 PM	**International Standards Organization (ISO) CCUS Process and Its Role in Shaping the CCUS Regulatory and Market Landscape** **Steve CARPENTER, Vice President, Advanced Resources International and US TAG Chair, ISO TC 265 on Carbon Dioxide Capture, Transportation and Geological Storage**
4:30 PM	**Wrap-up and Workshop Close** **Craig HART, Renmin University of China**

3.3 Speaker Biographies

Rafael Acosta Quevedo
Federal Commission of Electricity
With over 22 years of experience at the Federal Commission of Electricity, Mr. Acosta had led studies on site selection for radioactive waste storage for the Laguna Verde Nuclear Power Plant. He has led and coordinated interdisciplinary teams on site selection studies for power plants at Altamira, Campeche and Tuxpan and sites for new nuclear power plants. In addition, Mr. Acosta has implemented studies for hydropower projects in Mexico and other countries, and worked on groundwater contamination and rehabilitation protection and environmental protection studies. He received the award for performance in the Superintendencia de Estudios Zona Golfo. He serves as an instructor of professional development courses in the GEIC (Management Studies in Civil Engineering). Since 2011, he has led geological survey projects for siting CO_2 storage for CCUS projects. Mr. Acosta obtained his degree in Geological Engineering, graduating in 1989 from the National Polytechnic Institute (IPN) in Mexico City

Kerry Bowers
Southern Generation Technologies, LLC
Mr. Kerry Bowers, President and CEO at Southern Generation Technologies, LLC (SGT), a whollyowned subsidiary of Southern Company responsible for licensing TRIG™ technology intellectual property world-wide. Mr. Bowers holds a B.Sc. in chemical engineering from Vanderbilt University. Prior to his role at SGT, Mr. Bowers was the Director of the National Carbon Capture Center, an internationally recognized R&D center founded and managed by Southern Company dedicated to the development and advancement of both pre- and post-combustion CO_2 capture technologies.

John Keith Bowman
Tellus Operating Group (TOG)
Mr. Bowman is an accomplished petroleum geologist with diverse work experience in the petroleum basins of the continental United States. Mr. Bowman is responsible for tertiary development and monitoring of TOG's producing CO_2 fields along with identification of CO_2 source opportunities and additional fields with tertiary application. Prior to TOG, Mr. Bowman served as a geologist with Sun Oil Company in Lafayette, Louisiana and Dallas, Texas, Petro Hunt, LLC located in Dallas, Texas and Denbury Resources in Plano, Texas. He was instrumental in developing Denbury's natural occurring CO_2 source in Mississippi along with tertiary design in Denbury's southwest Mississippi fields. Mr. Bowman received a B.S. in Geology from Georgia Southwestern University in 1982 and a M.S. in Geology from University of Southern Mississippi in 1986. He is a registered member of the American Association of Petroleum Geologist and certified as a Petroleum Geologist in Texas. He is an expert witness for the State Oil and Gas Boards of Mississippi, Louisiana, North Dakota, and Texas.

Steven M. Carpenter
Advanced Resources International

Steven M. Carpenter is a Vice President with Advanced Resources International, Inc. He has 25 years of experience in the energy, mining, federal, and international contracting industries. He is an internationally recognized Subject Matter Expert for climate change policy, carbon, and risk management issues. Mr. Carpenter's clientele include the Canadian Standards Association (CSA), International Organization for Standardization (ISO), the Interstate Oil & Gas Compact Commission (IOGCC), the Energy Mineral Law Foundation (EMLF), the Southern States Energy Board (SSEB), the World Bank/International Finance Corporation, EPA, DOE, DOD, USACE, USAID, USTDA, and the government of Turkey. Mr. Carpenter is a certified Greenhouse Gas Verifier & Quantifier under ISO 14064, 14065, and 17024. Mr. Carpenter is the Chair and Head of Delegation for the US Technical Advisory Group (TAG) to ISO TC-265: Carbon dioxide capture, transportation, and geological storage. Mr. Carpenter received the Lifetime Gubernatorial appointment to the esteemed rank of the Executive Order of the Ohio Commodore. He is a Trustee of the Energy Mineral Law Foundation, a member of the Advisory Board to the International Pittsburgh Coal Conference at the Swanson School of Engineering, at the University of Pittsburgh. Mr. Carpenter holds a Master's degree in Conflict Analysis and Engagement of Environmental Public Policy from Antioch University and a Bachelor's degree in Physics from Earlham College and will complete his Ph.D. next year.

