INTERNATIONAL TEST NETWORK FOR CO_2 CAPTURE: REPORT ON 4th WORKSHOP
(5th October 2002, Kyoto, Japan)

Report Number PH4/13
November 2002

Table of Contents

INTERNATIONAL TEST NETWORK FOR CO_2 CAPTURE: REPORT ON 4th WORKSHOP

(5th October 2002, Kyoto, Japan)

1. Overview of the network and past workshops

This workshop was the fourth in a series to discuss co-operation in development of MEA and related solvents to capture CO_2 from power plant flue gases. The previous events were, in Gaithersburg, USA in October 2000, and Calgary, Canada in November 2001, and Apeldoorn, Netherlands in May 2002.

Carbon dioxide capture and disposal is now included in most OECD countries' energy policies and R&D programmes as a potential contributor to carbon dioxide mitigation strategies. Techno-economic studies have generally concluded that in any widespread deployment the largest element of capital and operating costs will be associated with the capture element of the chain.

The overwhelming majority of fossil fuel fired power plants produce a low pressure low CO_2 concentration flue gas and actions to remove these are first likely to be based on some form of solvent scrubbing with separate solvent regeneration and recycle.

A number of proprietary processes capable of such capture are on the world market and have been for many years, based on the use of monoethanolamine (MEA) or a derivative of it. However, these have not been developed for large power plant operations and could be much improved in efficiency and economic performance. Considerable R&D and systems modelling is being undertaken to these ends. The network encourages collaboration and speeds the prospects for meaningful demonstration and dissemination of CO_2 capture and storage.

Gaithersburg

At the Gaithersburg workshop participants identified a number of areas for potential technical co-operation and/or information exchange. These included:-

- Solvent design to suit the particular composition of flue gases, especially the presence of SO_2.
- Absorption column design, in particular identification of suitable packings and packing heights
- Integration of the energy system within the power plant flowsheet and minimising the thermal penalty associated with solvent regeneration.
- Modelling and evaluation to determine potential economies of scale and impact on sent out power costs
- Collaboration and possibilities for cost sharing in R&D activities.

Arising from the above considerations 4 tasks were identified for further investigation:-

A. Process Simulation
B. Process and Economic Assessment
C. Innovation at Test Facilities
D. Feasibility Study

Calgary

The Calgary workshop was convened to further develop possibilities associated with Task A and to some extent Task B. Presentations were made on the following topics

- a review of the status and confidence in available vapour – liquid equilibria data
- rate data modelling
- mass transfer
- the International Test Centre (ITC)
- the Boundary Dam project, GTI's test facilities
- the benefits and limitations of pilot plant work software issues and systems

Apeldoorn

The primary intentions for this workshop were to

- advance work on simulation and modelling
- begin review of practical results
- consider finances for future events

The delegate list showed an increase in European attendees and a decline in USA and Canadian citizens. Hence, the Agenda contained a number of country reviews and up-dates on the general topic of CO_2 capture and storage before moving to specific activities related to process modelling, systems modelling and economics and practical activities concerned with MEA and similar solvent based CO_2 capture.

An outstanding action from this meeting was to provide information on the IEA GHG database on RD&D projects on carbon capture and storage. This is now available on http://www.co2sequestration.info. At the moment it contains some 84 entries of which 31 relate to capture.

A highlight was the identification by the system modellers of ways of collaboration, which were developed in an off-line meeting between meetings.

2. Kyoto Workshop attendance and agenda

This was the biggest workshop so far with 39 registrants from 9 countries. Breakdown by country and type of organisation is given below. It reveals the dominance of the fundamental research community.

