Coalbed Methane, A Fossil Fuel Resource with the Potential for Zero Greenhouse Gas Emissions – the Alberta, Canada Program 1996 -2009: A Summary

Introduction

The Alberta Research Council, Inc. (ARC) of Alberta, Canada, led a group of provincial, national and international organizations to exploit coalbed methane (CBM) by testing a novel process of injecting carbon dioxide (CO_2) into Alberta's vast, deep, unmineable coal beds to release the trapped methane. This process is called Enhanced Gas Recovery (EGR) or Enhanced Coalbed Methane (ECBM) and is similar to the popular practice of using CO_2 injection to enhance production from oil reservoirs. With coal-based EGR, the injected CO_2 is adsorbed in the coal and stored in the matrix of the coal seams, releasing the trapped methane into the coal cleats that can be produced and sold for profit.

Future work in this area can lead to the design of efficient null-greenhouse-gas emission power plants that are fuelled either by mineable coal or by the methane released from the deep coal reservoirs. In this closed CO_2 process, the waste CO_2 produced from the coal burning or methane-burning power plants is injected into the CBM reservoirs to produce more methane, and the cycle continues. In addition, a geological sink is established in the coal beds, virtually eliminating any release of CO_2 to the atmosphere. In the future, bacterial processes using coal as an energy source may be developed to convert the CO_2 back to methane, thus extending the cycle and making it sustainable. An abundance of deep coal beds in Canada and the USA makes geological storage of CO_2 applicable to many areas in North America where coal-burning power plants are located.

ARC is not the first to pilot this process. Burlington Resources has successfully injected CO_2 into relatively high permeability coalbeds in the San Juan basin in the USA. They are stimulating coalbed methane production and recovery. The injected CO_2 is adsorbed into the coal matrix and remains in the ground after completion of gas production. However, further testing and demonstration are needed to apply this process to low permeability reservoirs such as those found in Alberta, Canada and elsewhere in the world.

Summary

The ARC-led project had two main objectives:

• ***to reduce greenhouse gas emissions by subsurface injection of CO_2 into deep coalbeds; and***

• ***to enhance coalbed methane recovery factors and production rates as a result of CO_2 injection.***

The overall program was divided into five phases:

I. The proof of concept study – initial assessment and feasibility of injecting carbon dioxide, nitrogen and flue gases into the low permeability bituminous Mannville coals of Alberta.

II. The design and implementation of a CO_2 micro-pilot test following Amoco Production Company procedures.

III. The design and implementation of flue gas (CO_2 + N_2) micro-pilot tests.

IV. Source – sink matching, simulator improvements and economic assessment model.

V. Extension of micro-pilots to lower rank bituminous and higher rank anthracitic coals

Each phase followed four steps:

i. The Resource: To characterize the resource properties of Alberta CBM reservoirs and identify the best geological site for a multi-well pilot.

ii. Enhanced Production: To assess the CBM reservoir response to injected flue gas compositional changes.

iii. Reservoir Simulation Software: To improve the predictive capability of ECBM reservoir simulators.

iv. Surface Facilities: To identify flue gas sources and calculate the cost of enriching the CO_2-component of the flue gas supply and delivery to the CBM reservoir.

An iterative process is used combining the data collected from these four steps to complete an economic evaluation of the CO_2-ECBM recovery process in order to justify multi-well pilot demonstrations.

Phase I (1997-1997)

A paper study was completed to see if injected gases (CO_2) would stay in a deep coal seam (Mannville at 1260 meters) while enhancing CH_4 production. Computer modeling indicated that this was possible. Results also showed reservoir storage from two to three times the amount of CO_2 injected versus CH_4 produced in a coal seam. Based on the success of Phase I, the project passed the first go/no-go decision and proceeded to Phase II.

Phase II (1997-1999)

Phase II was comprised of three tasks: (1) geology, geotechnical and engineering, (2) numerical modelling, and (3) a micro-pilot field test.

The field test was carried out in an existing Gulf Canada well at Fenn-Big Valley, Alberta. The test consisted of a CO_2 injection/soak/production single well test and was designed to meet three primary goals. The first goal was to accurately measure data while injecting CO_2 into and producing CO_2 and methane from a single well using a "Huff and Puff" strategy. The second goal was to evaluate the measured data to obtain estimates of reservoir properties and sorption behaviour. The third goal was to use simulation models to predict the behaviour of a large scale pilot project or full field development. This phase is a preliminary and necessary step leading to the planning of a full-scale 5-spot pilot test.