Michael L. Godec
Advanced Resources International
Michael L. Godec, a Vice President with Advanced Resources, has prepared numerous assessments of the potential sequestration capacity and economic potential associated with geologic storage in oil and gas fields, deep saline aquifers, gas shales, and unmineable coal seams. He has examined CO_2 storage and possible CO_2-EOR opportunities for numerous proposed power plants and other industrial facilities, both in the U.S. and internationally. He participated in all the U.S. Department of Energy efforts to assess the CO_2-EOR and associated CO_2 storage capacity in depleted oil fields. He has completed numerous recent studies assessing the global potential for CO_2-EOR and associated CO_2 storage, including studies for APEC, the IEA Greenhouse Gas Research Programme, UK Department of Energy and Climate Change, and UNIDO. For 2009-2010, Mr. Godec was a Society of Petroleum Engineers Distinguished Lecturer on the subject "Environmental Performance of the Exploration and Production Industry: Past, Present, and Future." Mr. Godec has an M.S. in Technology and Human Affairs from Washington University in St. Louis, and a B.S. in Chemical Engineering from the University of Colorado, Boulder.

Craig Hart
Renmin University of China, School of Environment and Natural Resources
Craig A. Hart is the ENN Group Associate Professor at the School of Environment and Natural Resources, Renmin University of China, and a lecturer at Johns Hopkins University's Energy Policy & Climate program. In addition, Craig is a practicing attorney in the fields of project finance, carbon finance and capital markets. He has represented project developers in energy and carbon management projects in the United States, Asia, and China, including on IGCC power projects under China's 863 Program. Mr. Hart is a voting member of the U.S. Technical Advisory Group to ISO TC-265: Carbon dioxide capture, transportation, and geological storage.

He has advised industry groups and served as a consultant to international organizations including the UNDP, Asian Development Bank and APEC on greenhouse gas management and regulation in the United States and Asia. He holds a Ph.D. from the Massachusetts Institute of Technology and a J.D. from the University of California at Berkeley.

Dean and Professor MA Zhong
Renmin University of China, School of Environment and Natural Resources
MA Zhong is Dean and Professor of the School of Natural Resources at Renmin University of China. Dean Ma regularly advises China's government ministries and the State Council, as well as international bodies including the World Bank, the Asian Development Bank, World Wildlife Federation, UNDP, and the Global Environmental Facility. He serves on several Chinese government advisory committees, including the Sciences and Technology Advisory Committee of the State Environmental Protection Agency, China Council for International Cooperation of Environment and Development, China Ministry of Agriculture, State Development and Planning Commission. Dean Ma's research and writing includes carbon management, water protection, and pricing of environmental resources. He has worked extensively on designing environmental pollution and other market-based environmental trading systems for China. Dean Ma holds his Ph.D. in Environmental Economics from Renmin University of China.

Jazmin Mota
Energy Ministry of Mexico
Jazmin Mota is Director of the Clean Technologies at the Energy Ministry of Mexico. She is in charge of the Carbon Capture, Use and Storage Project and responsible for implementing Mexico's CCUS Technology Road Map. She has been a consultant to the World Bank supporting initiatives between the World Bank and the Government of Mexico. Previously, she worked at the Federal Commission of Electricity leading projects for CO_2 storage capacity in deep saline aquifers in order to evaluate the storage potential in the north of Mexico. She has participated in forums and outreach programs at various universities in the region. Ms. Mota completed her geological engineer degree at the National Autonomous University of Mexico where she also currently teaches.

