



# CO<sub>2</sub> CAPTURE & STORAGE

*international progress &  
future prospects*

## WORKSHOP SUMMARY

A workshop co-hosted by:  
The Royal Society  
The Royal Academy of Engineering  
IEA Coal Industry Advisory Board  
7/8 November 2007

International Energy Agency  
9, rue de la Fédération – 75015 Paris

## WORKSHOP PROGRAMME – Wednesday, 7 and Thursday, 8 November 2007

### OPENING SESSION: Setting the Scene

Chair for Day 1: Mr Steven F Leer, Chairman and Chief Executive Officer, Arch Coal & CIAB Chairman

Welcome address: Prof Richard Macrory, Barrister, Professor of Environmental Law

Director – Centre for Law and the Environment, University College London

### SESSION 1: The Compelling Case for CCS in CO<sub>2</sub> Mitigation Strategies

Chaired by Lord Oxburgh KBE FRS HonFREng, President, Carbon Capture and Storage Association

The Stern Review – the economics of climate change

Ms Hannah Ryder, International Climate Change Division, UK Department for Environment, Food and Rural Affairs and co-author of The Stern Review

CCS in the IEA's Energy Technology Perspectives 2006

Mr Neil Hirst, Director – Energy Technology and R&D, International Energy Agency

The Power to Reduce CO<sub>2</sub> Emissions in the US Electric Sector

Mr Henry A (Hank) Courtright, Senior Vice President, Electric Power Research Institute

Jumpstarting CCS in Europe – the need for and benefits of EU-wide policies

Mr Jan Panek, Head of Unit – Coal & Oil, DG TREN, European Commission

### SESSION 2: CCS Technology Status

Chaired by Mr Nick Otter OBE, Director – Technology and External Affairs, Alstom

CO<sub>2</sub> Capture Technology

Dr Malcolm Wilson, Director – Office of Energy and Environment & Adjunct Professor of Engineering and Graduate Studies, University of Regina

Carbon Capture and Storage – from strategy to commercial projects

Mr Reidulf Klovning, Special Advisor – Environment and Climate Change, StatoilHydro

Global CO<sub>2</sub> Storage Potential

Dr John Bradshaw, Chief Scientist – Carbon Dioxide Capture and Storage, Geoscience Australia

### SESSION 3: Public Policy Perspectives and Commercial Drivers

Chaired by Mr Noé van Hulst, Director – Long-term Co-operation and Policy Analysis, International Energy Agency

European Policy Perspective – how to deliver 10-12 CCS demonstrations?

Mr Charles Soothill, Senior Vice President – Technology, Alstom & Vice Chairman of European Technology Platform on Zero Emission Fossil Fuel Power Plants Advisory Council

Asia-Pacific Partnership and Technology Transfer – Cleaner Fossil Task Force

Mr Stuart Dalton, Director – Generation, Electric Power Research Institute

China Climate Change Policy and CCS Development

Dr YANG Fuqiang, Vice President, The Energy Foundation and Chief Representative – Beijing Office

Overview of CCS Research in India – inter-sectoral perspectives in science and technology

Dr (Mrs) Malti Goel, Adviser/Scientist 'G' and Member Secretary IS-STAC, Ministry of Science and Technology

### DAY 2: Introductory Remarks

Chair for morning: Mr Philip Ruffles CBE FREng FRS, Chairman of workshop organising committee

### SESSION 4: CCS Demonstration Projects

Chaired by Dr Don Elder, Chief Executive Officer, Solid Energy New Zealand

Making Clean Coal™ Real – how can we move Clean Coal™ from an idea into a reality?

Mr Wilf Olson PEng, Combustion Gas Clean Up Lead, SaskPower Clean Coal™ Project

FutureGen – a path to success – the right project at the right time

Mr Michael J Mudd, Chief Executive Officer, FutureGen Alliance

Japanese CCS Projects

Mr Yoshihiko Nakagaki, President, Electric Power Development Company (J-Power)

Biomass Co-firing – an early CCS opportunity

Ir Sjaak van Loo, Director, Procede Biomass BV, The Netherlands and Chair of IEA Bioenergy Task Force on Co-firing

Updates from CIAB Members Mr Matthias Hartung, Executive Board Member, RWE Power and Prof Allan Jones, Head of R&D

E.ON UK (on behalf of Mr Bob Taylor, Board Member for Distribution & Technology) on their European demo. project activities.