Attendee Origins

Canada	13	Government	6
Japan	11	Industrial companies	9
USA	7	Research Organisations (not universities)	9
UK	2	Universities	15
Netherlands	2		
Australia	1		
Italy	1		
Sweden	1		
Switzerland	1		
Total	**39**	**Total**	**39**

Because this was a one day event only 11 presentations were made in 4 sessions. The fullest session concerned the system modelling and process economics reflecting the increasing co-operation and exchange between Canadian, US and UK contributors. For the first time there was a significant

Japanese presence, which included an overview introduction by NEDO and two excellent presentations by MHI and RITE. New insights into the rate data for MEA and its potential fit to available models were also revealed and the delegates heard about the intentions of a Canadian consortium to have retrofit and a new build power plants with solvent based CO_2 capture up and running in 2007 and 2010.

The full Agenda is at Annex I and the delegate list at Annex II.

3. Presentations by Attendees

Presentations were made as listed below. Copies of slides appear in the same order in Annex III.

- **John Topper**, IEA Environmental Projects Ltd, UK – Background and Objectives for this Workshop. This was aimed at first time attendees and summarised the aims and objectives of the series of workshops and introduced the agenda for this one.

- **Koichi Kudo** of NEDO on the Japanese Government programme in carbon capture and storage. He highlighted issues associated with public acceptance of CO_2 storage and capture and went on to emphasise the need to reduce capture costs and gave examples of R&D on membranes and absorption systems which NEDO are supporting.

- **Ed Rubin** on behalf of a group including Universities of Waterloo, Canada, Imperial College, UK and Carnegie Mellon, USA presented some thoughts on future activities for the group. These are reflected in section 4 of this report (below).

- **Shinichirou Morimoto** of RITE gave some comparative process performance and economic analysis for post combustion capture based on a 1000MWe coal fired PC plant using MEA or Pressure Swing Adsorption or Membranes. He presented estimated figures for internal energy consumption for each technology and derived costs per tonne CO_2 avoided. This were $46/tonne for MEA; $64/tonne for PSA; and $59/tonne for a hollow fibre polyamide membrane. He also suggested some ways in which the internal energy penalties might be reduced, and finally gave a summary of RITE's current practical evaluations of the polyamide membrane system.

- **Jon Gibbins** of Imperial College on the potential for energy savings in integrating capture plant with conventional PC power plant. He reminded the audience that it was unsafe to simply develop bolt on technology for retrofit since this inevitably missed opportunities to reduce internal energy consumption arising from optimised integration. He also pointed out that real plant probably would need to operate if the CO_2 capture plant is down, operate at part loads and load follow satisfactorily and in an ideal world would need to be upgradeable to allow for things such as new solvents, packings etc.

  He presented some comparisons starting from published studies of IEA GHG and EPRI which modelled CO_2 retrofit to PC plant showing losses in net efficiency of around 28%. By using KS1 (MHI's) solvent he indicated a reduced penalty of about 4% to around 24% which in turn reduced the cost of an avoided tonne of CO_2 from 43-45$/tonne to around $37/tonne. He then looked at the steam cycle and by choosing to extract heat from various parts for use in solvent regeneration he predicted further potential reductions to around 34-36$/tonne CO_2. If confirmed this indicates an early potential for about a 20% reduction in solvent based capture costs.

- **Colin Alie**, *et al,* of University of Waterloo with and up-date on the use of Aspen Plus in modelling MEA based capture. He reviewed the fit of Aspen Plus embedded VLE data for MEA/CO_2 and concluded that over the temperature range of interest (around 120C) there was a good fit – more on this in the later presentation of Rochelle, *et al*. Using IEA GHG base case of a 500MWe PC plant he reported on the evaluation of two different retrofit routes. In the first a supplementary CCGT plant is built to maintain station output. In the second the de-rating is

accepted as a result of over 40% of the steam being extracted for operating the CO_2 regenerator reboiler. Again this emphasises the importance of carefully considered integration of retrofit CO_2 capture with the existing steam cycle in order to minimise the efficiency penalty.