Vanessa Nuñez-López
Bureau of Economic Geology, University of Texas
Ms. Nuñez-López is a Petroleum Engineer and Research Associate with the University of Texas Bureau of Economic Geology. She leads a number of the Bureau's carbon storage projects and conducts extensive education and outreach on various aspects of geologic carbon storage. Previously, Vanessa worked for Chevron Corporation as a reservoir engineer for 5 years. Some of the projects Ms. Nuñez-López leads includes: NRG-Petra Nova, West Ranch CO_2 Monitoring Plan (CO_2 retention in a commercial EOR operation); Leveraging Carbon Storage Research and Technology for Applicability in Conventional EOR Projects; Geological Carbon Storage resource of references; Hastings Field Monitoring, Verification and Accounting (MVA) Program; technical support for several Gulf Coast Carbon Center (GCCC) studies (e.g., SECARB's Cranfield, NRG's Hilcorp MVA); and reservoir engineer for BEG's SLOAN project, a project to determine the capability of U.S. shale gas to contribute to the natural gas supply for the next 20 years.

Esmeralda Rivera Rodriguez
PEMEX
Ms. Esmeralda Rivera Rodriguez is an engineer with PEMEX focusing on the design of surface facilities and laboratory reservoir modeling. She currently works in the area of enhanced oil recovery, where she participated in developing EOR plans in the Poza Rica and Tamaulipas Constituciones fields. She is a member of Mexico's working group for developing strategy for CCUS. She holds a masters degree in chemical engineering from the National Autonomous University of Mexico.

Scott Smouse
U.S. Department of Energy
Scott Smouse has over three decades of experience in nearly every aspect of fossil energy utilization, especially coal-based power generation. He is currently the Senior Advisor in the Office of Clean Coal and Carbon Management in the U.S. Department of Energy's (DOE's) Office of Fossil Energy. In his over 28-year DOE career, Mr. Smouse has served in various positions at the National Energy Technology Laboratory (NETL) and its predecessor the Pittsburgh Energy Technology Laboratory (PETC). From 1996 to 2014, he coordinated NETL's international RD&D activities, working with over 50 countries. From 1986-1996, he held senior positions in PETC's Office of R&D and then the Office of Clean Coal Technology. Since 2000, he has served as the Chair of the APEC Energy Working Group's Expert Group on Clean Fossil Energy. Prior to joining the federal government, he held positions in the U.S. private sector with Babcock & Wilcox Company, Dearborn Utility Services Company, and Pope Evans & Robbins Consulting Engineers. Mr. Smouse holds a B.S. in Chemistry from Fairmont State University and an M.S. in Fuel Science (Combustion) from Penn State University.

Pamela Tomski
Global CCS Institute
Pamela Tomski is the Senior Advisor Policy & Regulatory - The Americas with the Global CCS Institute and serves as a Nonresident Senior Fellow of the Energy and Environment Program at the Atlantic Council, a think tank in Washington-DC. She is also the Founder and Director of the Research Experience in Carbon Sequestration (RECS), an intensive summer program for graduate students and early career professionals on all aspects of CCS / CCUS. Pamela has worked for 15 years advancing CCS / CCUS technology through establishment of R&D collaborations and demonstration projects to education and capacity building, regulatory frameworks, and policy and market development. She is a Member of the National Coal Council (an advisory board to the U.S. Secretary of Energy), Advisory Board Member of the Southeast Regional Carbon Sequestration Technology Training Program (SECARB-Ed), Advisor to the CCUS Research Coordination Network, and served as Director of Education, Outreach and Regulatory Compliance for the Big Sky Carbon Sequestration Partnership. Pamela is a member of the CSLF Financing Task Force, and an expert peer reviewer of the IEA Greenhouse Gas Technologies Conference and IEA Clean Coal Centre. She is an Adjunct Professor at Tuskegee University, serves as Advisor to the National Energy Education Development Project and the Inter-

University Student Initiative in Carbon Sequestration (ISICS). She received a BA in International Affairs and Middle East History from The George Washington University.