The field test was a success. Results supported the conclusions of Phase I, showing substantial enhanced methane production as a result of CO_2 injection (see Figure 1). All three primary goals established for the test were met. The first goal was met as the data set that was collected is of high quality. The second goal was met as the data were evaluated to obtain accurate estimates of reservoir properties and sorption behaviour. The third goal was met as simulation models were used to conclude that a full-scale pilot CO_2 - EGR project is technically possible at the Fenn-Big Valley location but not currently economic. Phase II was successfully completed in April 1999.

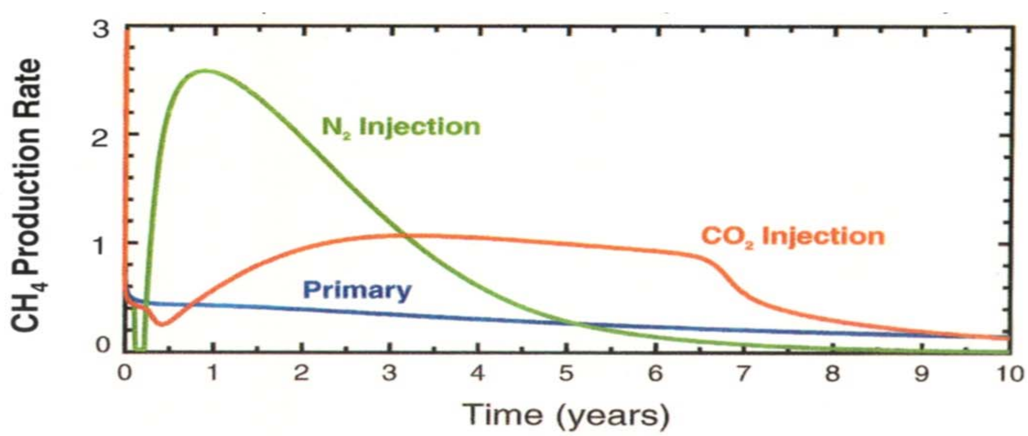

Figure 1. *Primary, nitrogen and carbon dioxide injection scenarios for enhanced coalbed methane recovery at Fenn-Big Valley. Injection is at constant flow rate. Production rate is normalized.*

Phase III (1999-2001)

Based on Phase II results, the project passed the second go/no-go decision and proceeded to Phase III. We began the 1999/2000 efforts by evaluating options for the treatment of flue gases, compression, and the associated economics to optimize CO_2 storage and methane production both at the pilot and commercial scales. Then we drilled and completed a second well and performed a simulated flue gas micro-pilot test. This was the world's first pilot test of injecting flue gas into coal seam.

In October 1999, the second well was successfully drilled and completed at Fenn-Big Valley in the Mannville coals. Core samples were collected to allow accurate determination of the gas-in-place value, gas composition, and gas storage capacity. Two micro-pilot tests were performed on the new well in the spring of 2000, one by injecting pure nitrogen and the other by injecting a 50/50 mixture of CO_2 and N_2. Meanwhile, in the original well a simulated coal-fired flue gas was injected by using the exhaust from a compressor engine used for underbalanced drilling (flue gas composition 13% CO_2, 87% N_2). The combination of nitrogen and carbon dioxide may result in greater hydrocarbon recovery without maximizing carbon dioxide sequestration. The results of these micro-pilot tests were used to design a multi-well pilot to be installed in the future phases of development.

In terms of the numerical modelling tool, the three software products evaluated were adequate for predicting primary production of coalbed methane. However, only one was suitable for modelling flue gas injection. None of the reservoir simulation software products were capable of accurately predicting the produced gas composition observed during the field test. Improved understanding of the process mechanisms, for example, multiple gas sorption and diffusion, and changes in coal matrix volume due to sorption or desorption of CO_2, was needed to guide the future development of the simulation models.

A surface facility spread sheet was developed to better assess the cost of capture of CO_2 from flue gas streams.