- **Ed Rubin and Anand Rao** of Carnegie Mellon University on potential to reduce capture costs. Using the NETL sponsored IECM – Integrated Environmental Control Model, they have looked at capture for a new PC plant and are in the early stages of developing a similar appraisal for IGCC, with and without capture. Interesting work in progress is examining capture costs with a probabilistic approach. For instance estimates ranging from \$40-\$80/tonne of CO_2 with a 50% point at around \$54/tonne were shown based on current knowledge. Speculation on reducing both the spread of possible costs and their absolute values was presented and suggestions made as to which plant areas might contribute to equipment cost and energy consumption reductions.

  This modelling system was developed with US DoE funding and can be downloaded from the web site at http://www.iecm-online.com . Queries to Anand Rao on abr@cmu.edu .

  Nobuo Imai of Mitsubishi Heavy Industries on the application and use of their KS-1 sterically hindered amine solvent. Mr Imai showed that compared to MEA, KS-1 has better CO_2 loadings, lower heat demand for regeneration, minimal degradation to form heat stable salts and much lower corrosivity. He showed some cost data, which indicated that operating costs would be about 30% lower than for MEA and overall cost/tonne of CO_2 avoided about 20% lower

  The original investigation into solvents and packings had been done on a slip-stream pilot plant at the Nanko power plant. There was now a 160t/d CO_2 capture facility at a Urea plant in Malaysia using KS-1 solvent.

- **Paitoon Tontiwachwuthikul** of University of Regina (International Test Centre) reminded the delegates of the extensive facilities, staffing and partnership arrangements at the International test Centre, described the range of pilot and demonstration plant available and gave an up-date on some of the findings on plant data.

  The latter related to work on CO_2 loadings in MEA solutions of varying strengths, and the related rate data; also some investigations into higher capacity absorption column packings and some examination of alternative amine solvents.

- **Bill Richards** of Nova Scotia Power on the aspirations of the Canadian Clean Power Coalition. The CCPC is conducting studies to assess the feasibility and costs of retrofitting pulverised coal fired power stations with CO_2 capture and it will also assess in less detail the costs of new plants on a greenfield site. Three Canadian fuels will be considered when selecting the most suitable plant: bituminous coal (Nova Scotia/Ontario), sub-bituminous coal (Alberta) and lignite (Saskatchewan). The main studies that will be conducted will be:

  - Evaluation of amine scrubbing and CO_2/O_2 combustion in new and retrofit plants
  - Evaluation of coal gasification options in new and retrofit plants
  - Evaluation of retrofit emission control options

  The work package on retrofit emission control options will calculate the costs of retrofits to control emissions of other pollutants (SO_x, NO_x, particulates and mercury) to the standard that would be achieved by a plant with CO_2 capture. This will enable the net cost of capturing CO_2 to be calculated. The CCPC will also carry out some other smaller studies, for example to investigate options for storing captured CO_2 in Canada.

- **Gary Rochelle** of University of Texas on findings in some recently completed studies on MEA. These looked at rate data and models in wetted wall columns, forcing of data fits with model predictions, rate optimisation, sensitivity to absorber and stripper heights and sensitivity to stripper

pressure. Amongst many interesting observations, the pros and cons of the presence of heat stable salts evinced most reaction from delegates. Although these salts contribute to deteriorating absorber performance a certain level actually enhances CO_2 loading and improves release in the stripper. Other conclusions indicated that :

- Stripper pinches set optimum solvent rate
- Heat duty is not sensitive to stripper height
- Optimum stripper pressure around 2 atm
- Absorber T bulge dramatic
- Absorber intercooling ineffective

4. Direction of future activities

Ed Rubin led a brief discussion on whither the network in order to attempt to focus the supply of data and the systems modelling. A brief presentation is in Annex 3 (the third in the list). He pointed out that so far this was a voluntary group, with no funding and an evolving set of participants. He suggested that it was time to develop some focus, and below in the text box are the suggestions from one of his slides

What to Attempt?
Case study of a power plant linking all elements of the interaction hierarchy
– new plant?
– retrofit plant?
IEA premises as a starting point
Expectations for the next meeting (9 months)
– tightening the network
– informal subgroups
– defining information needs & connections
– preliminary results
– new questions and issues

Since there seemed to be no disagreement about the needs and expectations, the co-ordinator will be in touch to develop some of these themes over the next few months.