### SESSION 5: Impact of Legal, Regulatory and Public Perception Issues on Investment

Chaired by Mr Bill Koppe, Development Manager, Anglo Coal Australia

Legal Aspects of Storing CO<sub>2</sub> in the Marine Environment – London and OSPAR

Mr Tim Dixon, AEA Energy & Environment and Senior Policy Advisor to Energy Technologies Unit, UK BERR

Public Perception in Relation to the Potential Large-scale Commercial Deployment of CCS

Mr James J Dooley, Snr Staff Scientist, Joint Global Change Research Institute, Pacific Northwest National Laboratory / Battelle

Climate Policy Uncertainty and Investment Risk

Dr William Blyth, Associate Fellow, Chatham House, Sustainable Development Programme & Director, Oxford Energy Associates

### SESSION 6: Panel Discussion – Formulating an International Strategy for CCS

Chaired by Mr Steven F Leer, Chairman and Chief Executive Officer, Arch Coal & CIAB Chairman

Dr Jim Smitham, Deputy Director, CSIRO, Australia

Mr Tim Dixon, AEA Energy & Environment and Senior Policy Advisor to Energy Technologies Unit, UK BERR

Dr Steve Lennon, Managing Director – Resources & Strategy, Eskom

Dr GU Dazhao, General Manager, Department of Science & Technology Development, China Shenhua Energy Company

Mr Roger Wicks, Head of Energy, Anglo American

Dr Rolf Linkohr, Special Advisor to the European Commissioner for Energy and Director, Centre for European Energy Strategy

## Aims of the Workshop

To consider the science, technology, engineering, commercial, regulatory and policy challenges to deploying carbon dioxide capture and storage (CCS) technologies. Participants representing key international stakeholders from across Europe, Japan, North America, Australasia, South Africa, China and India also considered the timescales on which these technologies can be deployed and other issues such as the public acceptability of CCS.

## Discussion Issues

- Role of CCS in mitigating climate change
- Geological potential to store CO<sub>2</sub>, including interaction with holders of oil and gas rights
- Capture technologies, including the definition of “capture-ready” power plants
- Legal and regulatory issues, including the question of permanence
- Incentives, including international mechanisms, fiscal measures and carbon pricing
- Public acceptability
- Technology transfer

## Key Questions

- Is the development of CCS for fossil fuels progressing with sufficient urgency?
- Are there any residual technological barriers to the implementation of CCS?
- Can we rely on commercial markets to deliver CCS technologies without further action?
- If not, what measures do governments and regulatory authorities most urgently need to deliver and what more should industry itself be doing?
- How can CCS be encouraged in emerging economies where new coal-fired plants are being installed on a massive scale?
- How will high and volatile coal prices affect the uptake of CCS?
- Will progress with other low-emission technology options make CCS more or less important?
- What role can bio-fuels play in conjunction with CCS?
- The focus is on power generation with CCS, but what of other sectors, e.g. iron and steel, cement and transport?