In parallel, during 2000, geological studies were carried out to evaluate the geology the Edmonton Group coal deposits in Alberta. The Edmonton coals are located at shallower depths and may be more permeable than the Mannville coals, and are in close proximity to major power plants and would be convenient for CO_2 sequestration. The reservoir properties of these shallower coals, in particular the natural fracture permeability, cannot be determined by the study of available geologic data. As a result, four formation evaluation wells were drilled into the Horseshoe Canyon and Ardley coals.

Phase IV (2002 – 2005)

Based on Phase III results, the project passed the third go/no-go decision and proceeded to Phase IV. In Phase IV, the project was expanded to include the response of CBM reservoirs to sulfur gases to further evaluate injection of acid gases (CO_2 and H_2S) into deep coals. Methods of modeling permeability changes due to swelling strain were added to the CMG (Computer Modelling Group) commercial GEM compositional numerical simulation model, and along with the existing pressure stain permeability modifiers have increased the accuracy of history matching and forecasting of the enhanced recovery. The economics of enhanced coalbed methane (ECBM) recovery were further refined by optimizing the process using the improved numerical simulators and linking it to the surface facility economic model (i.e. the Integrated Economic Model for IEM). In parallel, matches of 12 types of CO_2 sources with CBM reservoirs were made for Alberta aid in planning for the future.

Phase V: CSEMP (2004 – 2009)

A Suncor-led consortium with ARC in charge of the research component of the project (entitled CSEMP which stands for CO_2 Storage and Enhanced Methane Production) conducted a micro-pilot in the lower rank shallower Ardley coals of Alberta. Once underway the project was delayed due to regulatory hurdles due to the shallow depth of the coal seam. Over 1000 tonnes of CO_2 were injected into a micro-pilot and two well pilot. Extensive monitoring of the micro-pilot and pilot were completed using a combination of downhole pressure gauges (external to the casing, located in the coals and in an aquifer directly above the coal seam), seismic, tiltmeters, shallow water wells and atmospheric monitoring. Extensive history matching allowed a conceptual commercial project to be developed. It was concluded that the Ardley coal was not as attractive as the higher rank Mannville coal for production of methane. This was due to the shallower depth of the Ardley containing lower gas-in-place and being of lower rank requiring more CO_2 to displace an equivalent amount of methane.

Conclusions

Since it takes at least two cubic feet of CO_2 for each cubic foot of methane produced from the Mannville, the CO_2 cost would take up more than $2 US of the gas price on a per thousand cubic feet of methane basis (assuming CO_2 at $1 US per thousand standard cubic feet or $19 US per tonne.) Alternately, flue gas (which comprises mainly of nitrogen and carbon dioxide) injection has its merits. From an economic perspective, flue gas injection offered better economics than pure CO_2 injection (unless there is a credit for CO_2). Flue gas injection appears to enhance methane production to a greater degree possible than with CO_2 alone while still sequestering CO_2, albeit in smaller quantities. The CO_2 will remain sorbed in the coal while the majority of the nitrogen will be produced along with the hydrocarbons. In this case, however, the process will require an extra processing step of rejecting the N_2 from the produced gas stream. Therefore, considering both economic and CO_2 sequestration factors, there might be an ideal CO_2/N_2 composition where both factors will be optimized. Technical issues that need to be addressed in the next phase of the development include flue gas conditioning, compression and delivery, N_2/CH_4 separation and improvement of the numerical reservoir simulators.

ARC's Outlook to the Future for CO_2-ECBM Research and Piloting

Currently, there are a number of commercial reservoir models which use coal swelling algorithms similar to that developed by ARC to model the dynamic permeability changes that take place during a CO_2-ECBM project. Although these simulators yield much more accurate results than those that only consider pressure strain to affect the permeability, there is still an important permeability component missing: that due to shear failure. In high permeability reservoirs, hydro fracturing (a technique which imposes new stress fields around a well as a result of high rate injection) has been utilized for many years in the oil and gas industry to create a high permeability planar fracture extending past areas of formation damage to enhance production. However, in low permeability reservoirs, the nature of the induced stress field should be that which promotes shear failure over a volume (termed Domain Stimulation). Domain stimulation technology has allowed industry to commercialize gas production from low permeability gas shales and tight sands. It should also apply to coals. Simulators need to be able to predict shear failure and the effect it has on permeability in order to move marginal CO_2-ECBM projects to commerciality. ARC currently has a joint industry program (JIP) which has developed a Domain Stimulation software model and is developing permeability correlations for this.