5. Resources

Immediately following the workshop the IEA Greenhouse Gas R & D Programme Executive Committee met in Tokyo on 7-8 October. In presenting the development of this network to members John Topper (co-ordinator) pointed out that only one individual (from industry) had attended all 4 workshops and that the influence of location and implications for travel budgets, particularly for some of the key academic researchers. It was agreed that where the co-ordinator considered attendance of particular key individuals might be supported by modest subsidy of travel (ie for non-funded academics) assistance could be rendered from IEA GHG resources.

He reminded workshop delegates that an Expression of Interest to the European Commission for network funding had been submitted in May 2002. All the EOI's had now been published on their Cordis web site. It was notable that a similar EOI was submitted by a CO_2 Net team under the leadership of TNO (Paul Feron). How the Commission intended to proceed in terms of what to support, when to invite proposals and tendering procedures was still unclear. IEA Environmental Projects Ltd would prefer to collaborate rather than compete and are awaiting developments.

6. Next Meeting(s)

National Energy Technology Laboratories (NETL) in the USA have provisionally agreed to host the 5th Workshop in the Pittsburgh area in May or early June 2003. There remains a possibility of associating this workshop with 2nd National Carbon Sequestration Conference, which is intended to take place at around the same time.

Thereafter, it would be the intention to hold the 6th workshop in Europe at beginning of 2004. Offers from potential European hosts would be welcome. The 7th workshop will probably be in association with the GHGT7 conference in Vancouver in September 2004.

7. Thanks and Acknowledgements

All participants wish to thank Dr Takekawa of NEDO who generously acted as host and supplied a room with very good presentational facilities, lunch and refreshments.

8. Contacting the Co-ordinator

The IEA Greenhouse Gas R&D Programme co-ordinate the development of this network and arrange the workshops.

Queries about or copies of this report can be obtained by contacting:

either John Topper john.topper@iea-epl.co.uk
or Paul Freund paul@ieagreen.demon.co.uk
or via the "feedback" facility in the IEA GHG website's home page http://www.ieagreen.org.uk

ANNEX I

Workshop Agenda

CO_2 Capture Test Network – Kyoto Workshop

Saturday, 5th October 2002

0900 – 0915 hrs	REGISTRATION
0915 hrs	**SESSION 1 – Welcome, Introduction and Review**
John Topper For IEA GHG	Welcome and Introduction Dr Takekawa and Koichi Kudo for NEDO John Topper for IEA Greenhouse Gas R&D Programme
0945 hrs	**SESSION 2 – SYSTEMS MODELLING and ECONOMICS**
Peter Douglas University of Waterloo	1) Opening Remarks by Peter Douglas and Ed Rubin on vision for future collaboration in systems modelling. 2) CO_2 Separation process review by RITE – Japan 3) MEA capture systems integration by Jon Gibbins, Imperial College – UK 4) Energy Integration of MEA based Capture on a Coal Fired Power Plant by Colin Alie, University of Waterloo – Canada 5) Potential to Reduce Capture costs by Ed Rubin and Anand Rao, Carnegie Mellon University – USA 6) General Discussion
1230 hrs	LUNCH
1400 hrs	**SESSION 3 – PILOT PLANT AND PROCESS STUDIES**
Malcolm Wilson University of Regina	1) CO_2 Capture Technology of KS-1by Nobuo Imai and Kazuo Ishida of MHI Japan 2) Up-date on work by I TC Regina, Paitoon Tontiwachwuthikul – Canada 3) Canadian Clean Power Coalition by Bill Richards of Nova Scotia Power 4) General Discussion
1530 hrs	BREAK
1600 – 1645 hrs	**SESSION 4 – FUNDAMENTAL STUDIES**
Gary Rochelle University of Texas	Modelling of CO_2 Capture by Gary Rochelle, University of Texas – USA
John Topper 1700 hrs	NEXT STEPS AND SPRING 2003 WORKSHOP FINAL REMARKS AND CLOSURE