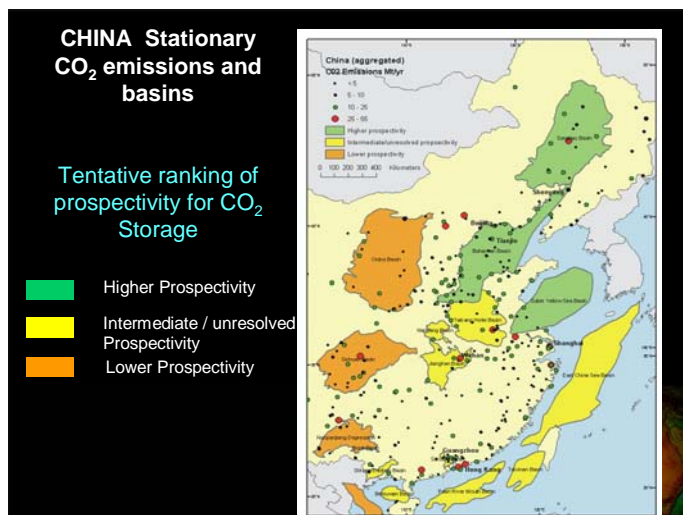
## Summary

This workshop, co-hosted by the Royal Society, the Royal Academy of Engineering and the IEA Coal Industry Advisory Board (CIAB), examined the future prospects for carbon dioxide capture and storage (CCS), and progress with its demonstration as a pivotal climate change mitigation technology. The workshop followed the annual CIAB plenary at which senior executives from coal-related industries considered the implications of future energy scenarios from the IEA's newly published *World Energy Outlook 2007*. Against a background of rising global energy demand and a continued reliance on fossil fuels for the next twenty-five years, the need to address climate change creates an additional challenge to future energy security. The necessary deep cuts in CO<sub>2</sub> emissions, as indicated by the IPCC and increasingly reflected in government policies, mean that urgent progress is needed on low-carbon technologies for power generation and other industrial processes, including CCS for coal- and natural gas-fired plants. The significant progress reported at the workshop on the legal and regulatory frameworks to enable CCS is encouraging, and included the steps now being taken by the European Commission to incorporate CCS in the EU Emissions Trading

Scheme. However, to promote its rapid demonstration and deployment alongside other technologies, governments must also take positive steps to reduce investment risk.



Many projects with the potential to demonstrate the viability of CCS for power generation were presented, with the common conclusion that these now require greater policy and financial support. Indeed, the political desire to address climate change must be turned into actions that lead to public understanding and support for the necessary and substantial costs involved. Assessments have shown that CCS could reduce these costs, but commercial-scale demonstration of the various CCS technology options is required to do this and also to build the confidence that would enable their widespread deployment, including in the world's rapidly developing economies, such as China and India. Many participants referred to the important role that the Kyoto Protocol's Clean Development Mechanism could play here, but only if CCS is made eligible for tradeable credits. A straw poll at the workshop revealed that the majority of those present believed that non-commercial CCS could be demonstrated at large scale by 2014, with commercial operation achieved between 2016 and 2020. These remain challenging targets that can only be achieved if the urgency expressed by some spreads to become a demand of the majority. Experienced practitioners warned that the remaining technical, economic, policy, regulatory and legal issues must be addressed simultaneously and with determination. In particular, proving the safe storage potential for CO<sub>2</sub> is as urgent as demonstrating the capture technologies and potentially as challenging as developing major oil and gas fields. Failure to succeed with CCS would force painful and perhaps unmanageable policy choices between pursuing energy security and addressing climate change. In this respect, CCS emerges as an indispensable part of the solution.



## Annex – Workshop Participants

### CIAB MEMBERS

Mr	Preston	CHIARO	Chief Executive – Energy, Rio Tinto	GBR
Mr	Andrea	CLAVARINO	Chairman, Assocarboni and Executive Vice President, Coeclerici Group, Assocarboni	ITA
Dr	Don	ELDER	Chief Executive Officer, Solid Energy	NZL
Mr	Robert H	GENTILE	President & CEO, Leonardo Technologies	USA
Mr	Matthias	HARTUNG	Member of the Executive Board, RWE Power	DEU
Mr	Jim	HENNESS	Chief Executive, Delta Electricity	AUS
Mr	Wayne	ISAACS	President & COO, BHP Billiton Energy Coal	ZAF
Mr	Steven F	LEER	Chairman & CEO, Arch Coal	USA
Dr	Steve J	LENNON	Managing Director – Resources & Strategy, Eskom	ZAF
Mr	C Wick	MOORMAN	Chairman, President & CEO, Norfolk Southern	USA
M.	Jean-Claude	MULLER	Président Directeur Général, ATIC Services	FRA
Mr	Yoshihiko	NAKAGAKI	President, J-Power (Electric Power Development Company)	JPN
Mr	Petr	PAUKNER	Chairman of the Board, Coal Energy	CZE
Mr	Doug	RITCHIE	Managing Director, Rio Tinto Coal Australia	AUS
Dr	Jürgen W	STADELHOFER	President & CEO, Coal & Minerals	DEU
Mr	Alain	VERRY	Operating Vice President of Fossil-Fired Generation & Engineering, EDF	FRA
Mr	Angel L	VIVAR RODRIGUEZ	Director of Energy Resources & Environment, UNESA	ESP
Mr	Roger	WICKS	Head of Energy, Anglo American	ZAF