Additionally, the promise of CO_2 credits allowing marginal projects to become commercial needs to be evaluated. Although a CO_2-ECBM project might not currently be commercial, it could be in the future as CO_2 credits become more valuable. Any economic assessment needs to take this into account. A fast screening tool is needed which evaluates the integrated CCS process. In this regard, ARC, in partnership with Energy Navigator, is further developing the Integrated Economic Model for CCS as a software package which allows scenarios to be evaluated rapidly with respect to capture, transportation and storage through ECBM or in aquifers.

At all coal ranks, CO_2 is more selectively absorbed on coal compared to methane. At low ranks, the selectivity is higher (i.e. 10 to 1 for lignite compared to 1.2 to 1.0 for anthracite). However the sorption capacity for methane increases rapidly with rank. Therefore, anthracitic coals, which have similar permeability to low rank coals, are the most attractive candidates because they have a higher methane content and they will sorb less CO_2 per molecule of methane produced although the absolute amount of CO_2 sorbed is similar to low rank coals. Anthracitic coals have been identified in the Shanxi Formation in the Qinshui basin of China which are an attractive target. This has been confirmed from a micro-pilot conducted by ARC in partnership with CUCBM (China United Coalbed Methane Corporation). Currently, CUCBM is working with several international companies to develop this into a full scale pilot with ARC as the technology provider.

Finally, there is concern about the contamination of the coal resource with $CO_{2,}$ if at some future date, the coal is to be mined. ARC has been working on microbial regeneration of CBM reservoirs and conversion of stored CO_2 to methane. Both processes involve the injection of nutrients and/or methanogenic consortia into the coal beds. Under appropriate growth conditions, methanogenic consortia can generate significant quantities of methane over a relatively short time period in the subsurface by subtracting energy and hydrogen from the coal as illustrated in Figure 2. The process effectively converts the coal and the CO_2 to methane which can lead to an increase in permeability due to the consumption of a small fraction of the coal. This leads to a more effective primary production of the CBM in later cycles. If the coal resource was to be mined in the future, the final cycle would end at the degasification step of primary CBM production after all the CO_2 had been converted to methane.

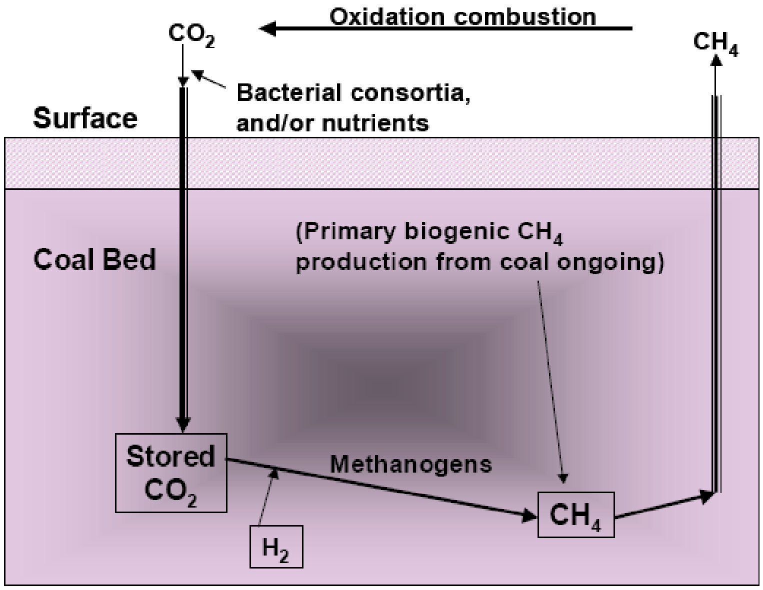

Figure 2. *Enhanced CBM followed by microbial regeneration of the CBM reservoir.*

Consequently, ARC would predict a bright future for CO_2-ECBM. It not only adds to our reserves of natural gas which is the cleanest burning fossil fuel, but it also can help reduce release of GHGs to the atmosphere by trapping the injected CO_2 in the coal seams on a geologic time scale.