ANNEX II

CO_2 Capture Test Network

5 October 2002 – Kyoto, Japan

DELEGATE LIST

Colin Alie, Graduate Student
University of Waterloo
Department of Chem Engineering
Waterloo, Ontario CANADA
N2L 3G1
Tel: +1 519 888 4567 ext 2913
Fax: +1 519 746 4979

Marie Anheden
Vattenfall Utveckling AB
Stockholm 162 87
Sweden
Tel: +46 8 739 6212
Fax: +46 8 739 6802
marie.anheden@vattenfall.com

Andy Aroonwilas
University of Regina
Faculty of Engineering
Regina, Saskatchewan CANADA
S4S 0A2
Tel: +1 306 585 3565
Fax: +1 306 585 4855
aroonwi@uregina.ca

John Barrie, Technical Director
Fluor Daniel Canada Inc.
55 Sunpark Plaza SE
Calgary, Alberta CANADA
T2X 3R4
Tel: +1 403 537 5228
Fax:
john.barrie@fluor.com

Amit Chakma, Professor
University of Waterloo
Department of Chemical Engineering
Waterloo, Ontario CANADA
N2L 3G1
Tel:
Fax:
achakma@admmail.uwaterloo.ca

Tim Culliane
Graduate Student
University of Texas at Austin
Department of Chemical Engineering
Austin, TX 78712, USA
Tel: +1 512 471 7230
Fax: +1 512 475 7824
jculln@che.utexas.edu

Jon Davis
Principal Coal Technologist
Rio Tinto Technical Services
2 Kilroe Street
P O Box 2207
Milton, QLD 4064
Australia
Tel: +61 7 3327 7617
Fax: +61 7 3327 7640
jon.davis@riotinto.com

Eric Croiset
Asst Prof Chemical Engineering
University of Waterloo
Department of Chemical Engineering
Waterloo, Ontario CANADA
N2L 3G1
Tel: +1 519 888 4567 ext 6472
Fax: +1 519 746 4979
ecroiset@uwaterloo.ca

Peter Douglas
Professor
University of Waterloo
Department of Chemical Engineering
Waterloo, Ontario CANADA
N2L 3G1
Tel: +1 519 888 4567 ext 2913
Fax: +1 519 746 4979
pdouglas@cape.uwaterloo.ca

Alain Bill
Project Leader, CO_2 & Climate Change
Alstom Ltd
Segelhof 1
5405 Baden-Dattwil
Switzerland
Tel:
Fax:
alain.bill@power.alstom.com

Paul Feron
TNO Milieu, Energie en Procesinnovatie (TNO-MEP)
Business Park E.T.V.
Laan van Westenenk 501
Postbus 342, Apeldoorn 7300 AH
The Netherlands
Tel: +31 55 549 3151
Fax: +31 55 549 3410
p.h.m.feron@mep.tno.nl

Jon Gibbins, Senior Lecturer
Imperial College, Thermofluids Section
Mechanical Engineering Department
London SW7 2BX
UK
Tel: +44 20 594 7036
Fax: +44 20 823 8845
j.gibbins@ic.ac.uk

George Goff, Graduate Student
University of Texas at Austin
Department of Chemical Engineering
Austin, TX 78712
USA
Tel: +1 512 471 7230
Fax: +1 512 475 7824
goff@che.utexas.edu

Koichi Kudo
Global Environment Technology Development Department, NEDO
Sunshine 60, 30F
1-1, 3-Chome Higashi-Ikebukuro
Toshima-Ku, Tokyo 170-6028
Japan
Tel: +81 3 3987 9369
Fax: +81 3 5391 1744
kudokic@nedo.go.jp