### CIAB ASSOCIATES

Mr	Julian	BEERE	Vice President – Strategy, BHP Billiton Energy Coal	ZAF
Ms	Alison	BROWN	General Counsel & Company Secretary, Solid Energy	NZL
Ms	Sylvie	CORNOT- GANDOLPHE	Energy Advisor to Chairman, ATIC Services	FRA
Mr	Geoff	CROCKER	Chairman, SUEK AG	RUS
Mr	Stuart M	DALTON	Director – Generation Sector, Electric Power Research Institute	USA
Mr	Michael D	DANCISON	Director – New Generation Development, American Electric Power	USA
Dr	François	GIGER	Strategy Manager – Thermal Generation & Engineering Division, EDF	FRA
Mr	Dazhao	GU	General Manager, Department of Sci-tech Development, China Shenhua Energy Co.	CHN
Mr	Takenori	IWASAKI	Manager – Business Planning Department, J-Power (Electric Power Development Co.)	JPN
Prof	Allan	JONES	Head of Research & Development, E.ON UK	GBR
Mr	Kauno	KAIJA	Director – Group Services, Helsinki Energy	FIN
Mr	Robert (Bob) P	KING	President – CNX Land Resources & Senior VP of Administration, CONSOL Energy	USA
Mr	Bill	KOPPE	Development Manager, Anglo Coal Australia	AUS
Ms	Coretta	MAGONGOA	Executive Manager, Eskom	ZAF
Mr	Tim	MARPLES	Business Performance Manager, UK Coal	GBR
Mr	Wolfgang	MÜLKENS	Energy Analyst, Bundesverband der Deutschen Industrie	DEU
Mr	Fredrick D	PALMER	Senior Vice President – Government Relations, Peabody Energy	USA
Mr	Stan	PILLAY	Senior Divisional Manager – Sustainable Development, Anglo Coal	ZAF
Ms	Wendy	POULTON	General Manager – Corporate Sustainability, Eskom	ZAF
Ms	Maggi	RADEMACHER	Dept of Fuel Management and Residues, E.ON Kraftwerke	DEU
Dr	Hans-Wilhelm	SCHIFFER	Head – Energy Economics, RWE Power	DEU
Mr	Donald W	SEALE	Executive Vice President & Chief Marketing Officer, Norfolk Southern	USA
Mr	Deck	SLONE	Vice President – Investor & Public Relations, Arch Coal	USA
Mr	J Gordon (Skip)	STEPHENS	Washington Representative, Joy Global	USA
Dr	Martin	WEDIG	Manager – Business Development, Coal & Minerals	DEU
Mr	Colin	WHYTE	General Manager – Sustainable Development, Xstrata Coal	AUS
Mr	Ross H	WILLIMS	Vice President – Commercial Relations, BHP Billiton Mitsubishi Alliance	AUS
Mr	Xiuzhang	WU	Deputy Chief Engineer, Shenhua Group Corporation	CHN
Dr	Carl	ZIPPER	Associate Professor, Virginia Polytechnic Institute & State University	USA

### GUESTS

Mr	Milton	CATELIN	Chief Executive, World Coal Institute	GBR
Dr	John	TOPPER	Managing Director, IEA Clean Coal Centre	GBR

### WORKSHOP SPEAKERS & CHAIRS

Dr	William	BLYTH	Associate Fellow, Chatham House & Director, Oxford Energy Associates	GBR
Dr	John	BRADSHAW	Chief Scientist – Carbon Dioxide Capture and Storage, Geoscience Australia	AUS
Mr	Tim	DIXON	Snr Policy Advisor to Energy Technologies Unit, BERR, AEA Energy & Environment	GBR
Mr	Jim	DOOLEY	Senior Staff Scientist, Joint Global Change Research Institute, Battelle	USA
Dr	Malti	GOEL	Adviser/Scientist 'G' & Member Secretary IS-STAC, Ministry of Science & Technology	IND
Mr	Reidulf	KLOVNING	Special Advisor – Environment & Climate Change, Corporate HSE, StatoilHydro	NOR
Dr	Rolf	LINKOHR	Special Advisor to EU Commissioner for Energy & Director, Centre for European Energy Strategy	BEL
Prof	Richard	MCRORY	Barrister & Director – Centre for Law and the Environment, University College London	GBR
Mr	Wilf	OLSON	Combustion Gas Clean Up Lead, SaskPower Clean Coal Project	CAN
Mr	Nick	OTTER	Director – Technology and External Affairs, Alstom	GBR