Project Related Publications

Enhanced Coalbed Methane Recovery

20. Comparison of CO_2-N_2Enhanced Coalbed Methane Recovery and CO_2 Storage for Low- & High-Rank Coals, Alberta, Canada and Shanxi, China, W.D. Gunter, Xiaohui Deng and Sam Wong, Proceedings of the 24th International Applied Geochemistry Symposium, Fredericton, New Brunswick, Canada, 675-677, June 1-4 (2009)

19. Enhanced Coalbed Methane Production and CO_2 Storage in Anthracitic Coals – Production Assessment and Economics at South Qinshui Basin, Shanxi, China, W.D. Gunter, D. Macdonald, S. Andrei, S. Wong, X. Deng, D. Law, J. Ye, S. Feng, Z. Fan and P. Ho, Proceedings of the 2008 Asia Pacific CBM Symposium (ISBN:978-1-864999-26-6), Eds: P. Massarotto, S.D. Golding, X. Fu, C. Wei, G.X. Wang and V. Rudolph, University of Queensland, Qld 4072, Australia, paper 075, 8 pages (2008)

18. Recommended Practices for CO_2-Enhanced Coal Bed Methane Pilot Tests in China, Bill Gunter, Sam Wong and Xiaohui Deng, Rudy Cech, Sorin Andrei and Doug Macdonald, ISBN 978-7-116-05833-0, 275 pages (2008)

17. Permeability Changes in Coal Seams During Production and Injection, Ian Palmer, Matt Mavor and Bill Gunter, Proceedings of the 2007 International Coalbed Methane Symposium in Tuscaloosa, Alabama, Paper 0713, 20 pages (2007)

16. Recommended Practices for CO_2-Enhanced Coalbed Methane Pilot Tests Based On Canadian Experience in China, Bill Gunter, Sam Wong and Xiaohui Deng (Alberta Research Council Inc.), Rudy Cech (Sproule International Ltd.) Sorin Andrei, Doug Macdonald (SNC Lavalin Inc.), Prepared for Canadian International Development Agency (CIDA), Project A-030841, 174 pages (2007)

15. Enhanced Coalbed Methane and CO_2 Storage in Anthracitic Coals – Micro-Pilot Test At South Qinshui, Shanxi, China, Sam Wong, David Law, Xiaohui Deng, John Robinson, Bernice Kadatz, William D. Gunter, Ye Jianping, Feng Sanli and Fan Zhiqiang, International Journal of Greenhouse Gas Control, Vol. 1 #2, 215-222 (2007)

14. Secondary Porosity and Permeability of Coal vs. Gas Composition and Pressure, M.J. Mavor and W.D.Gunter, SPE Reservoir Evaluation and Engineering, 114-125 (April, 2006)

13. Coalbed Methane Production & CO_2 Storage: the Win-Win Association?, J Michael Gatens, MGV Energy Inc , William D. Gunter, Alberta Research Council , Proceedings of the 18th World Petroleum Congress (DVD format), RFP8, ISBN 978-0-85293-450-0, Pub., Energy Institute, London, 11p (2006).

12. CO_2 Storage and Enhanced Methane Production: Field Testing at Fenn-Big Valley, Alberta, Canada, with Application, W.D. Gunter, M.J. Mavor and J.R. Robinson, Proceedings of the 7th International Conference on Greenhouse Gas Control Technologies: Volume I, *E.S.Rubin, D.W. Keith & C.F. Gilboy (Eds.)*, Elsevier Ltd., 413-421 (2005)

11. ECBM Micro-Pilot Test in the Anthracitic Coal's of the Qinshui Basin, China: Field results and Preliminary Analysis, J. Robinson, B. Kadatz, S. Wong, W.D. Gunter, F. Sangli, and F. Zhiqiang, Proceedings of the Third International Workshop of Prospective Roles of CO_2 Sequestration in Coal Seam, Hokkaido University, Sapporo, Japan, October 2004, 33-44 (2004)

10. Alberta Multiwell Micro-Pilot Testing for CBM Properties, Enhanced Methane Recovery and CO_2 Storage Potential, M.J. Mavor, W.D. Gunter and J.R. Robinson, Proceedings of the SPE Annual Technical Conference and Exhibition held in Houston, Texas, U.S.A., 26–29 September 2004, SPE Paper 90256, 14p (2004)