Shuji Yumitori
Global Env't Technology Development Department, NEDO
Sunshine 60, 30F
1-1, 3-Chome Higashi-Ikebukuro
Toshima-Ku, Tokyo 170-6028
Japan
Tel: +81 3 3987 9368
Fax: +81 3 5391 1744
yumitorisji@nedo.go.jp

Raphael Idem,
University of Regina
Faculty of Engineering
Regina, Saskatchewan CANADA
S4S 0A2
Tel: +1 306 585 4160
Fax: +1 306 585 4556
raphael.idem@uregina.ca

Nobuo Imai, Project Manager
Mitsubishi Heavy Industries, Ltd.
Environmental Project Department
3-3-1 Minatomirai
Nishi-ku, Yokohama 220-8401
Japan
Tel: +81 45 224 9331
Fax: +81 45 224 9933
nobuo_imai@hq.mhi.co.jp

Kazuo Ishida, Process Engineering Manager
Mitsubishi Heavy Industries,
3-3-1 Minatomirai
Nishi-ku, Yokohama 220-8401
Japan
Tel: +81 45 224 9754
Fax: +81 45 224 9948
kazuo_ishida@hq.mhi.co.jp

Daniel Jansen
System Assessment Group
Netherlands Energy Research Foundation (ECN)
Business Unit Clean Fossil Fuels
P O Box 1, Petten 1755 ZG
The Netherlands
Tel: +31 224 56 4571
Fax: +31 224 56 8504
jansen@ecn.nl

Pete McGrail
Battelle Memorial Institute
Global Change Group
901 D St. SW, Suite 900
Washington, DC 20024
USA
Tel: +1 202 646 7810
Fax: +1 202 646 5233
mcgrailp@battelle.org

Anand Rao
Carnegie Mellon University
Dept. of Engineering & Public Policy
129 Baker Hall
Pittsburgh, PA 15213
USA
Tel: +1 412 268 5605
Fax:
abr@andrew.cmu.edu

Shinichirou Morimoto
Chemical Research Group
RITE
9-2 Kizugawadai, Kiz-cho
Soraku-gun
Kyoto 619-0292, Japan
Tel: +81 774 75 2306
Fax: +81 774 75 2319
morimo@rite.or.jp

Shingo Kazama
Senior Researcher
RITE
9-2 Kizugawadai, Kiz-cho
Soraku-gun
Kyoto 619-0292, Japan
Tel: +81 774 75 2306
Fax: +81 774 75 2319
kazama@rite.or.jp

Richard Rhudy
EPRI
3412 Hillview Avenue
Palo Alto, CA 94304-1395
USA
Tel: +1 650 855 2421
Fax: +1 650 855 8759
rrhudy@epri.com

Gary T Rochelle, Professor
University of Texas at Austin
Department of Chemical Engineering
Austin, TX 78712
USA
Tel: +1 512 471 7230
Fax: +1 512 475 7824
gtr@che.utexas.edu

Ed Rubin
Carnegie Mellon University
Dept. of Engineering & Public Policy
129 Baker Hall
Pittsburgh, PA 15213
USA
Tel: +1 412 268 5897
Fax: +1 412 268 1089
rubin@andrew.cmu.edu

Kiyotaki Arai
NEDO, Global Environment Technology Dept.
1-1, 3-chome, Hiashi-Ikebukuro
Toshima-ku, Tokyo 170-6028
Japan
Tel: +81 3 3987 9369
Fax: +81 3 5391 1744
araikyt@nedo.go.jp