Lord Ron	OXBURGH	President, Carbon Capture & Storage Association	GBR
Mr Jan	PANEK	Head of Unit – Coal & Oil, DG TREN, European Commission	BEL
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Mr Charles	SOOTHILL	Senior Vice President Technology, Alstom	CHE
Mr Sjaak	VAN LOO	Director, Procede Group	NLD
Dr Malcolm	WILSON	Director – Office of Energy and Environment, University of Regina	CAN
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#### WORKSHOP ORGANISING COMMITTEE

Dr Jon	GIBBINS	Senior Lecturer, Imperial College	GBR
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Dr Alan	WALKER	Policy Advisor, Royal Academy of Engineering	GBR

#### IEA, OECD & STAFF

Mr Kamel	BENNACEUR	Energy Analyst, IEA	INT
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Mr Jacek	PODKANSKI	Principal Administrator, IEA	INT
Mr Brian	RICKETTS	Energy Analyst – Coal, IEA	INT
Mr Christoph	SCHOLTEN	Counsellor, Permanent Mission of Germany to the OECD	DEU
Mr Noé	VAN HULST	Director – Long-term Co-operation and Policy Analysis, IEA	INT
Mr Mirko	ZAMBELLI	Second Secretary, Swiss Delegation to the OECD	CHE

#### WORKSHOP DELEGATES

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Mr Frédéric	DA SILVA LIMA	CO <sub>2</sub> Business Analyst, ALSTOM Global Power Sales	FRA
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Mr Thorsten	DIERCKS	Secretary General, European Association for Coal and Lignite	BEL
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Mr Olivier	IMBAULT	Vice President World Energy Conversion Market, Air Liquide	FRA
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Mr Robert	STASTNY	Environment & Energy Policy Manager, International Chamber of Commerce	FRA
Ms Debbie	STOCKWELL	International Climate Change Division, Dept. for Environment, Food & Rural Affairs	GBR
Mr Paul H	SUDING	Head of REN21 Secretariat, Renewable Energy Policy Network for the 21st Century	FRA
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## Organising Committee

Philip Ruffles (co chair) / Deck Slone, Arch Coal (co chair) / Keith Batchelor, Foster Wheeler / Stu Dalton, EPRI / Mike Dancison, AEP / Jon Gibbins, Imperial College / Richard Heap, Royal Society / Brian Heath, CIAB / Allan Jones, E.ON UK / Bill Koppe, Anglo Coal Australia / Ned Leonard, CEED / Nick Otter, Alstom / Lord Oxburgh / Brian Ricketts, IEA / Nick Riley, British Geological Survey / Hans Wilhelm Schiffer, RWE Power / Alan Walker, Royal Academy of Engineering / Martin Wedig, Coal and Minerals / Colin Whyte, Xstrata Coal.

## The Royal Society

The Royal Society, the national academy of science of the UK and the Commonwealth, is at the cutting edge of scientific progress. It supports many top young scientists, engineers and technologists. It influences science policy, it debates scientific issues with the public and much more. It is an independent, charitable body which derives its authoritative status from its 1400 Fellows and Foreign Members.

## The Royal Academy of Engineering

The Royal Academy of Engineering brings together the UK's most eminent engineers from all disciplines to promote excellence in the science, art and practice of engineering. Its strategic priorities are to enhance the UK's engineering capabilities; to celebrate excellence and inspire the next generation; and to lead debate by guiding informed thinking and influencing public policy.

## IEA Coal Industry Advisory Board

The IEA Coal Industry Advisory Board (CIAB) comprises a group of 40-50 members, typically senior executives of coal mining companies or major power utilities. It brings advice to the IEA on, for example, the continued use of coal as a secure source of energy and on measures to mitigate the environmental impact of coal use. The CIAB holds occasional workshops on topics of particular importance to the industry and IEA.



## Coal Industry Advisory Board

For more information about the IEA Coal Industry Advisory Board, please refer to [www.iea.org/ciab](http://www.iea.org/ciab), or contact Brian Ricketts at the IEA ([brian.ricketts@iea.org](mailto:brian.ricketts@iea.org)) or Brian Heath,, CIAB Executive Co-ordinator ([mail@ciab.org.uk](mailto:mail@ciab.org.uk)).

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