Lee Youngblood
Mississippi Power
Lee Youngblood is a native of Mississippi and serves as Mississippi Power's Kemper Communications Manager. Previously, he held positions in broadcasting and print journalism, and served as Press Secretary to U.S. Senator Trent Lott (1998 to 2007), as well as the Communications Director for the Disaster Recovery Division of the State of Mississippi. He holds a B.S. and M.S. in Mass Communication, Mississippi College.

ZHAO Yongpan
Shaanxi Yanchang Petroleum (Group) Co., Ltd.
Zhao Yongpan is Assistant Dean and Reservoir Engineer at the Research Institute of Shaanxi Yanchang Petroleum (Group) Co. Ltd. where is he is engaged in applied research on EOR in low-permeability reservoirs. He earned his master's degree from China University of Petroleum in 2010, majoring in oil and gas development.

3.4 List of Workshop Participants

Surname	First name	Organization
ACOSTA	Rafael	CFE
BAI	Jianming	Huadian Heavy Industries Co.,Ltd.
BOWERS	Kerry	Southern Company
BOWMAN	Keith	Tellus Operating Group
CARPENTER	Steven	ARI
CHEN	Dave	KEA
CHEW	Emily	MSCI
DOU	Jinliang	China Soda Indestry Association
FLATGARD	Spence	Capitol Resources LLC
GODEC	Michael	ARI
GUO	Hanguang	Qingdao Soda Ash Industrial Company Ltd
HART	Craig	Renmin University of China
JIN	Guo	BERUN Group
KHESHGI	Haroon	ExxonMobil Research and Engineering Company
KOEPPEN	Michael	Koeppen, Elliott & Associates, Ltd (KEA)
LIU	Tianjun	Huadian Heavy Industries Co.,Ltd.
LIU	Zheng	Huadian Heavy Industries Co.,Ltd.
MA	Zhong	Renmin University of China
MOTA	Jazmin	CFE
MOU	Frank	KEA

PANG	Guanglian	China Petroleum and Chemical Industry Federation (Department of International Cooperation)
POWELL	Guy	Exxon Mobil Corporation
RIVERA RODRIGUEZ	Esmeralda	Pemex
SMOUSE	Scott	U.S. Department of Energy
SUN	Weishan	China Petroleum and Chemical Industry Federation/ Leadership Team Member of China CCUS Project
TOMSKI	Pam	GCCSI
WANG	Shengli	BERUN Group
WANG	Jing	KBR
WENG	Hui	Member of China CCUS Project /China Petroleum and Chemical Industry Federation
XUE	Xuetong	China Petroleum and Chemical Industry Federation (General Office)
YAN	Xianghua	Huadian Heavy Industries Co.,Ltd.
YANG	Yong	China Huadian Engineering Co.,Ltd
YANG	Chuanwu	China National Chemical Engineering Co., Ltd.
YING	Jiahui	Renmin University of China
YING	Jufeng	China Huadian Engineering Co.,Ltd
YOUNGBLOOD	Lee	Mississippi Power
YUAN	Jian	SEDIN Engineering Co., Ltd.
ZHAN	Wenjuan	USCS - US Embassy, Beijing
ZHANG	Qinggeng	SEDIN Engineering Co., Ltd. CNCEC
ZHAO	Yongpan	Shaanxi Yanchang
ZHU	Jiayan	Renmin University of China
ZONG	Fan	Member of China CCUS Project /China Petroleum and Chemical Industry Federation

3.5 Workshop Feedback

Feedback forms were completed by 15 participants rating speakers based on "how useful" the talk for increasing the participant's knowledge of CCUS and relevance of CCUS. Based on a scale of "Low,", "Medium," and "High," all speakers were rated on average as medium to highly useful and relevant to increasing participant's knowledge of CCUS. Comments suggesting focusing on sharing experiences, encouraging more discussion, and more site visits.

3.6 Workshop Presentations

EWG 15/2013A

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