Tohmei Takekawa, Director Global Environment Technology Dept., NEDO 1-1, 3-chome, Hiashi-Ikebukuro Toshima-ku, Tokyo 170-6028 Japan **Tel:** +81 3 3987 9369 **Fax:** +81 3 5391 1744 takekawatmi@nedo.go.jp	Kelly Thambimuthu CANMET Energy Technology Centre Natural Resources Canada 1 Haanel Drive Nepean, (Ottawa) Ontario CANADA K1A 1M1 **Tel:** +1 613 996 5759 **Fax:** +1 613 992 9335 kelly.thambimuthu@nrcan.gc.ca	Paitoon Tontiwachwuthikul, Professor of Engineering University of Regina Faculty of Engineering Regina, SK CANADA S4S 0A2 **Tel:** +1 306 585 4160 **Fax:** +1 306 585 4556 paitoon@uregina.ca
John Topper, Managing Director IEA Environmental Projects Ltd Gemini House 10-18 Putney Hill London SW15 6AA UK **Tel:** +44 208 246 5261 **Fax:** +44 208 780 1746 john.topper@iea-coal.org.uk	Amy Veawab, Assistant Professor University of Regina Faculty of Engineering Regina, Saskatchewan CANADA S4S 0A2 **Tel:** +1 306 585 5665 **Fax:** +1 306 585 4855 amy.veawab@uregina.ca	Malcolm Wilson, University of Regina 150 - 10 Research Drive Regina, Saskatchewan CANADA S4S 7J7 **Tel:** +1 306 337 2287 **Fax:** +1 306 337 2301 mwilson@cas.uregina.ca
Piergiorgio Zappelli EniTecnologie Italy **Tel:** **Fax:** pzappelli@mail.enitecnologie.eni.it	Frank Mourits Climate Change Technologies Natural Resources Canada 580 Booth St (14F/C4) Ottowa, Ontario K1a OE4 **Tel:** +1 613 947 3482 **Fax:** +1 613 995 6146 fmourits@nrcan.gc.ca	Bill Richards Senior Engineer Env'l Services Nova Scotia Power Inc PO Box 29 Mill Pond Road, Point Aconi Bras d'Or, Nova Scotia CANADA B1Y 3Y6 **Tel:**+1 902 736 1828 **Fax:** +1 902 736 0564 William.richards@nspower.ca
Miho Nakamura RITE 9-2 Kizugawadai, Kiz-cho Soraku-gun Kyoto 619-0292 Japan **Tel:** +81 774 75 2306 **Fax:** +81 774 75 2319 nakamura@rite.or.jp	Tadahashi Maruyama Chief Researcher RITE 9-2 Kizugawadai, Kiz-cho Soraku-gun Kyoto 619-0292 Japan **Tel:** +81 774 75 2306 **Fax:** +81 774 75 2319 maruyama@rite.or.jp	Masaki Iijima, Manager Planning & Development Group, Mitsubishi Heavy Industries, Ltd. 3-3-1 Minatomirai Nishi-ku, Yokohama 220-8401 Japan **Tel:** +81 45 224 9400 **Fax:** Masaki01_iijima@hq.mhi.co.jp

ANNEX III

PRESENTATIONS

Please refer to the individual presentations (on the CD)

John Topper, IEA Environmental Projects Ltd	**ANNEXIII–1 Topper.ppt**
Koichi Kudo, NEDO	**ANNEXIII–2 Kudo NEDO.ppt**
Edward Rubin	**ANNEXIII–3 Rubin1.ppt**
Shinichirou Morimoto, RITE	**ANNEXIII–4 RITE.ppt**
Jon Gibbins, Imperial College	**ANNEXIII–5 Gibbins.ppt**
Colin Alie *et al,* University of Waterloo	**ANNEXIII–6 AlieWaterloo.ppt**
Edward Rubin and Anand Rao	**ANNEXIII–7 Rubin-Rao.ppt**
Nobuo Imai, MHI	**ANNEXIII–8 Imai.ppt**
Paitoon Tontiwachwuthikul, ITC	**ANNEXIII–9 PT-ITC.pdf**
Bill Richards, Nova Scotia Power	**ANNEXIII–10 RichardsCCPC.ppt**
Gary Rochelle, University of Texas	**ANNEXIII–11 Rochelle.ppt**