9. Secondary Porosity and Permeability of Coal vs. Gas Composition and Pressure, M.J. Mavor and W.D.Gunter, Proceedings of the SPE Annual Technical Conference and Exhibition held in Houston, Texas, U.S.A., 26–29 September 2004, SPE Paper 90255, 14p (2004)

8. Enhanced Coalbed Methane Recovery and CO_2 Storage: Micro-Pilot Testing at Fenn-Big Valley, Alberta, Canada, W.D.Gunter and M. J. Mavor, Proceedings of the 1st International Workshop on the Present Status and Perspective of CO_2 Sequestration in Coal Seam, Tokyo, Japan, JCOAL & JCOSC, 101-116, Sept. 5 (2002)

7. Testing for CO2 Sequestration and Enhanced Methane Production from Coal, M. J. Mavor, W..D.Gunter, J.R. Robinson, D. H-S. Law and John Gale, SPE paper 75680, Presented at the SPE Gas Technology Symposium, May 30-April 2, Calgary, 14 p (2002)

6. CO_2-Enhanced Coalbed Methane Recovery Demonstration Pilot- A Case for Australia, S. Wong, K. MacLeod, M. Wold, W.D. Gunter, M.J. Mavor and J. Gale, Proceedings of the 2001 International CBM Symposium, Tuscaloosa, USA, May 14 to 18, 75-86 (2001).

5. Site Ranking for CO_2-Enhanced Coalbed Methane Demonstration Pilots, S. Wong, W.D. Gunter, and J. Gale, Proceedings of the 5th International Conference on GHG Control Technologies, Cairns, Australia, (Editors: D. Williams, B. Durie, P. McMullan, C. Paulson, Andrea Smith) CSIRO Publishing, 531-536 (2001).

4. Economics of Flue Gas Injection and CO_2 Sequestration in Coalbed Methane Reservoirs, S. Wong, W.D. Gunter, D. H.-S. Law and M.J. Mavor, Proceedings of the 5th International Conference on GHG Control Technologies, Cairns, Australia, (Editors: D. Williams, B. Durie, P. McMullan, C. Paulson, Andrea Smith) CSIRO Publishing, 543-548 (2001).

3. **Enhanced Recovery of Coalbed Methane with Carbon Dioxide Sequestration– Selection of Possible Demonstration Sites**, International Energy Agency Greenhouse Gas R&D Programme Report Number PH3/34, 178p. (2000).

2. **Economics of CO_2 Sequestration in Coalbed Methane Reservoirs,** S. Wong, W.D. Gunter, M.J. Mavor. Proceedings of SPE/CERI Gas Technology Symposium 2000, SPE 59785, April 3-5, Calgary, Alberta, 631-638 (2000).

1. **Deep Coalbed Methane in Alberta, Canada: A Fuel Resource with the Potential of Zero Greenhouse Gas Emissions,** W.D.Gunter, T.Gentzis, B.A.Rottenfusser and R.J.H. Richardson, Energy Convers. Mgmt. 38 Suppl., S217-S222 (1997).

Enhanced Coalbed Methane: Methanogenesis

4. **Characterization of a Subsurface Coalbed Methanogenic Culture and its Role in Coalbed Methane Recovery and CO2 Utilization**. Karen Budwill, Marc Bustin, Karlis Muehlenbachs, and W.D. Gunter, Proceedings of the 7th International Conference on Greenhouse Gas Control Technologies: Volume II-Part II, *M. Wilson, T. Morris, J. Gale & K. Thambimuthu (Eds.)*, Elsevier Ltd., 2213-2216 (2005)

3. **CBM Through ECBM Followed by Bacterial Regeneration of the CBM Reservoir: An Approach to Sustainability**, K. Budwill, B. Kadatz, and W.D. Gunter, Proceedings of the Third International Workshop of Prospective Roles of CO_2 Sequestration in Coal Seam, Hokkaido University, Sapporo, Japan, October 2004, 97-108 (2004)

2. **Microbial Methanogenesis and its Role in Enhancing Coalbed Methane Recovery**, Karen Budwill, Canadian Society of Exploration Geophysicists Recorder Vol.28 (9), 41-46 (2003)

1. **Methanogenic Activity on Coal and Sequestered CO_2 for Enhanced Coalbed Methane Recovery,** Karen Budwill, Andrew Beaton, Marc Bustin, Karlis Muhlenbachs and W.D. Gunter, Proceedings of the 6th International Conference on GHG Control Technologies, Kyoto, Japan, (editors: J. Gale & Y. Kaya), Pergamon Press, 697-702 (2003)

Enhanced Coalbed Methane Recovery: Numerical Model Comparison

10. **Economics of Enhanced Coalbed Methane (ECBM) Production using Different CO_2 Injection Sources: Pure CO_2 versus Coal Combustion Flue Gas versus Acid Gas Streams**, Xiaohui Deng, Sam Wong, John Faltinson, W.D. Gunter, Proceedings of the 8th International Conference on Greenhouse Gas Control Technologies (2006)

9. **Improvements in Coalbed Methane and Enhanced Coalbed Methane Reservoir Simulators**, W.D. Gunter, D.H.-S. Law and Matt Mavor, Proceedings of the 2005 International Coalbed Methane Symposium, University of Alabama, Tuscaloosa, Alabama, 20p (2005)

8. **Comparison of Numerical Simulators for Greenhouse Gas Sequestration in Coalbeds, Part IV: History Match of Field Micro-Pilot Data,** D.H.-S. Law, L.G.H van der Meer and W.D. Gunter, Proceedings of the 7th International Conference on Greenhouse Gas Control Technologies: Volume II-Part II, *M. Wilson, T. Morris, J. Gale & K. Thambimuthu (Eds.)*, Elsevier Ltd., 2239-2242 (2005)

7. **Comparison of Numerical Simulators for Greenhouse Gas Sequestration in Coalbeds, Part III: More Complex Problems,** D.H.-S. Law and W.D. Gunter, Proceedings of 2nt National Conference on Carbon Sequestration, Washington, DC., May 5-8, 13 p. (2003)

6. History Matching of Enhanced Coalbed Methane (ECBM) Production Field Data, D.H.-S. Law and W.D. Gunter, Proceedings of the 2nd International Workshop on Research Relevant to CO_2 Sequestration in Coal Seam, Tokyo, Japan, JCOAL, KANSO & JCOSC, 67-77, Sept. 25 (2003)

5. Comparison of Numerical Simulators for Greenhouse Gas Storage in Coalbeds, PartII: Flue Gas Injection, D,H,-S. Law, L.H.G. van der Meer and W.D. Gunter, Proceedings of the 6th International Conference on GHG Control Technologies, Kyoto, Japan, (editors: J. Gale & Y. Kaya), Pergamon Press, 563-568 (2003)

4. Enhanced Coalbed Methane Recovery and CO_2 Storage: Simulation Issues and Model Comparison, W.D. Gunter and D.H.-S. Law, Proceedings of the 1st International Workshop on the Present Status and Perspective of CO_2 Sequestration in Coal Seam, Tokyo, Japan, JCOAL & JCOSC, 59-66, Sept. 5 (2002

3. Numerical Simulator Comparison Study for Enhanced Coalbed Methane Recovery Processes: Part I Pure CO2 Injection. D. H-S. Law, W.D. Gunter and L.G.H. van der Meer, SPE 75669, Presented at the SPE Gas Technology Symposium, May 30-April 2, Calgary, 12p (2002)

2. Comparison of Numerical Simulators for Greenhouse Gas Sequestration in Coal Beds Part I: Pure Carbon Dioxide Injection, D.H.-S. Law, L.G.H. van der Meer, and W.D. Gunter, Proceedings of 1st National Conference on Carbon Sequestration, Washington, DC., May 14-17, 15 p. (2001)

1. Modelling of Carbon Dioxide Sequestration in Coal Beds: A Numerical Challenge, D.H.-S. Law, L.G.H. van der Meer, M.J. Mavor and W.D. Gunter, Proceedings of the 5th International Conference on GHG Control Technologies, Cairns, Australia, (Editors: D. Williams, B. Durie, P. McMullan, C. Paulson, Andrea Smith) CSIRO Publishing, 537-542 (2001).